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# Design and Construction of a Standard Planetary Microfilming Camera Target Array (PMTA)

Bruno Glavich

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Design and Construction of a Standard Planetary Microfilming  
Camera Target Array (PMTA)

by  
Bruno B. Glavich  
and  
Richard T. Johnson

An Abstract

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

June, 1972

Thesis advisor: L. P. Albertson

## ABSTRACT

After researching the current applications, problems, and evaluation techniques of planetary microfilming systems, the authors designed and constructed a standard Planetary Microfilming camera Target Array (PMTA) that essentially satisfied three criteria, i.e. 1) inexpensive to produce, 2) simple to use, and 3) satisfies testing criteria for both microfilming equipment manufacture and user. Ten evaluation parameters were incorporated in two targets PMTA-I and PMTA-II. PMTA-I includes tests for 1) resolution, 2) readability of printed matter, 3) reduction ratio, 4) exposure and processing, 5) full field visual distortion, and finally 6) corner visual distortion. PMTA-II was designed to evaluate, 7) quantitative distortion, 8) continuous tone, 9) evenness of illumination, and 10) alignment of microfilming system.

## ACKNOWLEDGEMENTS

The authors would like to thank the people of Photographic Sciences Corporation for their technical assistance and moral support.

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CHAPTER I

AN INTRODUCTION

## Introduction

Although the concept of microphotography has been in existence nearly as long as the use of photography itself,<sup>1</sup> microfilming as a widely used tool for information storage has a relatively recent history.

Several types of microcameras are presently in use today. The rotary microfilm camera employs a dynamic system in which both the object and image plane are in motion during the period of exposure. The planetary microfilming camera normally employs a camera head which is mounted on a vertical column centered over and perpendicular to horizontal plane surface. During exposure both the film and the object to be photographed remain motionless. Figure 1 demonstrates graphically the operation of the planetary and rotary systems. A third microcamera system utilizes a step and repeat system in which the object to be photographed is placed on a copyboard and the back of the camera has the capability of adjusting its horizontal and vertical axis to allow several exposures with exact positioning on the image plane at the film surface.

Each camera system has its advantages over the other system but the planetary system is to be considered herein.

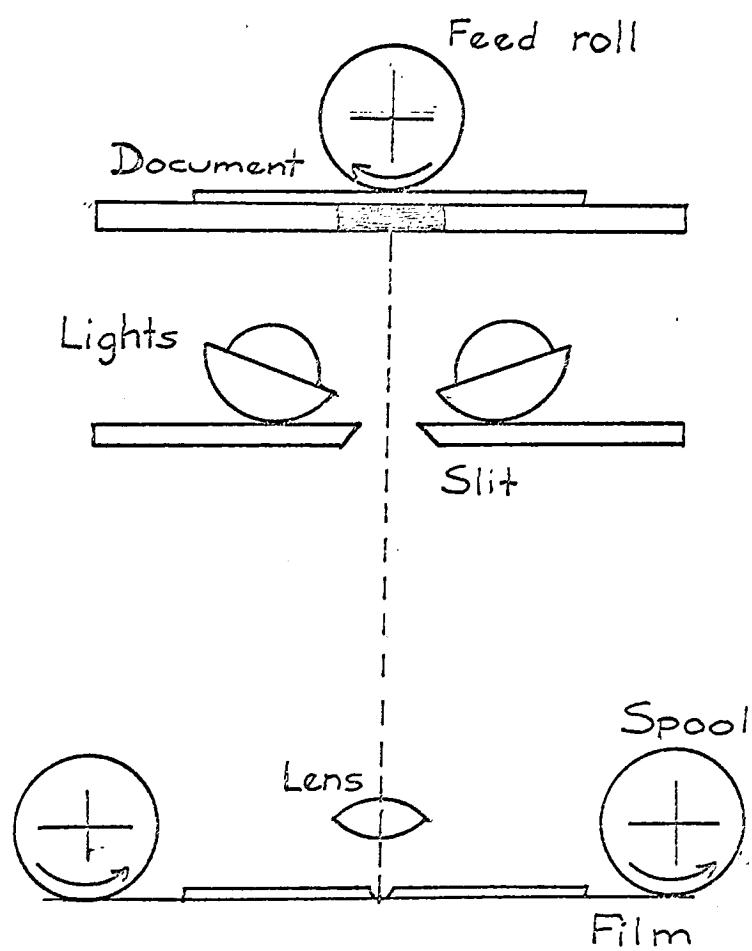
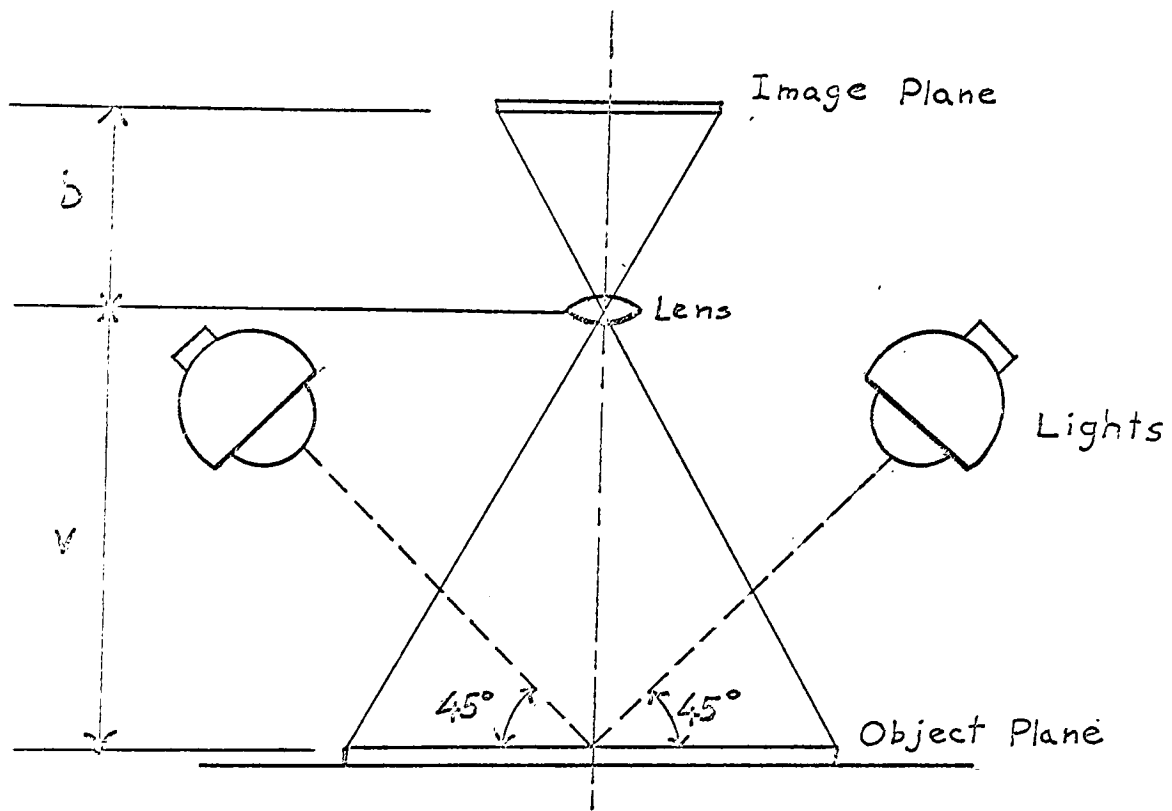


FIGURE 1

The planetary systems are used primarily because of their relatively low expense and great flexibility in use. The cameras are of two basic sizes, large and small. The break off point for this classification is determined by the size of format to be photographed. The 36 inch by 24 inch format is the break off point most commonly used.<sup>2</sup> That is to say, that formats larger than this specified size belong to the larger camera system while smaller formats are primarily photographed by the small camera.

In our study we have concerned ourselves with the smaller format cameras which are primarily used to record legal documents, small engineering drawings, and other such small format material. These smaller cameras are of two basic types. One has a fixed focus and fixed reduction and a second has both variable reduction and focus.

If a good method of planetary microfilming system evaluation was to be developed, it must fulfill several requirements.

