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Print Quality Measurement: The Application of Instrumental Analysis to Graphic Arts

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ABSTRACT

Instrumental analysis is a powerful tool when evaluation of print quality is desired.
Traces of prints were obtained by scanning them with a microdensitometer equipped with a reflection reading head attachment.
The ability of newsprint to produce a good print under specified printing conditions is evaluated by measuring the uniformity of the contrast between dots and backgrounds, as well as the uniformity of the dots.
A method of evaluation for these scans is formulated and discussed. Conclusions and reccomendations are made.

INTRODUCTION

"According to Webster's dictionary, 'legible' is something that can be read or deciphered easily."

The most reliable way of studying printability of different papers is by printing them on a proof press under standard conditions (those pertinent to a particular company), then comparing the results. The effect of different variables, such as pressure, ink type and loading can be studied in a similar manner, by comparing proof press prints made on the same paper (figure 1). However the comparison of the printed samples is commonly carried out by the visual ranking obtained by a panel of observers. This is exactly how the Graphic Arts Research Center analyzes their particular monthly runs.

Although such visual ratings do provide a useful guide in print quality measurement, the interpretations of the rankings, in terms of papermaking and/or printing variables, is limited by the subjective nature of the test.

If, for the moment, confinement of the discussion to single color printing, then the impression of the print quality obtained by the observer may be resolved into a number of factors:

i) Large printed areas. The main criterion for the print quality of such areas is undoubtedly the uniformity of the printed area, which is related to the smoothness of the paper under printing conditions.

ii) Half-tone areas, small letters and other detail. The criterion for the appearance of discontinuous printed areas, such as small letters, details, and half-tone dots are somewhat different than those for solid areas. Print quality depends on the faithfulness with which the details, letters, or dots have been reproduced. This depends on the uniformity of dots of the same density and the abruptness of the transition from printed to unprinted areas; the overall clarity of discontinuous areas is related to the contrast between the printed and adjacent unprinted area, i.e. the difference in reflectance between the printed and unprinted areas.

Optical scanning of printed characters (letters or half-tone dot patterns)* for input into computers have made contrast and sharpness the main critical appearance properties.[1]

[1] Albrecht, J. and Brune, M. "Evaluation of Print Uniformity with an Electronic Devise" Thirdteenth Tappi Testing Conference, Philedelphia 1962.

Good print quality depends primarily on:

a) the printed character* should present as high a contrast and sharpness as possible when compared to the background.

b) the transition from printed to unprinted areas must be sharp. Futhermore the edges of the pattern must not be jagged.

c) the characters* should not fill-in and there should be no voids within the outlines or extraneous ink within the clear areas.

Without doubt, the evaluation of discontinuous printed areas may also be carried out by panel rating of proof prints. It is unfortunate that the more complicated the nature the visual assessment becomes, the more prone it is to subjective human errors. There is then a definite need for instrumental techniques of analysis which will resolve the visual impression into such components as uniformity, definition, and contrast.

The most direct way of obtaining quantitative information is through the use of scanning instruments of the microdensitometer type. The requirements of such an instrument are:

i) a permanent record of the measurement as as afforded by a chart trace.

ii) resolution must be equal and preferably better than the eye.

INSTRUMENTATION

The instrumentation involved in establishing a basis for possible correlation and analysis is a microdensitometer and a strip chart recorder. In this study, the Ansco Model 4 Microdensitometer was used-due to its availiability.

The machine was converted from a transmittance reading unit to a reflective reading unit. This is accomplished by using the reflectance head attachment of the type in figure (2).

The sample is placed on the movable microscope stage at an angle of 45 degrees to the base of the stage. The reason for this arrangement was that after viewing the progress of a particular scan, it was found that the angle of the scan was approximately 45 degrees to the normal of the reflectance head (↙↗) when a 0 degree scan angle was desired. The sample angling produced the desired effect (←→).

To adhere to the prerequisites set for this type of analysis, an approximately 200 micron circular slit width was chosen to replicate what the human eye would observe.

Standard specifications were set for each scan that would be done. Throughout the entire experimentation process, they were:

1) Chart Speed..1.0 mm/sec.
2) Ocular......5x
3) Objective....11x
4) Circular Slit Width.......0.25 mm (diameter)
5) Lamp Voltage.6.0 volts

DATA EVALUATION AND ANALYSIS

"Graininess is a mental impression and as such, it cannot be directly measured by purely physical means."[2]

When one begins to attempt to measure the granularity of discontinuous half-tone dot patterns, he will have to draw a parallel to the work done by Jones and Higgins. They have made extensive studies of photographic graininess and granularity. To analyze the scans which were to come from experimentation, I had to modify their methods of analysis to the graphic arts field.

Most of the grainularity values derived by Jones and Higgins were based on the density differences between adjacent small areas. In the halftone images that I would be analyzing, it was found that if the density differences between the centers of adjacent black and white dots remain constant, no sensation of graininess is experienced. The perception of graininess requires random roughness.[3] As soon as a pattern becomes symmetrical, the sensation of graininess does not occur.

The visual appearance of graininess is caused by extremely small grains in the image. There are two general types that can be considered. The first one is what is called "black grain". Black grain is unwanted ink in non-image areas. It can consist of independent, minute specks of ink or irregular, ragged spreading of individual half-

2 Derr, A.J. "Application of a Microdensitometer to Photo Data Assessment", Fifth Annula Technical Symposium of the Society of Photographic Instrumentation Engineers [illegible]50.

tone dots.[3]

The second type is called "white grain". These are small specks in image areas where ink has not covered the paper. It can result from piling when water interferes with the transfer of the ink, when individual half-tone dots sharpen or their edges break away unevenly, and from minute holes or depressions in the surface of the paper that the ink cannot bridge or fill.[3]

From general observations made of the sheets obtained from GARC, certain things have been noticed:

i) The kind, size, and frequency, and location of the grains is generally determined by the cause of the grain.[4]

For example, grains caused by slur are black, appear only in the midtones and shadows, are always on the trailing edge of the dots, and can increase in size only toward the trailing edge of the sheet. If the cause is piling, the grains are white and appear in areas which should be covered by ink. They are not directional and both their size and frequency can increase. Grains caused by scum are blaok, they appear in non-printing areas, are not directional, and both their size and frequency can increase.

From these generalizations, it can be seen that the grains do not follow a Gaussian or normal distribution. There are lower and upper size limits, as well as limits in direc-

[3] Gartaganis, P.A. "Legibility of Carbon Paper Prints", American Ink Maker 41 (9) 25-29 1963.

[4] James, T.H. (ed) "Theory of the Photographic Process".

tion and location.

The above suggested that granularity of printed images might be determined by determining the variations or the differences between the signal to noise ratio on a particular dot pattern. This method for the analysis seemed to work quite well.

The noise of each scan is attributed to chance alone. On the printed page, this noise is attributed to paper stock, ink quantity, screen quality, and those already mentioned above. The signal, itself, is the dot screen pattern used to make the impression.

The quality of the printed page is dependent upon whether this noise is less apparent than the signal.

A typical "printogram" of a 150 line screen dot pattern is shown in figure 3. This is only a small portion of a total scan which is about nine feet in length. A sample of an entire scan is given in figure 4.

As can be seen, there are three distinct zones that correspond to a 25%, 65%, and 100% tints.

For a good half-tone print, one needs a maximum of contrast in all three zones and a maximum uniformity of printed and unprinted areas. (figure 5)

It was planned that each scan would be analyzed by a confidence limits method. This limit would not be an overall one for the entire scan but for each individual tint.

For example, the 65% tint would have a different limit than would the 100% tint. Each of these confidence limits would be set from a "standard" or the best quality tint obtained in a particular run. In actuality, one is comparing each individual tint of a sample with its best quality tint for a run.

The "standard" in normal terms is set on a print quality that is theorectically uniform for each dot pattern. The best standard, of course, would be one that has been statistically produced that would pertain to the best quality print that, in this case, GARC can produce with a certain specifications.