It must not only yield an adequate indication of what the system is doing while operating correctly, but more important the evaluation method must give an immediate indication of a fault in this photo-optical system. As yet, much of the microfilming system evaluation has been used on the go-no go method. That is to say, if the micro-filmed results were useable, then the system was said to be working, and if not useable - try again. The useability of the product necessarily has to be the final evaluation parameter, therefore the evaluation array

proposed herein will be based on such go - no go method. However, finer and more quantitative evaluation parameters will be employed to achieve this end.

As indicated by the title of this paper, there were two distinct phases of study - design and construction of a standard Planetary Microfilming camera Target Array (PMTA). The design phase included: 1) an indepth study of microfilming's present uses, needs, and standards, 2) a determination and justification of the evaluation parameters to be included in the PMTA, and finally 3) the layout specifications for the production of the target.

The construction phase included the photo-mechanical generation of individual members of the array and subsequent gatherings of these members into two PMTA's.

## FOOTNOTES FOR CHAPTER I

- 1.) Mees, C.E., and T. H. James, "The Theory of the Photographic Process", Third Edition, Macmillan, New York, 1967, p.542.
- 2.) Bujkovsky, G., and James L. Martin, "The Planetary Camera", Micro-film Techniques, PP 8-10, Nov.-Dec.1971, p.8.

CHAPTER II

DESIGN

## DESIGN

When originally considering the design of a composite planetary test target, it was thought that a target could be made of one universal format which would take into consideration all possible microfilm camera formats and uses. As our research progressed it was found necessary to continually reduce the scope of our thesis. The final result of our efforts for a composite standard Planetary Microfilming camera Target Array (PMTA) included two targets (PMTA-I and PMTA-II) which contained a total of ten evaluation parameters. These targets were designed only for format sizes of  $8\frac{1}{2}$ " x 11" and 11" x 14", and format reduction ratios of 16x, 24x, 28x and 30x.

PMTA-I includes tests for 1) Resolution, 2) Readability of printed matter, 3) Reduction ratio, 4) Exposure and processing, 5) Full field distortion, and 6) Corner distortion. PMTA-II was designed to evaluate 7) Quantitative distortion, 8) Continuous tone, 9) Evenness of illumination and 10) Alignment of imaging system.

The following arguments will consider the design of each individual evaluation parameter of PMTA-I and PMTA-II, in the numerical sequence, presented above.



## PMTA-I

- 1) Several important parameters affect the quality of a microfilm image. Because of the nature of microphotography, one of the more important areas concerns the ability of the photo-optical system to image small objects with good definition. This concept leads to the idea of: Resolution; the ability to render visible fine detail of an object,<sup>1</sup> and Resolving Power; the degree to which a lens, optical system, or image material is able to define the detail of an image.<sup>2</sup> Various resolving power measurement methods<sup>3</sup> have been developed as predictors of the resolution capabilities of a photo-optical system. None of these methods, however, purports to indicate exactly what can be resolved and what cannot. Taubes states, in his paper on legibility of microfilm images, that "images at different reduction ratios resolving the same resolution symbols will not permit the reading of the same letter height".<sup>4</sup> Therefore, many methods of RP measurement yield only an indication of the system's capabilities.

The National Microfilm Association (NMA) recognizes the NBS Microcopy Resolution Chart as the method to be utilized when attempting to determine the resolving power of a microfilmed image.<sup>5</sup> Therefore in an attempt to remain consistent with the goal of producing a PMTA that would reflect the

existing standards, the Microcopy Resolution Test Chart was utilized as the primary means of resolution measurement. The composite array incorporates 9 resolution targets. The first target was placed on axis in the center of the array as shown in figure 2. This target has groups of elements of five lines each with frequencies of spacing varying from 1.0 lines/mm to 18 lines/mm. Table 1 shows the maximum and minimum values of possible resolution after the target has undergone various specified reductions.

Microfilm systems normally operate with a resolution of approximately 100 lines per millimeter.<sup>6</sup> Therefore, even after blow back and/or duplicating of microfilmed material and subsequent loss of resolution, the resolution target would be capable of yielding a resolution measurement.

As shown in figure 2 there are also four sets of, two each, resolution targets mounted tangentially 80%<sup>7</sup> of the diagonal distance to their 8½" x 11" and 11" x 14" formats, respectively. These targets are also NBS Microcopy Resolution Test Charts but they only contain frequency groups 2.0 lines/mm through 10 lines/mm. Availability of space and resolution capabilities dictated the use of this range of resolution groups. Table II indicates the possible maximum and minimum resolution for this target at various specified microfilm reductions. Often military criteria must be met to satisfy specifications. Table II yields the lowest resolution group number which must be resolved in order to meet with military line width and print size specifications at a given reduction.

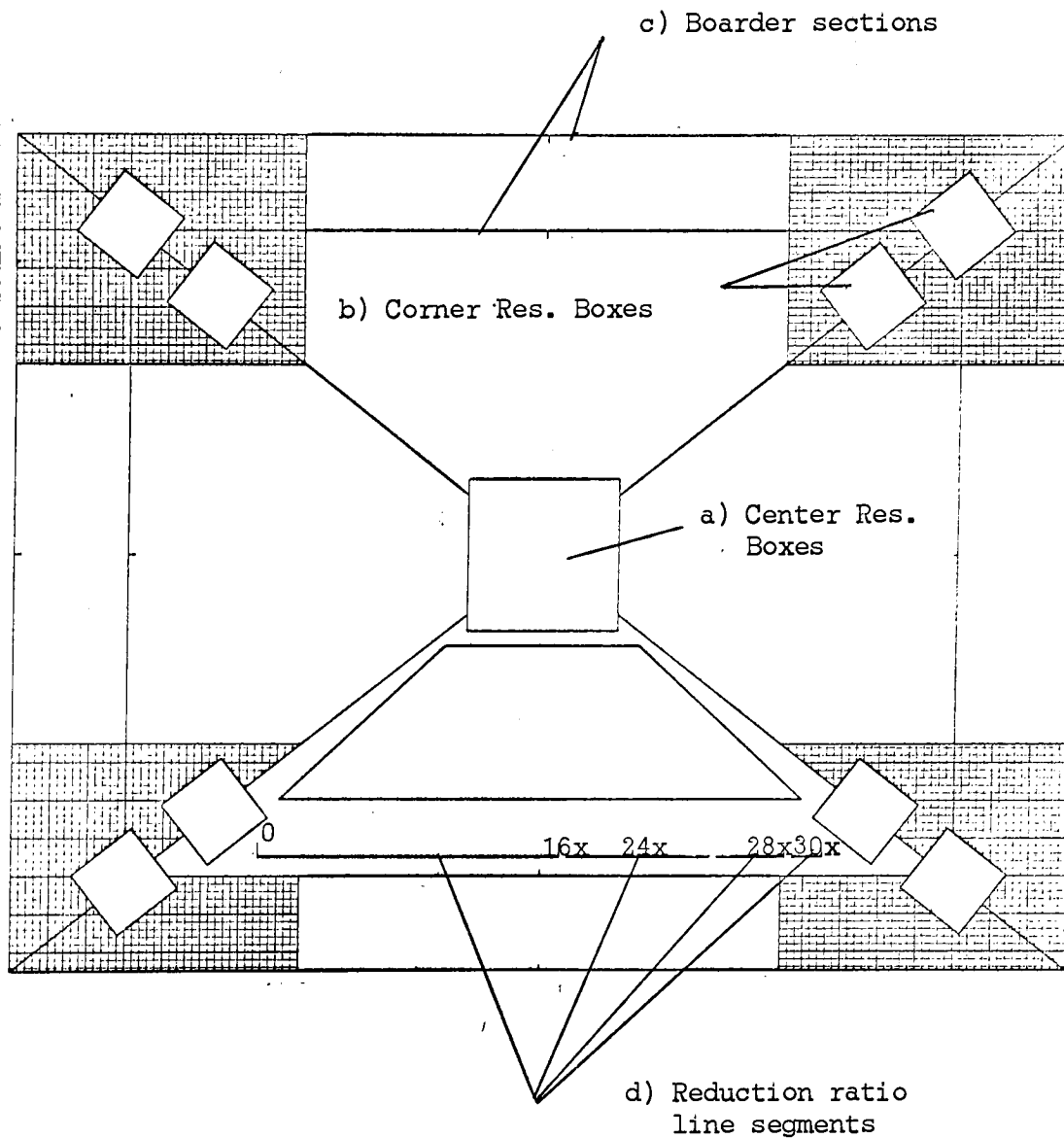


Figure 2

2.5x Reduction of Background Format of PMTA-I Showing a) Center Resolution, b) Tangentially Located Corner Resolution Boxes, c) Border of 11" x 14" and 8½" x 11" Formats and d) Reduction Ratio Line Segments.

TABLE I

Maximum and Minimum Values of Possible Resolution after Target Has Undergone Various Specified Reductions

Reduction	Minimum Resolution Group 1.0	Maximum Resolution Group 18
16x	16 l/mm	288 l/mm
24x	24 l/mm	432 l/mm
28x	28 l/mm	504 l/mm
30x	30 l/mm	540 l/mm

i.e. lines per millimeter

TABLE II

Maximum and Minimum Values of Possible Resolution after Target Has Undergone Various Specified Reductions

Reduction	Minimum Resolution Group 2.0	Maximum Resolution Group 10
16x	32 l/mm	160 l/mm
24x	48 l/mm	240 l/mm
28x	56 l/mm	280 l/mm
30x	60 l/mm	300 l/mm

TABLE 3

Minimum resolutions necessary for compliance with M. L. spec. 9868D

Reduction Ratio	Smallest NBS Pattern read	Resolution lines/mm
16x	7.1	114
24x	5.0	120
28x	4.5	126
30x	4.5	135

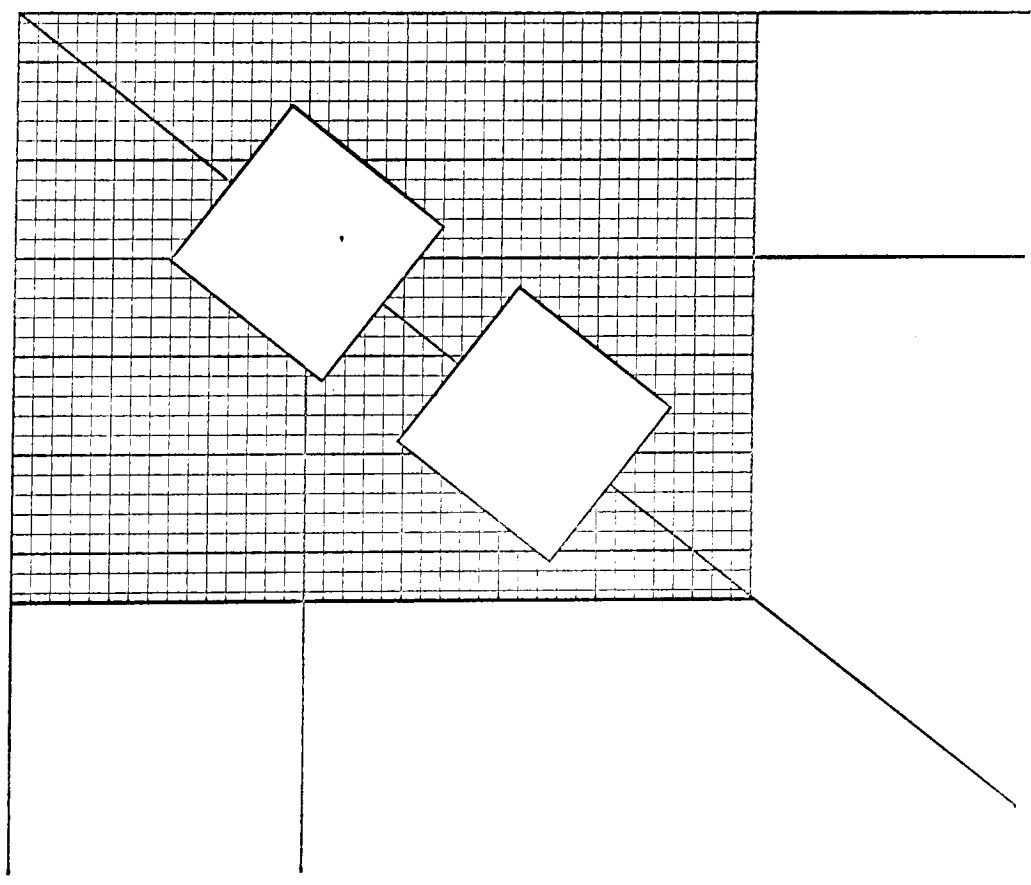


FIG. 3

Corner grid section used in the evaluation of distortion

2) Readability of Printed Matter - Considering that the majority of matter contained on the format size for which this target is designed is printed matter, a representative target could hardly be designed that did not contain varying styles and sizes of type.

In discussions with Alexander Lawson,<sup>8</sup> a specialist in typography it was pointed out that there are basically two schools of type face styles used most often. Almost 90% of the general printed matter today<sup>9</sup> is printed on one of a multitude of Roman type style. A Roman type face style is characterized by its complex style and curvatures plus serifs at letter endings. This type style is popular because of its pleasing appearance and because of the variety of patterns each letter has, thus being less monotonous to read. According to the studies made by Lawson, there are a number of very popular Roman type face styles<sup>10</sup> of which Baskerville is one. Baskerville type style will be included in the PMTA because of its popularity as a Roman type style.

A second type style that could not be ignored is sans serif which is characterized by letters that have no serifs. The American National Standards Institute (ANSI) is presently attempting to standardize a type style that is to be used in engineering drawings that are to be micro-filmed.<sup>11</sup> This particular sans serif type style has been developed by the NMA and is known as Microfont. The reason for its development is to have

a type style that is clear, easily legible and that microfilms well with little chance of readability error. Microfont is specifically known in the printing industry as a sans serif gothic style type with clean smooth lines.

The target will contain a type style box with sans serif and Roman (serif) styles represented by Microfont and Baskerville respectively. Each type style ranges in size from 4 point (i.e. approx. .04") to 14 point (i.e. approx. .14") in steps of 2 points. Each point size group is made up of 4 groups of 5 randomly chosen alphanumeric characters.<sup>12</sup> In the case of Microfont there are no lower case letters, therefore all letters are of similar height. In the case of Baskerville, five letter groups were chosen to represent a word, the first letter of which is a capital letter and the following four letters of which are lower case letters.

- 3) Reduction ratio is a third image quality parameter to be dealt with. The reduction ratio is controlled by the optical and mechanical portions of the photooptical system. The reduction is important to the image quality because of the tight specifications of image blow-back. The microfilmed image must maintain its correct reduction ratio to the object being photographed. If the total image is too large or too small, it is possible to lose portions of the image, or encounter blow-back disproportionment.

Military specification 9868D dictates that the reduction ratio must be within  $\pm 0.4\%$  of the specified reduction ratio. The reduction ratio of a system is often measured by including a line of known length on the test object and after being reduced onto film, the image is measured with an optical reticle and the reduction ratio is calculated by:

$$\text{Reduction Ratio} = \frac{\text{Object line length}}{\text{Image line length}}$$

This reduction ratio is then compared with the specified reduction ratio to determine if it falls within specifications.

A simple and accurate method to check reduction is a criteria that is wanted by the user as well as the manufacturer of planetary microfilming systems. Therefore we have to include this into the PMTA in such a way as to construct distances in such lengths to yield a constant value at various popular reductions. Thus, there would be a specific reduction that would yield a constant value after it is reduced. This constant value would be the same for all the reductions.

The NMA, in cooperation with ANSI, is trying to standardize the sizes of documents and drawings in a similar fashion as has ISO done in order to begin to limit and standardize the reduction ratios basically to 24x and 28x for 16mm applications and 16x, 24x, and 30x for 35mm systems.



Therefore, a measurement system as shown in figure 2d would be easily measured with a magnification loop and retical.

- 4) Exposure and processing is also a most important parameter of consideration. One method for evaluation of this parameter is the introduction of gray patches of differing reflectancies. After development, the gray patches are then measured by use of a diffuse densitometer such as the MacBeth model TD-102 transmission densitometer. Military Standard 9868D requires that when a gray patch of 50% reflectance is imaged and microphotographed, it must have a density of  $1.1 \pm 0.1$ . The NMA, in addition to this 50% reflectance patch, introduced a 6% reflectance patch, their proposed industry standard target for large engineering drawing. In addition to these two patches, we have inserted a third patch of 80% reflectance for a dual purpose, 1) to simulate and allow the measurement of the background density of a common brand of white bond paper and 2) to yield a three point approximation of a Density vs. log Exposure (Hand D) curve. If a microfilm user were to test his system periodically, these three points would be useful in detecting a change in his exposure and/or processing.
  