For this type of basic study, though, there was no statistical data from which to take a foothold since instrumental analysis of print quality is not generally used. To overcome this, the best quality sample, in the judgement of the panel, was analyzed along with several samples of varying quality from the same run. The scans covered the entire length of the sample used. (figure 6)

Each scan of each individual tint of the "standard was then approached in the following manner: (figure 7)

1) the highest and lowest peaks were looked for.
2) when found, the vertical unit difference was calculated through measurement.

3) this difference was then halved. The value would correspond to the constant effect that the paper would have in the overall makeup of the tint.

4) an upper limit of 80% and a lower limit of 20% is then set on the values obtained.

Example: 65% Tint

Total Unit Spread	55 units
Upper Limit (80%)	44 units
Lower Limit (20%)	11 units

The 80% and 20% limits were used because of the requirements of a standard are: maximum uniformity of printed and unprinted areas; maximum of contrast within the tint. These limits then would contain the major part of the best quality points of this standard, if the best quality print is judged by above two requirements.

After the limits had been set, overlays were prepared. The upper limit was marked by a red line; the lower limit by a green line; and the median by a yellow line. (figure 7)

This overlay was then placed over the corresponding tint of another sample of the same run.

To determine whether the scan of the tint was good, bad or average, the number of peaks outside the limits was counted. The greater the number of peaks outside-the poorer the quality of that tint.

This method was done for all three tints of a sample. From the analysis of these, a general, overall decision can be made of the sample as a whole. If any part of the sample is bad, then the entire sample is of poor print quality. This, of course, is not true for the reverse- if any part of the sample is good, then the entire sample is of good print quality.

The samples would then be put in decending order of quality and marked as such. (figure 8) The marks would range from one to ten (poor to excellant). This batching method would be dependent upon each individual company's needs and standards.

DISCUSSION

* * *

CONCLUSIONS AND RECCOMMENDATIONS

The concept which I have been working with has been very basic in format. The usage of instrumental analysis in analyzing print quality is in its elementary stages. This means that no standard method of evaluation of the chart scans has been decided upon.

The method, which I used, set limits that would assume the best quality print to be uniform and that no peak or valley would fall above or below these limits.

In deciding whether the entire sample is good, bad, or average, it would be up to the individual to decide. I would suggest, though, that a set of standards be set for the individual establishment.

The standardizing method which I used is not completely correct statistically. The method, though, is a feasible one if there is no groundwork to start from.

A proper way would be the gathering of data from a succession of a year's runs. This would provide accurate data from which standards could be formed.

Although the amount of initial work is great, once standards have been set, the task is an easy one for analysis.

I believe that instrumental analysis is more feasible than subjective evaluation. In my experimentation, I was only analyzing three tint zones, where possible subjective analysis could be done. But in analyzing the entire sheet, the amount of subjective error becomes greater. As a person reviews the sample, he begins to generalize about the things he sees and finally forms a general opinion even if it might not be quite accurate.

In instrumental analysis, generalizations cannot be made since one has specific data to work with. The only possible error that would evolve would be operator error in setting up the machinery for analysis (voltage, aperatures, filters, and so on).

The main difference between subjective analysis and objective analysis is that subjective analysis error, in this case, becomes compounded as each person of the panel reviews the samples. In objective analysis, the facts are in front of the observer. There is no guessing in analyzing the quality.

*　　　　*　　　　*

1) Instrumental analysis is feasible as a method of analyzing print quality.

2) Individual standards must be set before true analysis can be made. These standards are dependent upon the individual requirements of the company using this form of analysis.

3) Additional work must be made before a true form of instru-

mental analysis is put into practice. This additional work would involve a standard method of analysis of the scans made; what errors in print quality should be taken into consideration when analysis is made; what parameters are set when a particular ink and paper are chosen; what other things can be deduced from the scans made i.e. does the distance between peaks and valleys measure contrast of the dots; does the uniformity of the peaks show deviations from an average blackness of the dots; and does the deviations of the valleys show uniformity of the area between the dots.

4) The results that one gets from instrumental analysis shows that the large amount of initial work in preparation pays off. This will greatly help in producing printing of the highest quality when an establishment can tell at a glance where the trouble is in their printing methods.

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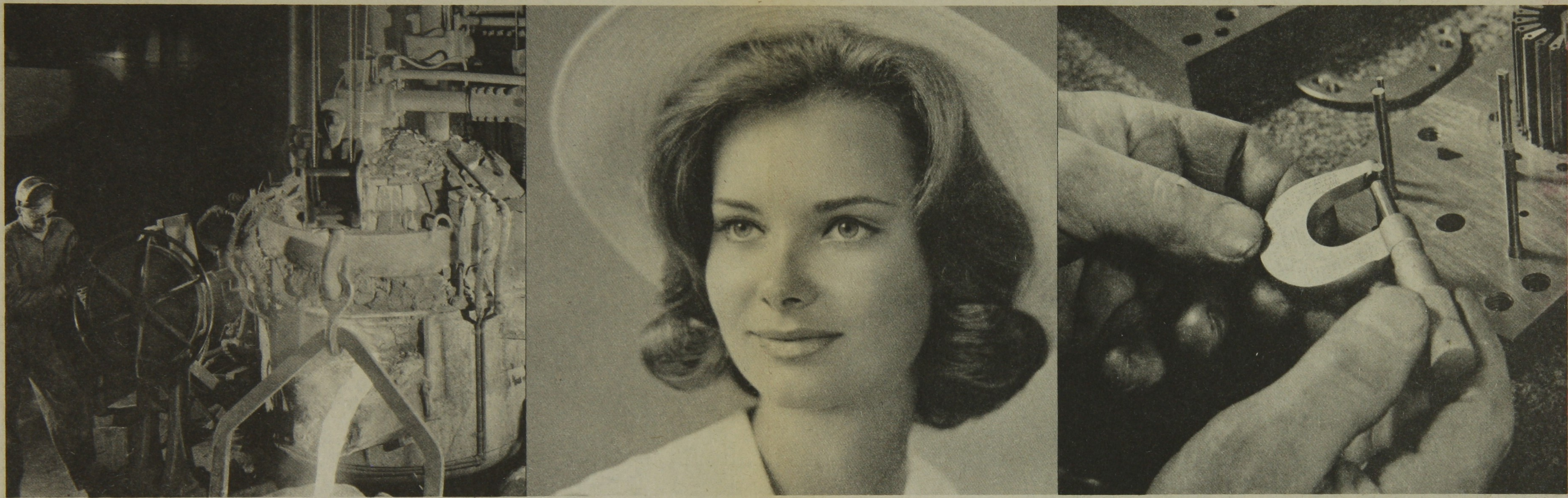

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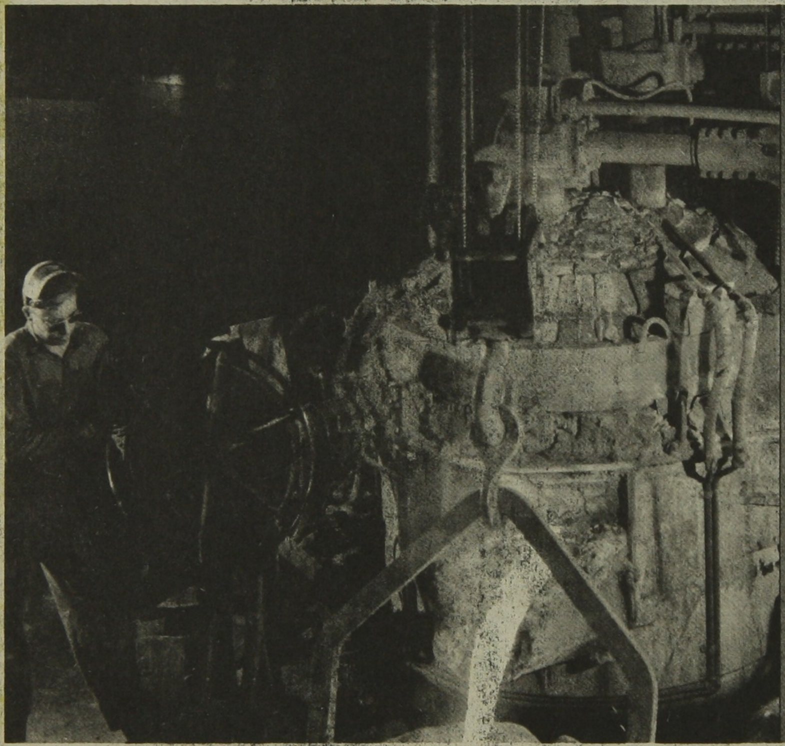