- 5) Full field distortion is the fifth area of consideration to be incorporated in the PMTA. Image distortion is manifested by a bowing of straight line and causes the image to lose its proportion. This effect is caused by an

optical aberration and, in the case of microfilming, can cause engineering drawings to be out of proportion and/or print characters to be formed outside their matrix positions. The border outlines of the 11" x 14" and 8½" x 11" formats lend themselves to the evaluation of this parameter. The target evaluator would subjectively determine whether or not the border line sections displayed bowing appearances.

- 6) Corner field distortion is the last evaluation parameter to be included in PMTA-I. Grid sections have been placed in the four corners of the PMTA to allow the target evaluator to subjectively determine if there is a noticeable amount of this off axis aberration. This grid section is made up of 0.1" squares. The format border lines passing through the grid section are .015". The major 1" and ½" division lines are .010" and the smallest interior lines are .005". These varying line widths can also aid the target evaluator in judging what line width will be lost after subsequent microfilm copies or blow backs. Table IV indicates comparable resolution that the line widths represent at varying reductions.

TABLE IV

Comparable Resolution for Line Widths at Various Specified Reductions

Reduction Ratio	Line Resolution *		
	.015	.010	.005
16x	21 l/mm	31 l/mm	63 l/mm
24x	31 l/mm	47 l/mm	94 l/mm
28x	37 l/mm	55 l/mm	110 l/mm

Reduction	Line Resolution *		
Ratio	.015	.010	.005
30x	39 l/mm	59 l/mm	117 l/mm

\* Resolution measures in lines/mm

#### PMTA-II

- 7) Quantitative distortion - the idea of mathematically placing a numerical value on distortion became evident when we realized that what one person would consider too much distortion, another would not. This was accomplished by defining distortion as

$$\text{Distortion} = \frac{\text{Corner length}}{\text{Center length}} = \frac{B}{A}$$

The target evaluator could measure distance A and distance B with a loop and retical and determine the quantitative distortion by dividing B by A. If there was no distortion then  $B/A = 1.0$ . On the other hand, if we had a value for distortion greater than 1.0, then this would be a pin cushion distortion. If the value was less than 1.0, then this would be barrel distortion. The idea is that the manufacturer would have an actual value that he could place on the amount distortion over a specific area and in that way could stand behind his product. Figure 4 illustrates the points of measurement.

- 8) Much of the microfilming being done today includes pictorial images of a continuous tone nature. Therefore it was decided to include a gray scale of varying reflectances. The exposure and processing evaluation parameter of PMTA-I already includes reflectance patches of 6%, 50%, and 80%. PMTA-II includes four patches of 10%, 30%, 50% and 70% reflectances with an overall background reflectance of 80%. Even after a 30x reduction of PMTA-II onto film, the 2.3mm gray patches would easily be measurable with a 1mm aperture of a transmission densitometer such as the MacBeth TD-102. These gray patches could then be plotted on a diffuse density versus log exposure curve to attain a day to day record of the tonal qualities of the microfilm system.
- 9) Evenness of illumination, according to several people the authors conferred with, could be one of the most important considerations. If the illumination of the object being photographed is not correct, hot spots can form on the image, washing out any printed matter. It is possible to subjectively evaluate this parameter with the use of PMTA-II by comparing different sections of the background to each other. The target evaluator could also take density readings of the different background sections and allow himself a much more quantitative method of comparison.
- 10) Alignment of the imaging system is the last parameter designed to be evaluated by PMTA-II. This evaluation method is quite simply accomplished

by placing PMTA-II on the object plane platform of the planetary camera in the position normally used for the specific format size in question. After exposure and processing, the distance from the 11" x 14" or 8½" x 11" format border to the edge of the film is measured with a magnification loop and retical. If there is any skew of the image position to the film, then the positioning of the object should be adjusted until correct.

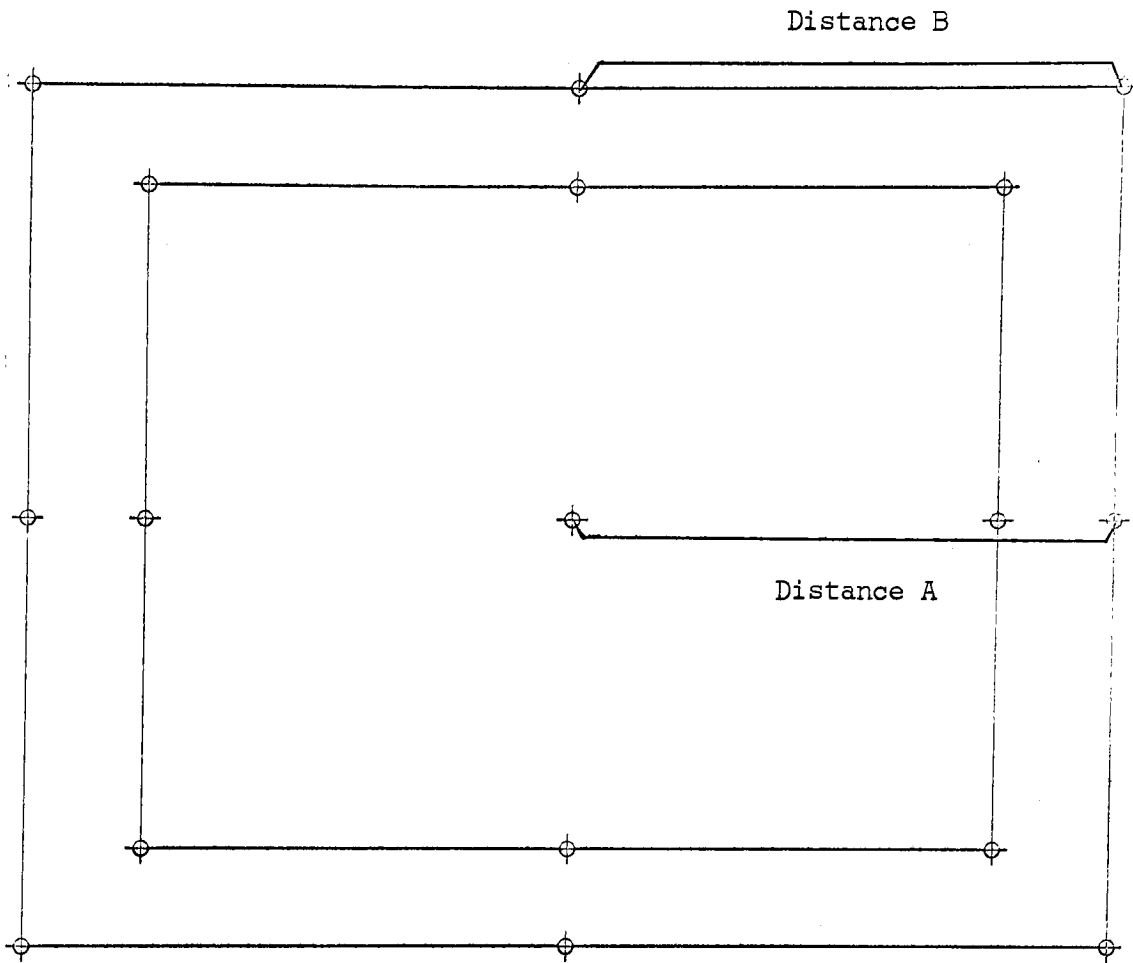


Figure 4

2.5x reduction of background of PMTA-II

## FOOTNOTES FOR CHAPTER II

- 1.) NMA, "Glossary of Terms for Microphotography and Reproduction Made from Microimages," Maryland, 1964.
- 2.) Ibid.
- 3.) Appendix A displays several currently used targets and their application and specifications.
- 4.) Taubes, Earnest P., "Determining Limits of Legibility of Microfilm Images," Photo Devices Inc., Rochester, New York.
- 5.) NMA, "Inspection and Quality Control Standard - First Generation (Original) Silver Halide Microfilm," 4th Draft, May 1971, p.6.
- 6.) "Micromation Film Manual," Stromberg Datagraphix Incorporated, San Diego, Calif. July 1970, p. 2-7.
- 7.) 80% is the percentage stipulated by the NMA's Inspection and Quality Control Standard for first generation silver halide microfilm.
- 8.) Alexander Lawson - Professor in the School of Printing at Rochester Institute of Technology. Specializes in typography, its history and development. Lawson has written numerous articles for Printing Impressions on type styles.
- 9.) This statistic has been compiled for the last 40 or so years by the American Institute of Printing in the so called "Fifty Books of the Year" where the 50 best books of the year are analyzed for print size, style, etc.