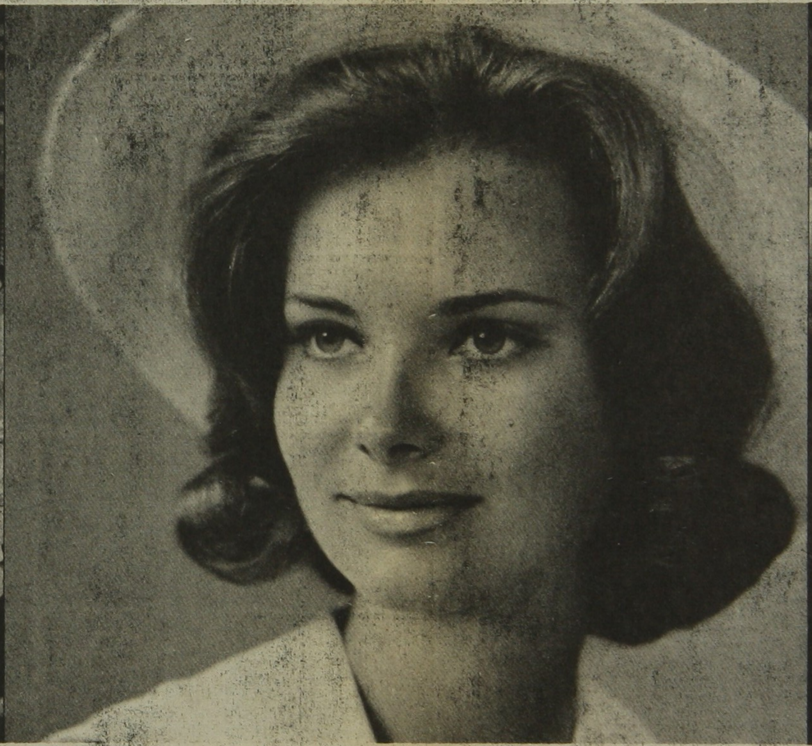

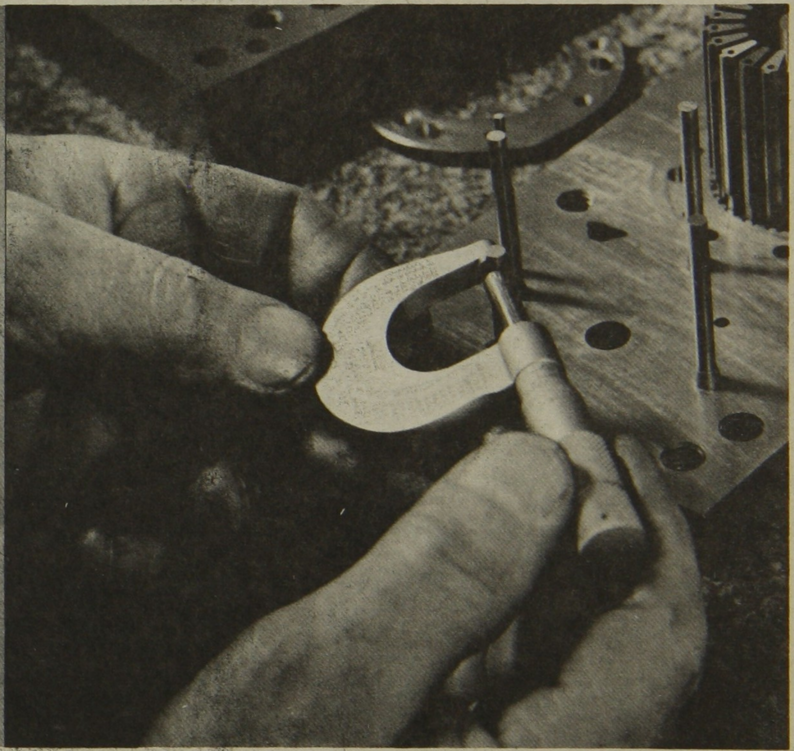

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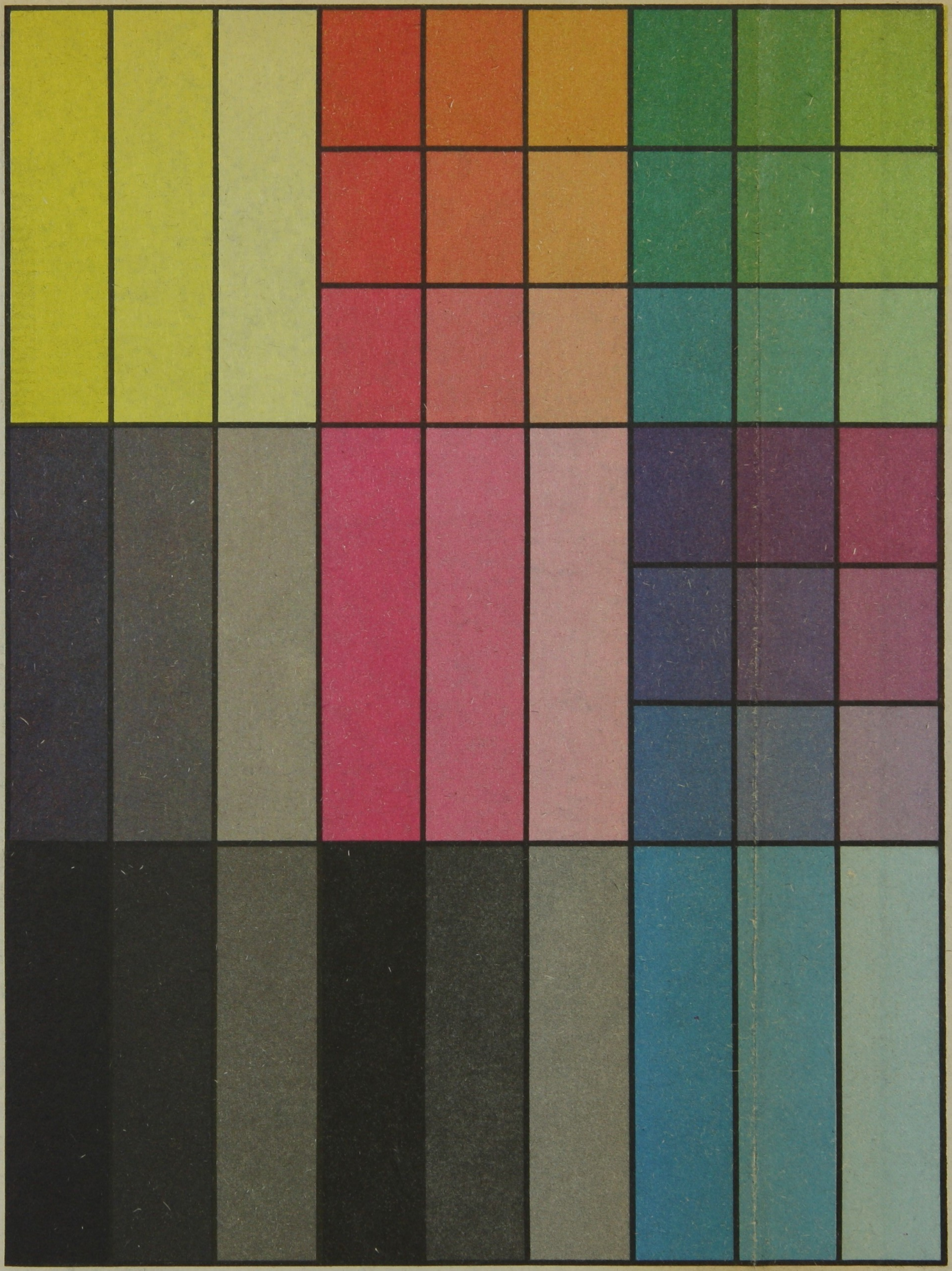

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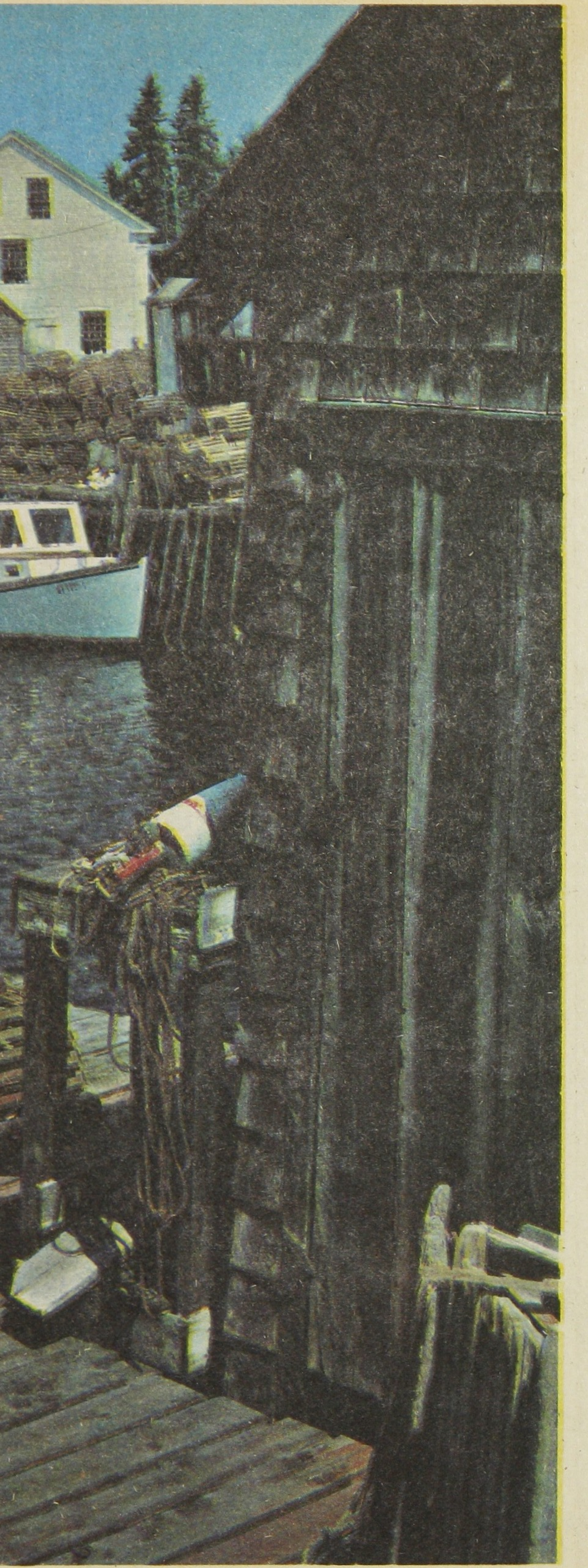


No. 1

No. 8

Web Offset Laboratory
Graphic Arts Research Center
Rochester Institute of Technology
Rochester, New York 14623

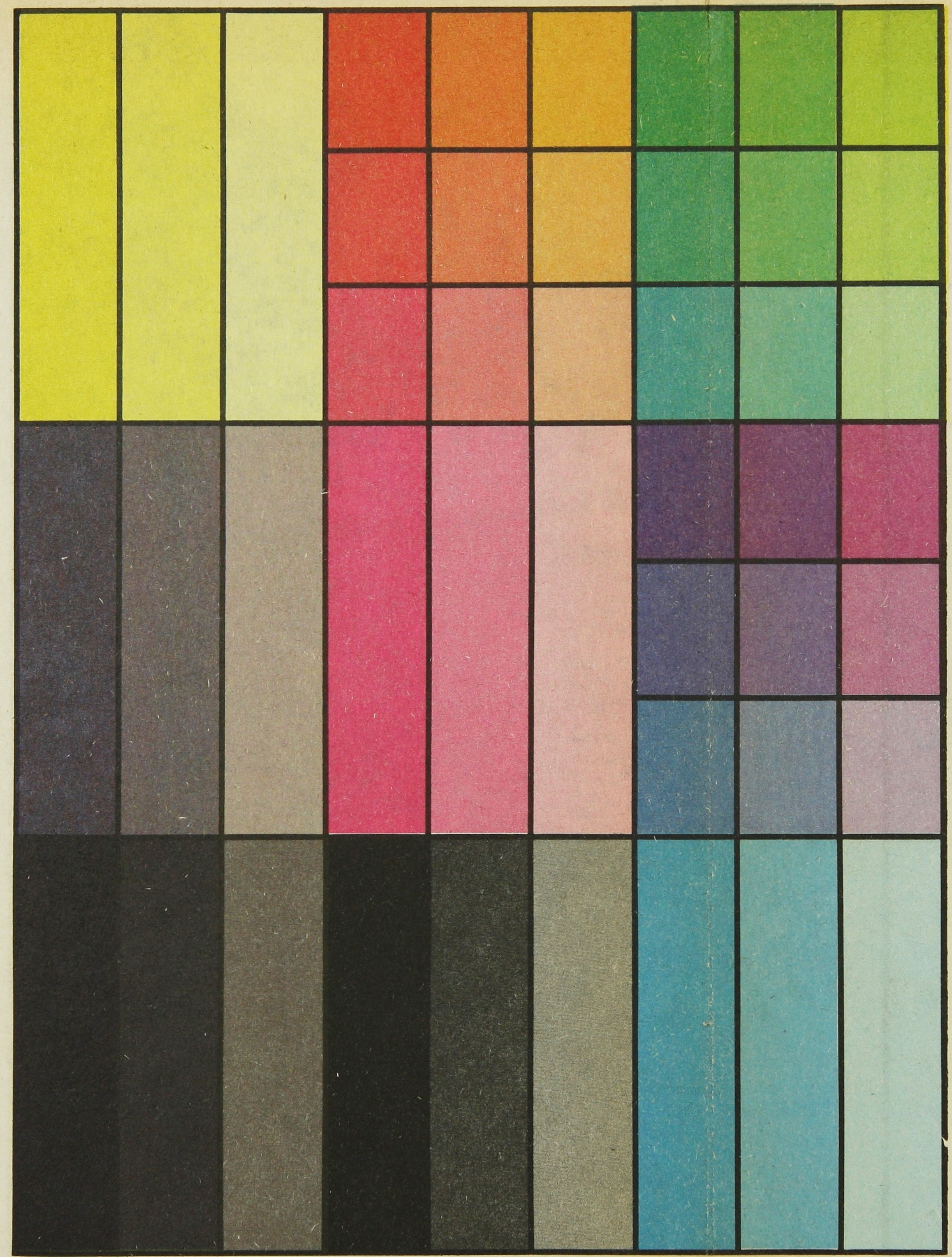
DATE

Subject	*Value*
No. 1 Process Color 150 line scree	Qualitative Printability Blistering
No. 2 Halftone 150 line scree	Qualitative Printability
No. 3 'T' Bar	Fold Cracking Coating Cracking Blistering
No. 4 SS Dots	Sharpness
No. 5 COP Chart	Picking — Linting Wet Picking — Linting Trapping
No. 6 Solids	Picking — Linting Blistering Printing Ink Density
No. 7 RIT Press Control Bar	Tone Reproduction Sharpness Trapping
No. 8	Dot Gain Slur
No. 9	Printing Show Through Gloss