- 10.) The most popular styles of print as analyzed by Lawson, among others, are Baskerville, Times Roman, Caledonia, Garamond, Janson, Bodoni, and Caslon.
- 11.) ANSI Standard Drafting Practices, ANSI Y14.2, "Line Conventions and Lettering". Draft March 1971, Proposed Revision, p.18.
- 12.) Ibid.



CHAPTER III

CONSTRUCTION

## CONSTRUCTION

Although both the authors had had prior experience in the production of targets and reticals, the complex nature of the PMTA's construction afforded both of us much additional thoughtful experience.

It had been thought that we could utilize a copy of the National Microfilm Association's endorsed Microcopy Resolution Test Target but, much to the authors' chagrin, copies that we attained were not of a high enough quality to allow faithful reproduction. Therefore, there was no other recourse but to produce our own five bar targets. This formidable task was started by attaining artwork specifications from the NMA. Because of the highly reliable 5x reduction capabilities of a 12 inch lens used at Photographic Sciences Corporation, it was decided to produce the initial artwork 25x the final size. Each of the 26 individual elements of the test target, i.e. groups 1.0 through 18, were produced on a precision x,y plotting table. After each element was reduced 5x, the total target was aligned in their correct respective positions and the complete target underwent the last 5x reduction. Through exposure and processing controls, it was possible to contain all elements to within  $\pm 5\%$  of a one to one bar to space ratio and specified size. Figure 5 shows groups 8, 9, and 10 at the initial 25x size. Figure 6 shows a 2.5x magnification of the target's final size.

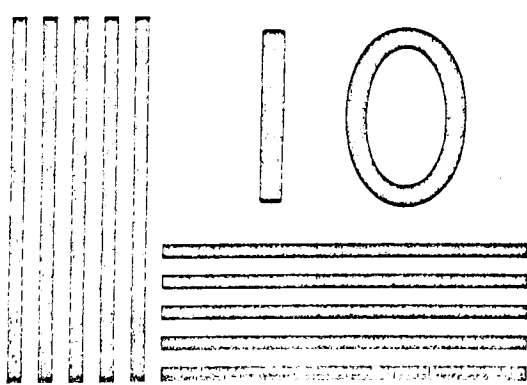
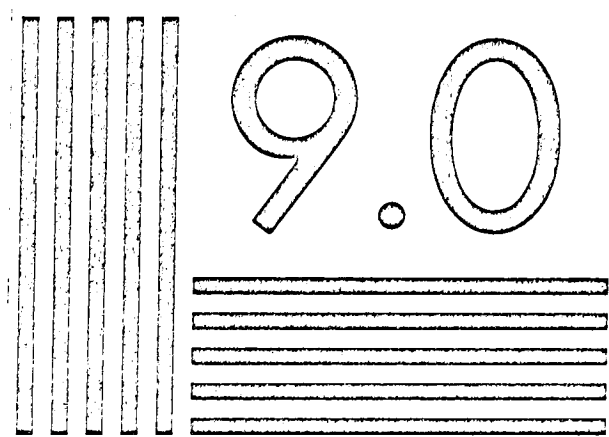
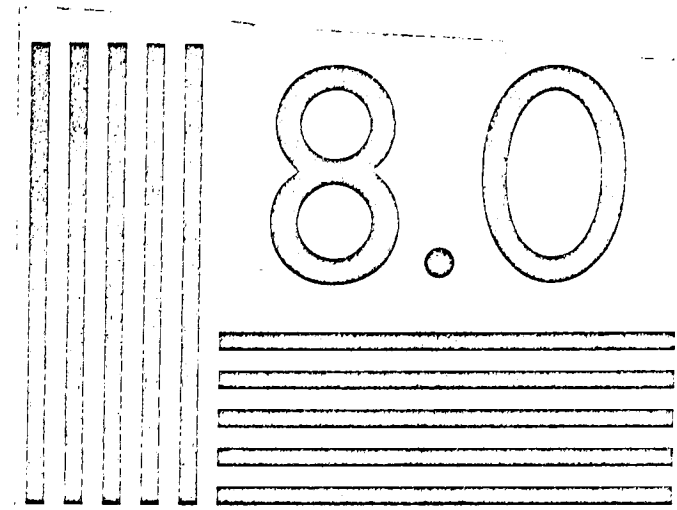


Figure 5

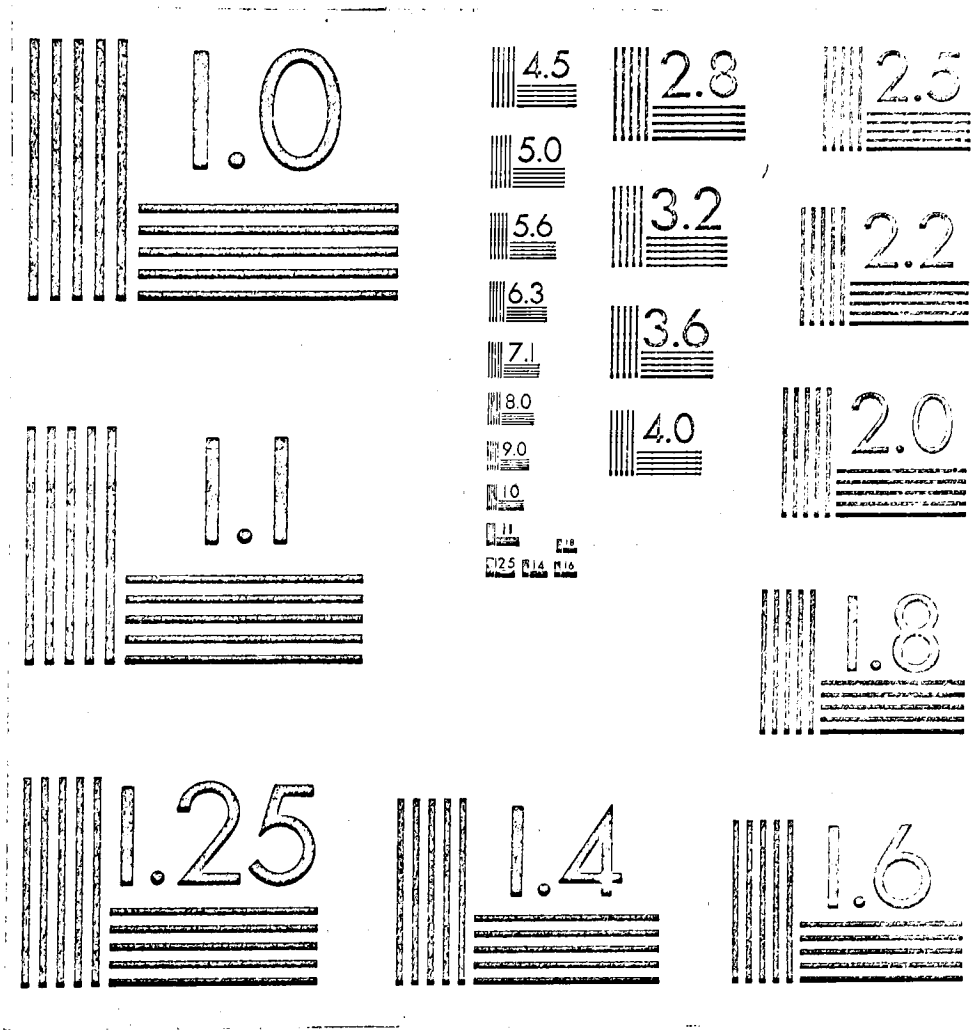


Figure 6

2.5x magnification of final resolution target

The type style box was part of the major background artwork as shown in the 2.8x reduction of figure 2. It was necessary to randomly select the letter as suggested in the design section and then mount each letter individually on clear mylar. After numerous groups of five letters, each was mounted. The random lettering of each type style underwent various specific reductions to produce the different point sizes needed. Figure 7 shows the composit type style box calling out the different point sizes and type styles.

Lettering was stripped onto the reduction line segments to indicate which line segment was to be used for specific reduction, i.e. 16x, 24x, 28x, and 30x as seen in figure 8.

second generation master negatives were made from the background artwork of figure 2 and the assembled targets and lettering. One third generation master positive was produced by a dual contact print exposure of the two master negatives in register. One fourth generation composit master negative was produced by contact printing the composit third generation master positive. At this point Kodak 96D Wratten neutral density filters were introduced to the transparent patch sections of the negative to allow the correct reflectances on the Positive Print Film. It was found that the base plus fog level of the reflection film material was approximately ~~20%~~<sup>80%</sup> reflectance.

Figure 9 shows a 2.5x reduction of the composit master positive.

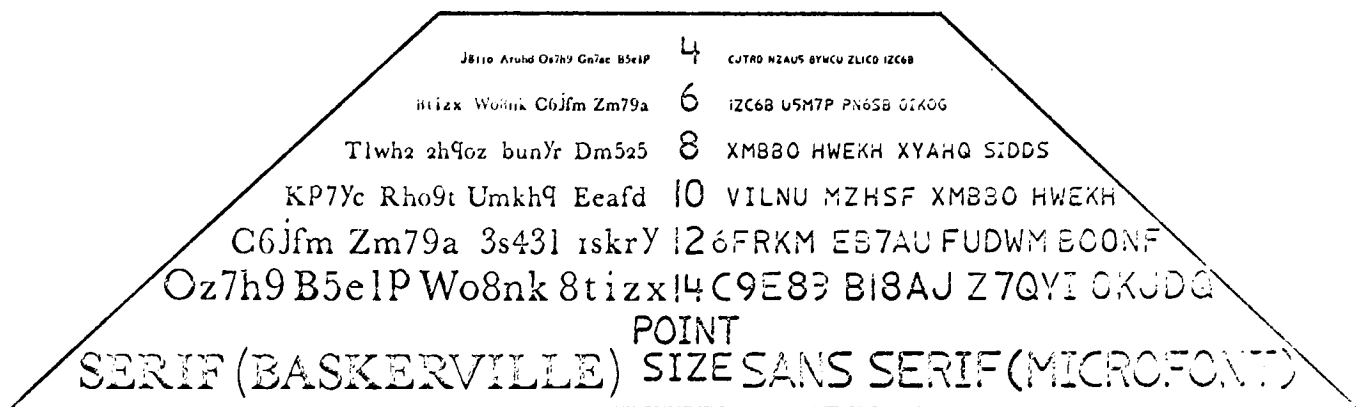


Figure 7

Type Style Box

SHOULD MEASURE .25" AT REDUCTION

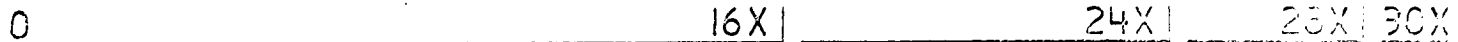


Figure 8

Reduction Ratio line segments

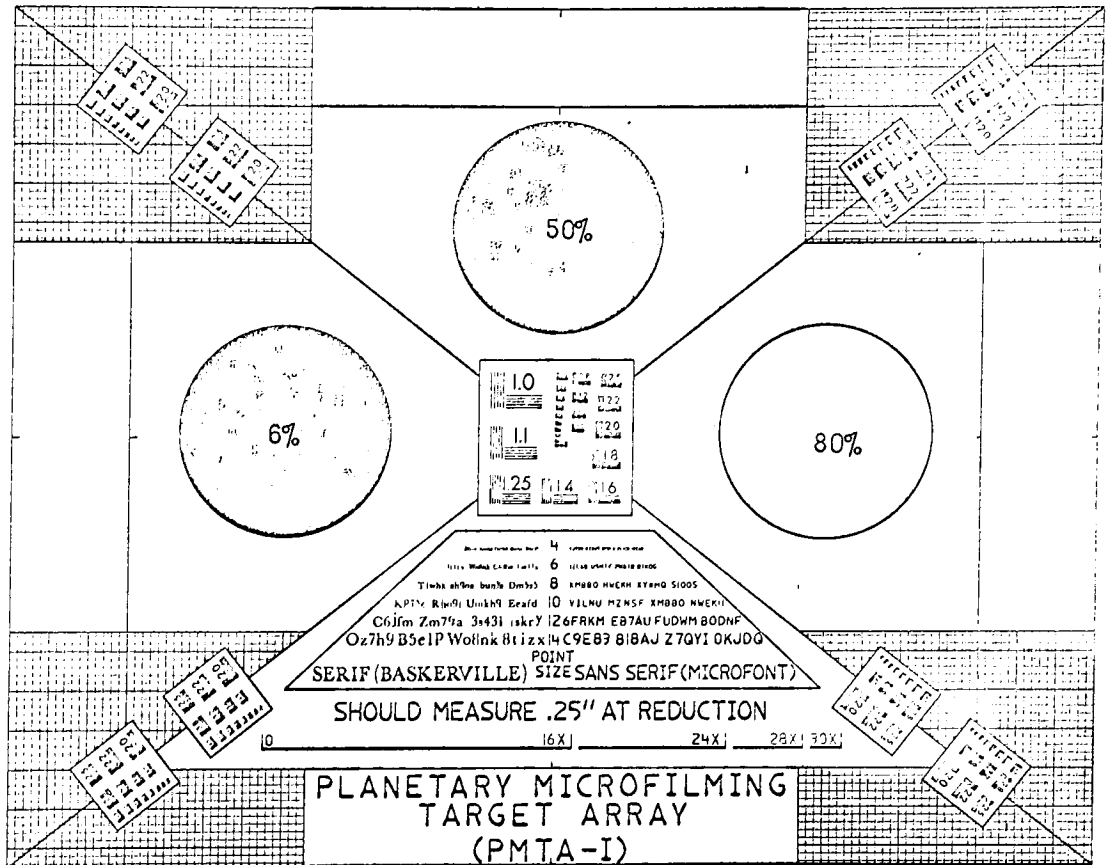


Figure 9  
Composit PMTA-I

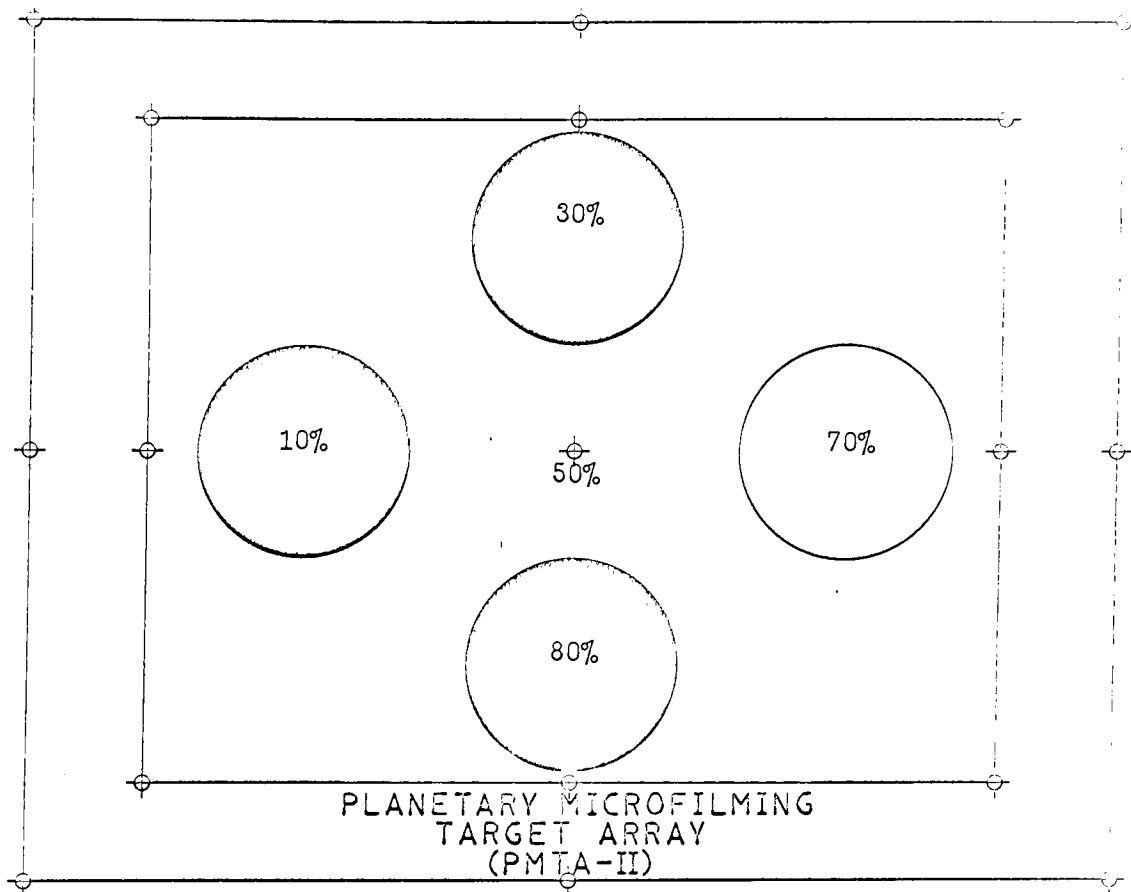


FIGURE 10

Composit PMTA - II



Notice that the 6% and 50% patches are opaque to allow a transparent mode when in the composit negative stage.