INK A ←

INK B →

TOP



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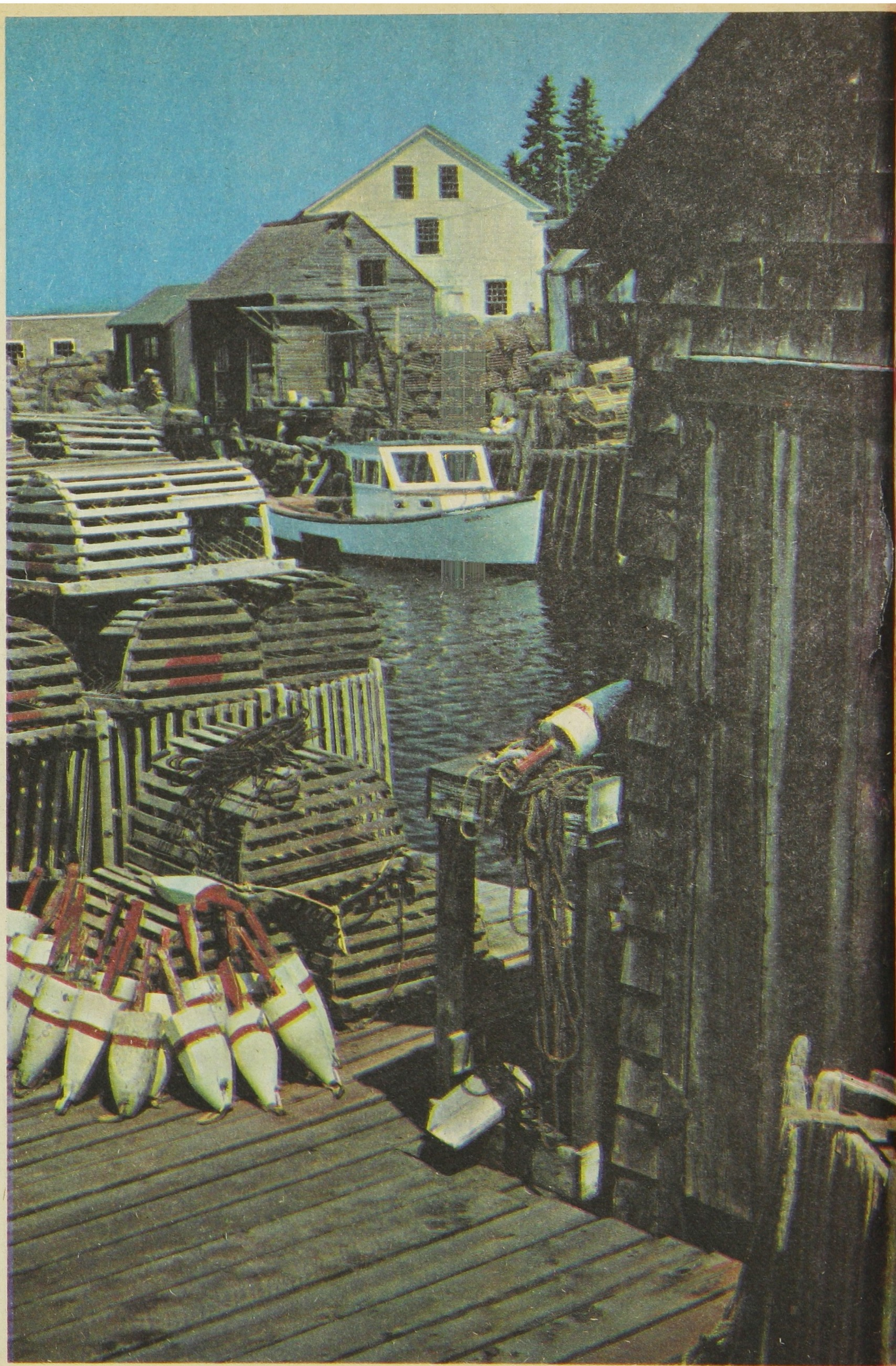

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No. 8

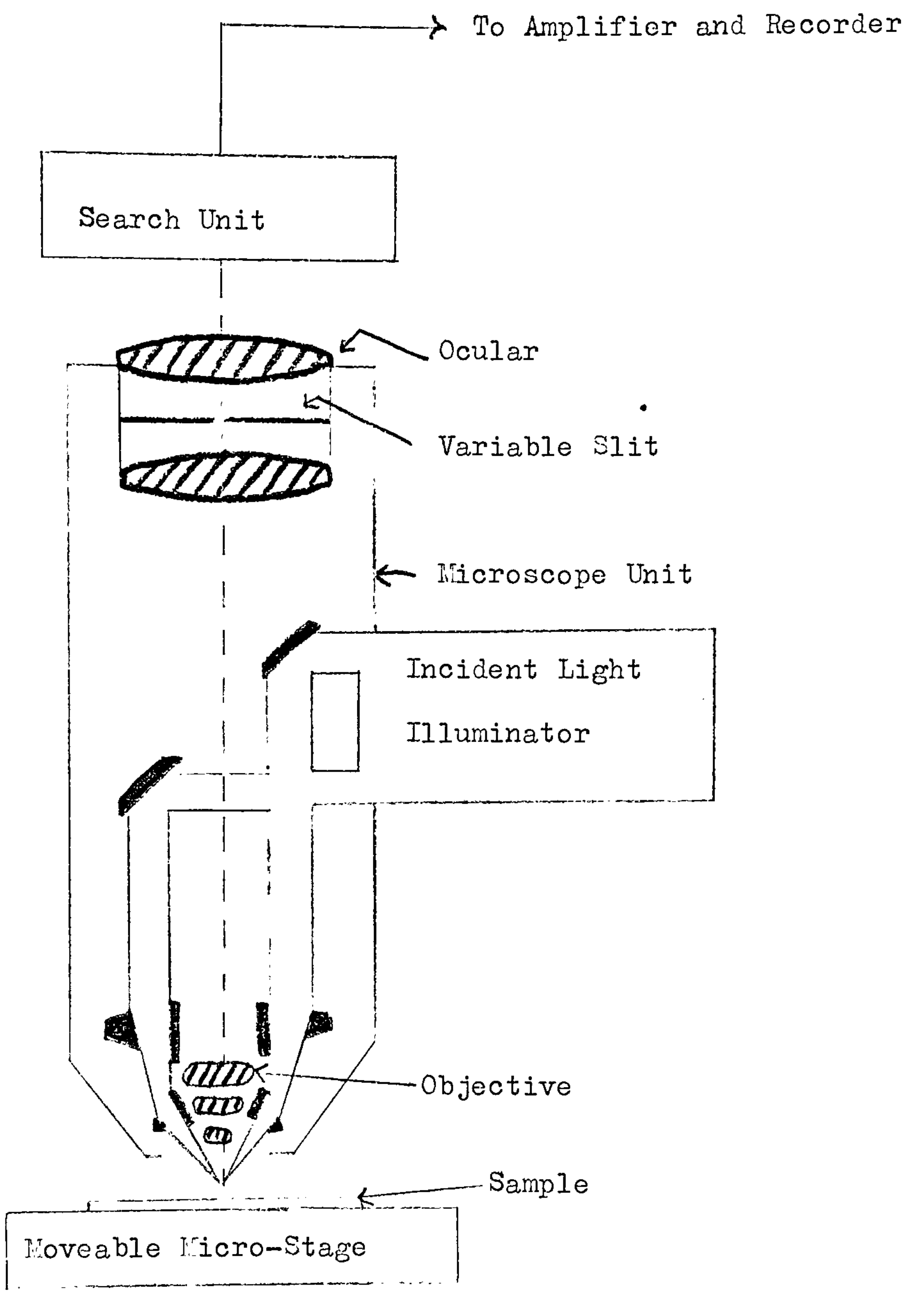
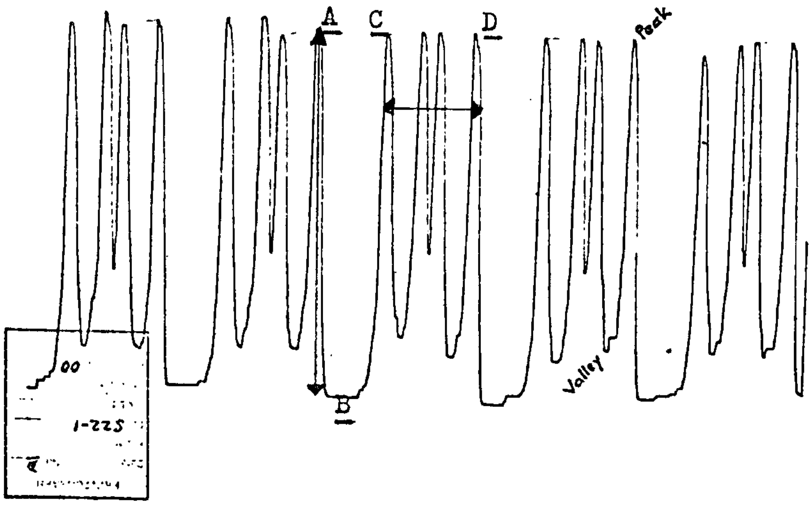