PMTA-II was completed in the same dual registered contact print of the second generation master line work negative and master lettering negative as done in PMTA-I. A subsequent composit fourth generation master negative was made from the composit third generation master positive and neutral density filters were inserted at this point to allow the correct reflectances of 10%, 30%, 50%, 70%, and ~~80~~90%.

Figure 10 shows a 2.5x

2 reduction of the third generation master positive.

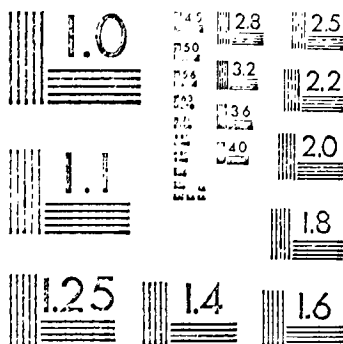
#### Summary

The authors feel that they have achieved the tri-fold purpose of their initial objective. A PMTA has been produced that is 1) inexpensive to produce, 2) simple to use, and 3) satisfies testing criteria for the user as well as the manufacture.

APPENDIX A

CURRENTLY UTILIZED RESOLUTION  
TARGETS-APPLICATIONS-SPECIFICATIONS

NBS MICROCOPY TEST CHART



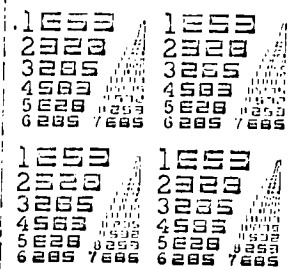
DATA

Bar length-to-width ratio..... 24:1  
 Bar width-to-space width ratio..... 1:1  
 Pattern frequency progression.....  $20\sqrt{10}$   
 Pattern frequency range..... 1 to 18lp/mm

APPLICATION

For resolving power evaluation of recording materials and optics employed in reduction imaging such as microfilm systems. For visual assessment; target layout does not lend itself to photoelectronic scanning easily.

ALPHANUMERIC BLOCK CHARACTERS



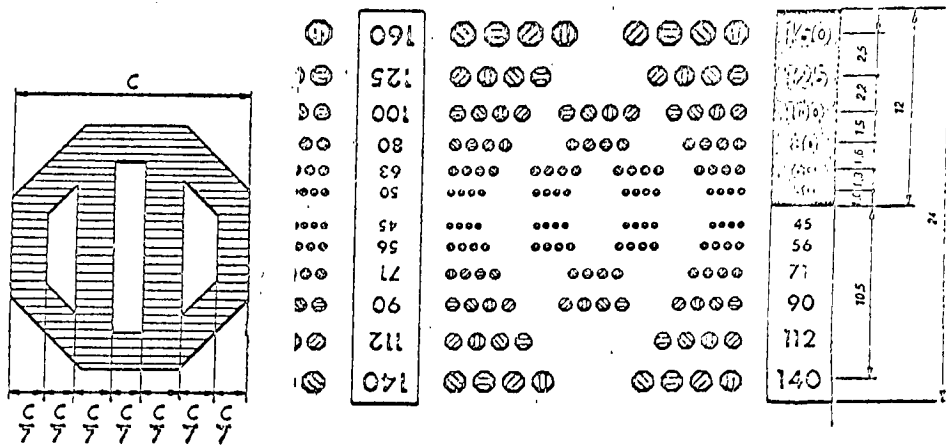
DATA

Bar length-to-width ratio..... 5:1  
 Bar width-to-space width ratio.... 1:1  
 Pattern frequency progression and range depend on the degree of the reduction of characters.

APPLICATION

Testing resolution of imaging materials and optical systems by by conventional bar type resolution patterns for evaluation by visual means. Not very suitable for photoelectronic scanning.

ISO MIRE



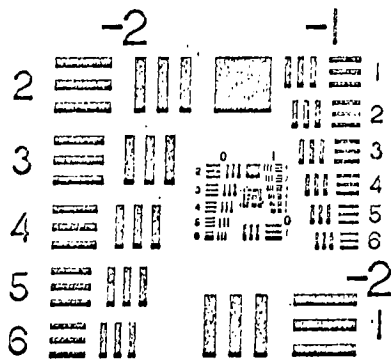
DATA

Equivalent resolving power.....  $R = 7/2C$   
 Pattern frequency progression.....  $6\sqrt{2}$   
 Pattern frequency range..... 2.19 to 7.79 lp/mm

APPLICATION

Primarily used in resolving power and typographical character legibility for microimaging exposure and blowback systems, and document copying applications. Target does not lend itself to photoelectronic scanning of the patterns.

USAF 1951

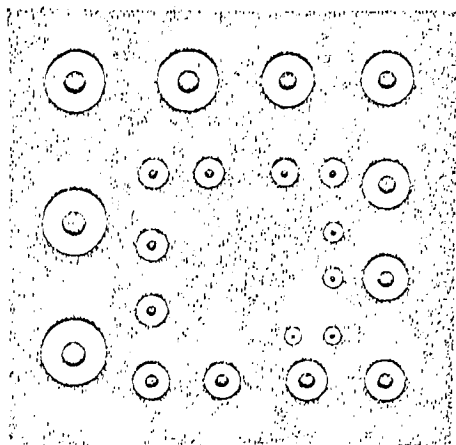


DATA

Bar length-to-width ratio..... 5:1  
 Bar width-to-space width ratio... 1:1  
 Pattern frequency progression....  $6\sqrt{2}$   
 Pattern frequency range..... .25 to 900 lp/mm

APPLICATIONS

Can be used for resolving power in imaging systems and optical systems. Also used for visual resolution measurements. Target is not very well suitable for electronic scanning.

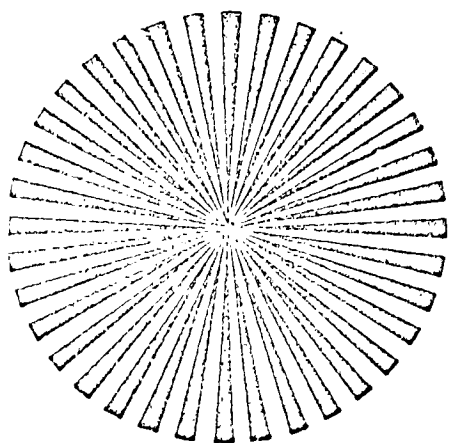
ANNALUS

## DATA

Central to outer ring diameter... 1:3  
 Pattern frequency progression....  $\sqrt{2}$   
 Design contrast-generally low.... 1.6:1

## APPLICATION

In testing resolution performance of lenses for aerial photography where low contrast detail is often encountered. This target is favored in Canada.

WEDGE-SHAPED RESOLUTION ELEMENTS

## DATA

Bar width and space width.....  $5^\circ$   
 Resolving power from center..... R.P. =  
 $90 / r$   
 where  
 $r$ =distance  
 in mm  
 $\theta$ =angular  
 separation  
 of bars

## APPLICATION

Ideally suited for detection of lens astigmatism and other aberrations. Not well suited for photoelectronic scanning unless it can be pivoted about its center.