Figure 2 SCHEMATIC OF THE MICRODENSITOMETER REFLECTANCE READING HEAD

THEORETICAL



ACTUAL

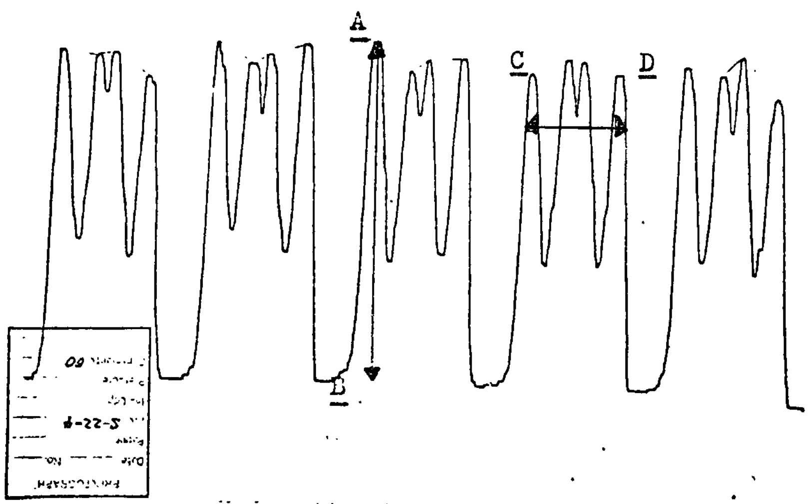


Figure 5

REQUIREMENTS OF A GOOD HALF-TONE

A - B MAXIMUM CONTRAST

C - D MAXIMUM UNIFORMITY

This example is only a small part of an entire scan. A less than standard scan is used to show how one uses the standard to analyze additional samples.
As can be seen, the print quality is average but the contrast of the dots is poor. This causes the peaks to be the way they are.

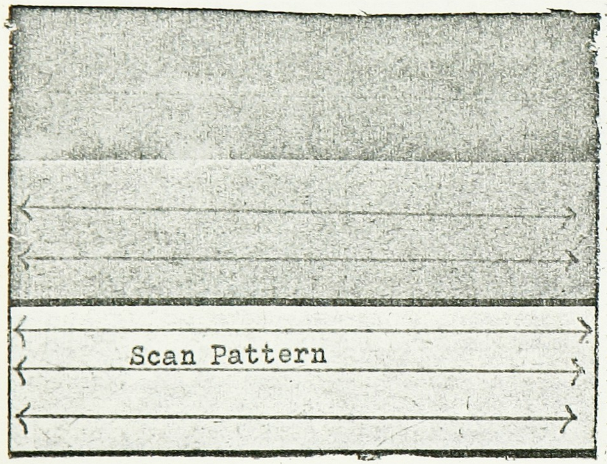


Figure 6

EXAMPLE OF THE SAMPLES USED

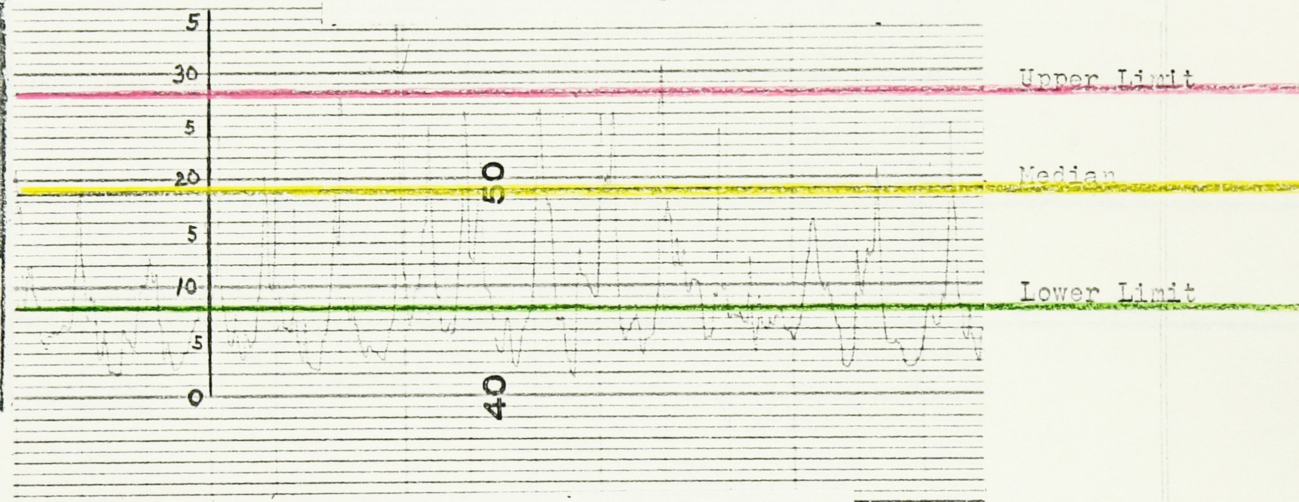


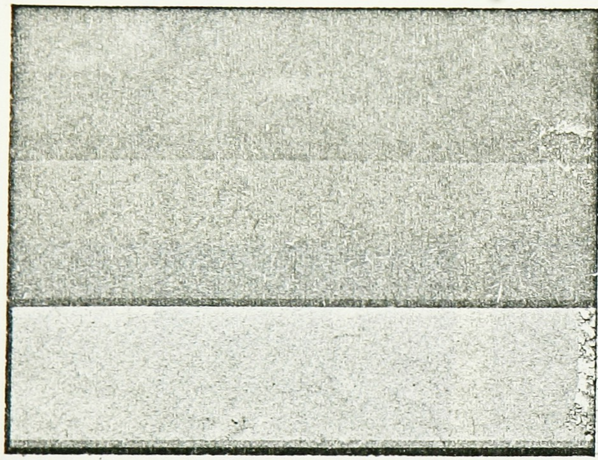
Figure 7

ANALYSIS OF THE STANDARD

65% Tint

Total Unit Spread	36 units
Upper Limits	28 units
Median	18 units
Lower Limits	7 units

This sample scan is from the same batch as the previous one. The print quality is average and the dot contrast has improved.



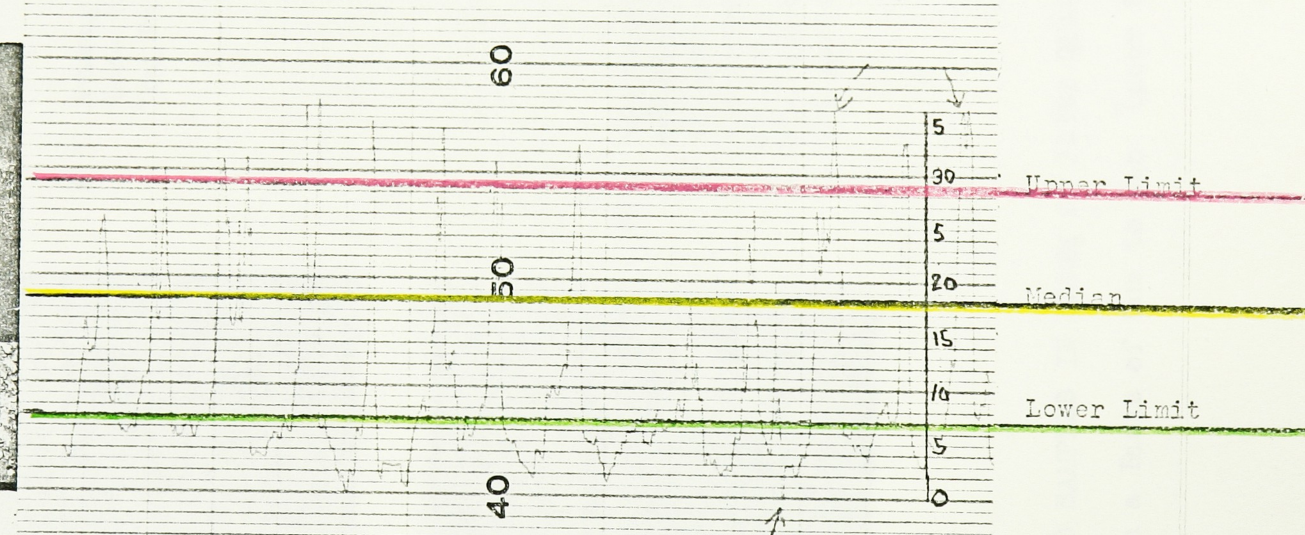
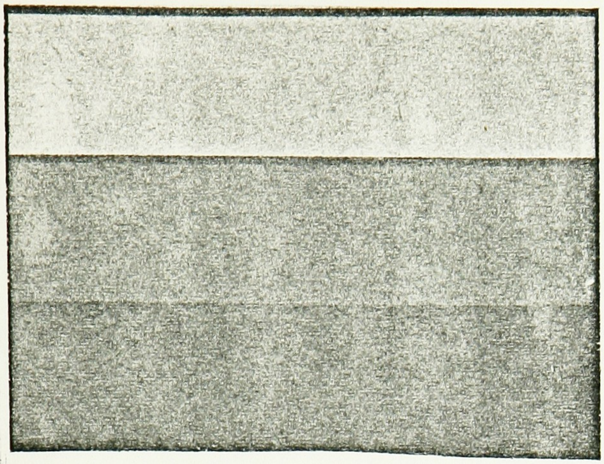


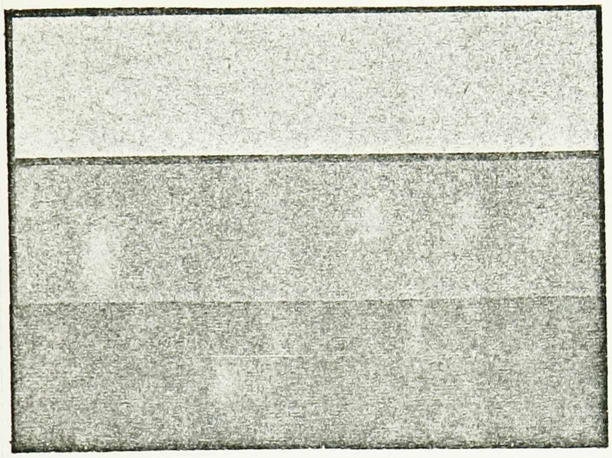
Figure 7a

ANALYSIS OF THE STANDARD

<u>65%</u> Tint (Same standard as #7)



10 Excellant Quality Print
Good Tones in All Tints
Dot Pattern Uniform



5 Average Quality Print
Tone is Bad in 65% Tint
Dot Pattern not Uniform

1 Poor Quality Print
Numerous Flaws can be seen Visually. Uneven flow of Ink caused by flaws in the Printing Process.(see Report) 25% and 65% Tint have poor Dot patterns.

Figure 8

EVALUATED SAMPLES IN ORDER OF PRINT QUALITY

Ranked on a Basis of One to Ten (poor to excellant)

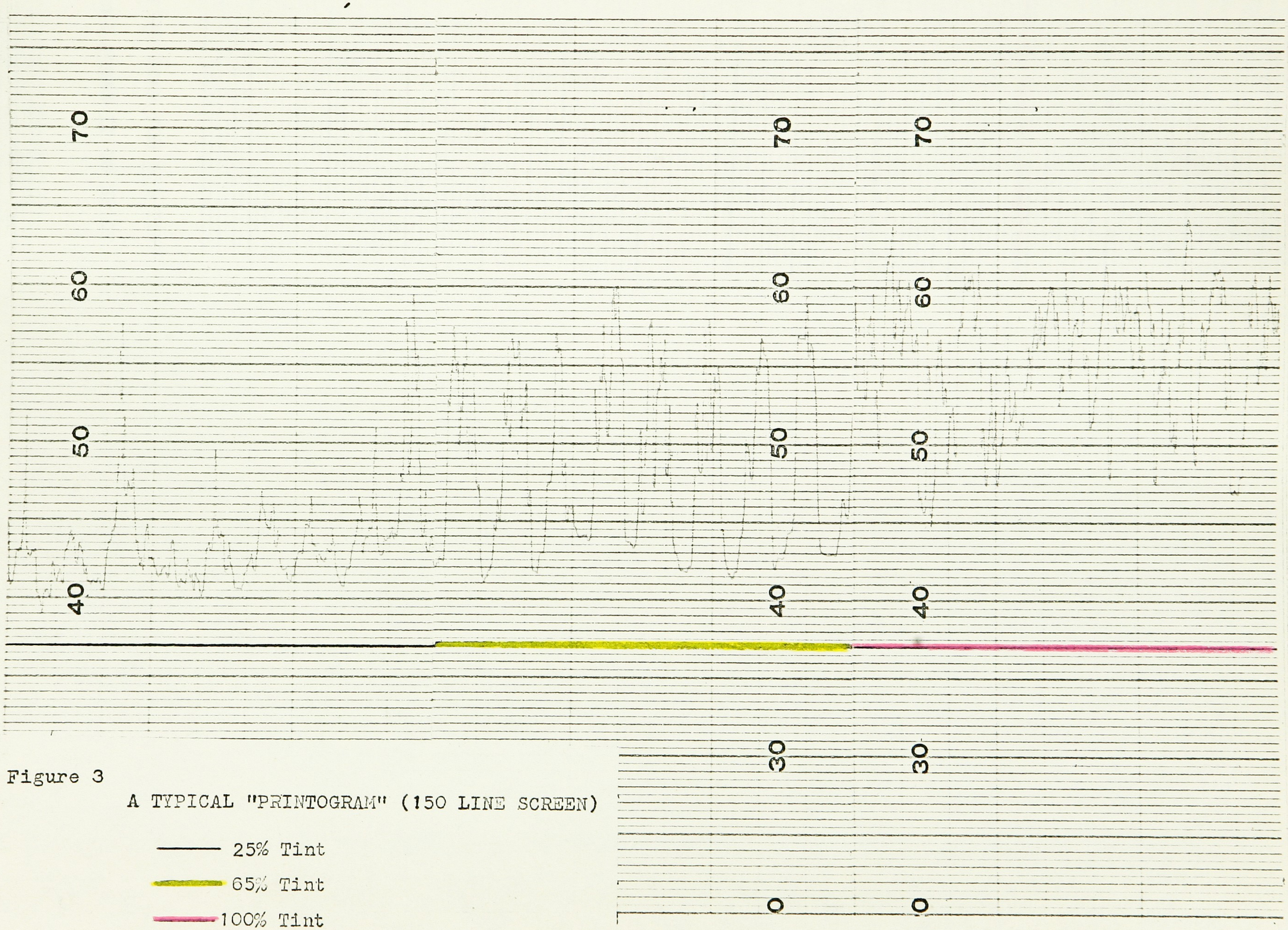


Figure 3

A TYPICAL "PRINTOGRAM" (150 LINE SCREEN)