## APPENDIX B

INSTRUCTION FOR THE USE OF THE NATIONAL BUREAU OF STANDARDS  
MICROCOPY RESOLUTION TEST CHART

INSTRUCTIONS FOR THE USE OF THE NATIONAL BUREAU OF STANDARDS MICROCOPY  
RESOLUTION TEST CHART

The useful reduction ratio of a microcopying camera is limited by the nature of the material to be copied, the resolving power of the lens, the resolving power of the photographic material, inaccuracy of focusing, vibration, and systematic relative motion of the optical image with respect to the photographic material. The resolution test chart is issued to assist in standardizing the evaluation of the performance of microcopying systems. The test patterns are made up of black lines on a white background, the lines being 24 times their width, and the lines and spaces being of equal width. The patterns range in spatial frequency from 1 to 10 lines per millimeter. Each pattern is made up of two groups of 5 parallel lines, the lines in the two groups being oriented perpendicular to one another. The number associates with each pattern is the number of lines per millimeter on that pattern.

To measure the resolving power of the microcopying system, place one chart in the center of the camera field, one at the center of a long side, and another at a corner. Orient the last two so that one group of lines is directed toward the center of the field. Photograph the charts in the same manner as documents and examine the processed films with a microscope, using a magnification from  $1/3$  to 1 times the number

of lines per millimeter to be observed. For example, to view 100 lines per millimeter, the magnification should be between 30 and 100.

If the camera is slightly out of focus, the copy of the chart may have other than 5 lines in some groups. This is "spurious resolution" and is sometimes accompanied by failure to resolve at one spatial frequency when apparent resolution occurs at a higher frequency. If there is no evidence of spurious resolution, find the smallest pattern in which the lines can be counted with certainty. The number on that pattern multiplied by the reduction ratio is the measures resolving power of the system in lines per millimeter. For example, if the finest resolved pattern is marked "4.0" and the reduction ratio is 29, the resolving power is 116 lines per millimeter.

Away from the center of the field, the resolution of lines directed toward the center is often not equal to the resolution at right angles to that direction because of lens aberrations. If the patterns perpendicular to one another are not equally resolved at the center of the field, one should suspect camera vibration or other image motion with respect to the film.

The resolution required to copy type depends upon the size of type, the reduction ratio, and the quality of reproduction required. For most practical purposes;  $R$ , the resolving power in lines per millimeter;  $e$ , the height in millimeters of the lower case "e" in the type to be copied;  $r$ ,



the reduction ratio; and  $q$ , an arbitrary "quality index," are related by the following equation:

$$R = \frac{qr}{e}$$

For excellent copy, in which the details of type are clearly defined,  $q$  must be 8 or more. If  $q$  is assigned a value of 5, the copy may be read without difficulty although serifs and fine details of type are not clear. If  $q$  is 3, the copy may be read with difficulty, the letters  $e$ ,  $c$ , and  $o$  being partly closed.

In 1963, the resolution chart was slightly modified. Space was left in the center so that a 10 times reduction of the chart could be placed there by anyone desiring to extend the spatial frequency to 100 lines per millimeter. The patterns from 2 to 10 lines per millimeter are in an array that may be used as an abridged chart. Although the form of the patterns is unchanged, the dimensions of the new charts conform more accurately to the nominal values.

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Reference: Bernard H. Fouquet, "The NBS Microcopy Resolution Test Chart", National Bureau of Standards.

## APPENDIX C

INSTRUCTIONS FOR USE OF PMTA

## USE OF PMTA

## PMTA-1

- 1) Resolution - is the ability of a photo-optical system to render visible fine detail of an object expressed as "resolving power" and measured in lines/mm.
- 2) Readability of Printed Matter - Use type style representative of style of lettering to be microfilmed. With a suitable magnification instrument, read the smallest twenty letters possible noting each one on a piece of paper. Compare the recorded values with the actual values and noting the number of correctly read letters. Decide how confident you want to be that you are reading those letters by:

<u>Out of 20 Read Correctly</u>	<u>% Confidence</u>
17	99
16	95
15	90

Example: If one wants to be 95% confident of what one is reading, then one must read out of 20 letters correctly of the smallest line possible.

- 3) Reduction Ratio - is the ratio of the linear measurement of a document to the linear measurement of the image of the same document expressed as 16:1, 24:1, etc. The measurement should be made with precise enough instruments to yield results meeting your specifications.
  
- 4) Exposure & Processing - in order to comply with accepted standards for checking resolution, the 50% reflectance patch should read  $1.1 \pm .1$  density after processing on a calibrated diffused densitometer (such as a MacBeth TD-102)
  
- 5) Full field distortion can be subjectively evaluated by examining the reduced image of the border regions of the PMTA for possible bowing.
  
- 6) Corner distortion can be evaluated by the use of the corner grid sections of the PMTA. Again, if upon examination of the film the corner grid section of the PMTA have a two fold purpose, 1) Corner distortion can be evaluated by examining the reduced image of the grid sections for possible bowing of lines or a symmetrical appearance of the individual squares, 2) The .015" PMTA format border lines, the .010" major division lines of the grid and the .005" minor division lines of the grid can be used to determine the reproduction quality of

straight lines. The table below yields comparable resolutions of the three line widths at the specified reductions.

Comparable Resolutions for Line Widths a Specified Reductions

Reduction	Line Widths		
	.015	.010	.005
	Line Resolutions *		
16x	21	31	63
24x	31	47	94
28x	37	55	110
30x	39	59	117

\* line resolutions are measured in lines/mm

7) Quantitative distortion can be measured by dividing the corner distance (B) between registration marks by the center distance (A) between registration marks, as shown in the figure below.

- 8) Continuous Tone - is the varying gradation of gray densities between blacks and white. For the microreproduction of continuous tone materials the user should first determine the optimal exposure and processing adjustments for a typical pictorial scene. When an image has been judged accepted the PMTA should be exposed and processed under the same conditions and the developed densities of the reflection patches should be recorded to be used as standard reference densities for subsequent micro-reproductions of continuous tone materials.
- 9) Evenness of Illumination - the background of the PMTA is a 50% gray to render it useable for this evaluation. Measure the corners and the center of the image on the processed microfilm with a densitometer having an apparatus no longer than 2 mm. (Such as a McBeth TD-101.) The readings should be relatively close to each other, if not, appropriate adjustments should be made.
- 10) Alignment of Imaging System - place the target in the position where material to be microfilmed would normally be located. After microfilming and processing, the image of the 11" x 14" or the 8½" x 11" format border to the edge of the film is measured with a suitable measuring instrument to check proper positioning and skewness of the image.

Procedure to be followed in  
testing with PMTA-I & PMTA-II

These steps are not necessarily the only pattern that can be used, but they are in a logical sequence that would render the most information out of your system and the shortest amount of time in adjustment.

- a) Run pre-exposed sensitometric strips through your processor to check if it is in control. These strips are exposure controlled and when developed in your processor can be used to diagnose processor problems. Both Eastman Kodak and Bell and Howell produce these strips.
- b) Exposure-adjust the exposure level to yield a density of  $1.1 \pm .1$  of the 50% reflectance patch when measured with a transmission densitometer. See #4.
- c) Resolution - read center & corner resolutions and note if they meet your needs. If not, adjustments in the focus might have to be made. See #1.
- d) Reduction - with an appropriate measuring instrument, measure the reduction and make necessary adjustments if necessary. See #3. Note that if adjustments are necessary, then the resolution should also be checked after adjustments since the two are interrelated.

e) Readability - read the smallest line possible and judge if acceptable.

See #2.

f) Over all and corner distortion - with the thick format boarder and the corner grid patterns, note if distortion is present and if it is acceptable.

See #5 and #6. If a more quantitative method is needed, use PMTA-II (see #7).

g) Evenness of illumination - this is to check, among other things, if the lights are properly aligned, if they all have the same intensity, or if there are any hot spots. To accomplish this, read #9.

h) Alignment of the image system - this is accomplished with the aid of the format boarder lines by measuring from the lines to the film edge.

See #10.

i) Quantitative distortion - measure with a suitable measuring instrument distances A and B calculate quantitative distortion. See #7. This value can be used as a measure on how much distortion prevails and can be used for setting a quality standard to compare with.

j) Continous tone - included are density patches of 10, 30, 50, 70, 80 percent reflectances that can be used for checking continous tone. See #8.



This is a general outline that can be used in the complete testing of your system with the aid of PMTA-I and PMTA-II.

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