— 25% Tint

— 65% Tint

— 100% Tint

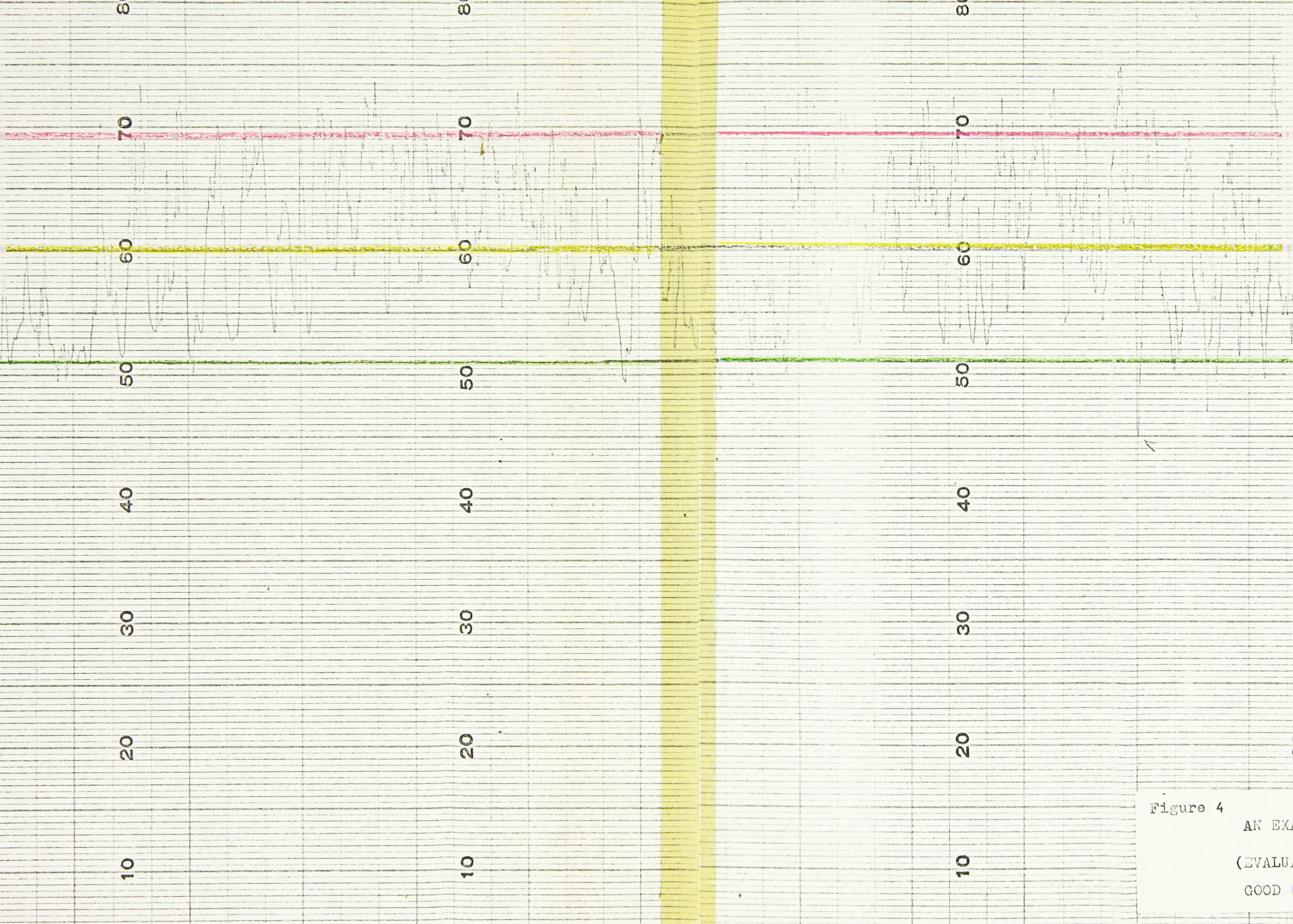
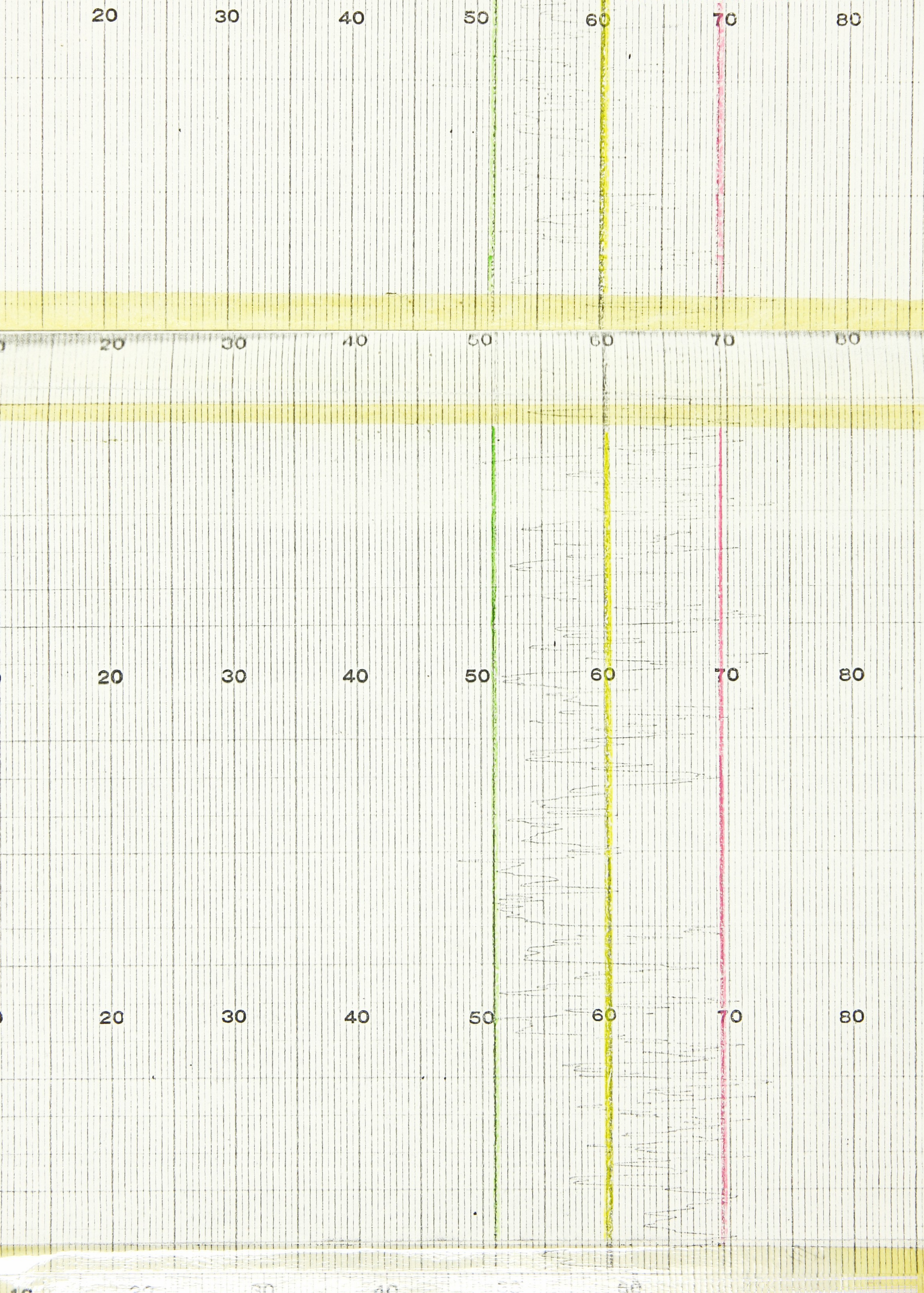


Figure 4
AN EXA
(EVALU
GOOD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