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PERFORMANCE COMPARISON TEST PLAN

FOR MANN-DATA MICRODENSITOMETER VERSUS

KODAK MODEL 5 MICRODENSITOMETER

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SUMMARY

A test plan is offered for comparing the optical systems of the Kodak and Mann-Data microdensitometers. This plan is intended as a guide for the preparation of a comprehensive test method. After negotiation between participants and preliminary testing, a final procedure can be written.

The general guide lines are given in the text for tests measuring the following characteristics.

a. Resolving Power

b. Modulation Transfer Function

c. Spread Function

d. Power Spectrum

e. Stray Light

A preliminary test procedure is given in Appendix 1 for use as a starting point in writing the final detailed test procedure.

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A. Introduction

1. Two types of microdensitometers are currently in use in determining the image quality of missions by means of edge tracing. It seems essential to compare, in some objective manner, the performance of the Mann-Data instrument with that of the Kodak Model 5. Testing of photographic microdensitometers is discussed by Altman,(1) Kleinsinger,(2) Charman,(3) and Snider.(4) (See indicated references at the end of this write-up.) No attempt will be made here, therefore, to describe exhaustive testing for all characteristics pertinent to this instrument's usage in photographic research. For example, the ability to read the absolute density of microareas to some degree of precision is the fundamental application of a microdensitometer, and yet this characteristic is of little interest in this testing since the current methods of edge tracing utilize relative density rather than absolute density. The ability to hold calibration for several hours and the ability to follow rapid changes in density become more important than attaining a high absolute accuracy.

2. A microdensitometer is composed of mechanical, electrical and optical systems. While a testing of the performance of all subassemblies is desirable, this test plan will concentrate on measurement of the optical system on the assumption that:

a. The mechanical and electrical systems are working reliably.

b. These systems are of secondary interest.

c. Some forms of mechanical or electrical malfunction would be noticed in the suggested optical tests.

3. The optical testing will include discussions of and, where available, procedures for measuring the resolution, modulation transfer function, spread function, power spectra, and stray light control in a microdensitometer.

B. Test Plan Discussion

1. Resolving Power

a. Of historic interest, if perhaps of no longer fundamental importance in edge tracing, is the resolution of the optical system. However, the ability to quickly and reliably bring the microdensitometer to focus is necessary. A test object for measurement of resolution could be any high quality, photographic long bar target. Also, some form of special diffraction grating could be made in which a limited number of lines are ruled in bands, with the bands arranged in a frequency series. A test object similar to the latter form is the Grayson's Rulings, (Beck, London--no longer available), which has been used by microscopists for resolution testing.(1) Lacking a test object, resolution can be inferred by the MTF/edge trace measurements given in the section on Modulation Transfer Function.

b. In comparing the resolution of the Mann instrument with that of the Kodak Model 5, it is recommended that one or more special photographic test objects be scanned on the two microdensitometers. The specific test object pattern is not critical, provided it be some form having long parallel bars arranged in a frequency series. A maximum frequency equal to or greater than 500 lines/millimeter is desirable. Scans

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made in the two instruments with equivalent slits can be compared on the basis of the percentage of modulation retained at the high frequencies. A more complicated analysis could be based on measurements of the profile (i.e.: wave shape) of the two sets of traces. This approach would be recommended only if satisfactory answers cannot be arrived at with simpler methods in the areas of interest.

2. Modulation Transfer Function

a. The modulation transfer function of the microdensitometer can be estimated, but not measured directly, by tracing a sharp photographic edge.(2), (3) The characteristics of the edge, such as sharpness, variability along the length of the edge, grain, and density range influences the results of the measurement. An obvious problem here, as in all suggested microdensitometer tests, is that of obtaining a good test object.

b. The procedure for MTF testing at this facility is:

(1) An X-ray exposed edge on Kodak High Resolution Glass Plate or High Resolution Film (available from N.B.S. by special arrangement) is used as a test object. The maximum density should be less than 2.0; the edge should be several inches long, and only the best portions should be used.

(2) Make recordings of the edge using the particular main slit configuration of interest (e.g.: 1 micron by 80 microns). The pre-slit should be as small as possible and edge/main slit alignment should be carefully adjusted. Carry all digital data to at least three significant digits.

(3) Data sampling should be at spacings, such as 0.10 to 0.25 micron to yield high frequency information.

(4) Make any analog recording at almost maximum scale expansion.

(5) Trace across several places along the edge. Turn the photographic edge 180° and trace similarly in the opposite direction.

(6) Take at least 100 data points per trace so that areas adjacent to the edge are represented.

(7) The digital data is transformed into instrument MTF by means of Fourier methods in the computer.(2),(4) The resultant data represents the best estimate of the frequency response of the microdensitometer.

c. The errors inherent in this method have not been measured. The straightforward technique for measuring the MTF of a microdensitometer by tracing calibrated sinusoidal test objects is suggested by Snider,(4) but he does not indicate whether such test objects are available.

3. Spread Function: A valuable measurement needing development is that of direct measurement of the spread function of the microdensitometer. A test object for this characteristic would probably consist of an extremely narrow clear line on a dark surround. Such a test object is not known to exist. Spread function can be derived from edge trace measurements, but will include the errors associated with edge tracing.

4. Power Spectra

a. A microdensitometer performance test which appears to have promise is in an early stage of development. This test involves the determination of the power spectrum (spectral density function). Standardized test methods have not been established at this time, but a typical experiment will be described below. The methods for interpreting the results of the measurement also are not well established. The principle is that if a scan is made of a white noise test object, the power spectrum produced is that of the slit/optics function of the microdensitometer.(5) If the test object is not white noise, the scan will produce a spectrum which has components of both the test object and the microdensitometer.

(1) A test object currently in use is a flashed and processed strip of Type 3404 film having a series of densities.

(2) The film strip is scanned using the normal slit geometry (e.g.: 1 by 80 microns).

(3) Density samples are collected at small increments of distance (approximately 0.4 microns), and the data values are recorded to three significant digits each.

(4) Maximum sensitivity or "density" expansion is employed. Three thousand or more data points should be taken.

(5) The density data are converted to transmission values and are reduced in the computer through autocorrelation techniques to power spectral density.(6),(7),(8) The resultant plot of power vs. frequency can, in a comparative measurement, show the relative sensitivities ("resolution") of the instruments to the band of frequencies.

b. Spurious noise coming from the instrument should be noticeable provided the test object grain density distribution is reasonably uniform.

c. The reliability, errors, methods, and interpretation of results of power spectrum measurements on microdensitometers are currently under study. Good comparison data is expected from this approach, however, despite current lack of experience with the method.

5. Stray Light

a. An image degrading effect present in all optical instruments is stray light or veiling glare. It is noticeable in microdensitometers as an error in the density recorded for fine black lines on a large, low density (clear) surround. Stray light is also a detrimental factor in edge tracing. Control is achieved through good design (e.g.: baffling, blackening, and glass surface coating) and good maintenance (i.e.: clean optics). When using instruments where hooding of the optical parts is not extensive, it may be necessary to operate in subdued light.

b. A qualitative test for stray light in a microdensitometer is the following:

(1) A special test object with a series of parallel black lines on a clear surround is required. The line width should vary in a series from approximately 100 microns to less than 5 microns. The test object exposure (via X-rays) is constant and brush developing is employed so that the densities of all the lines are equal.

(2) The test object is scanned with a narrow slit (e.g.: 1 x 80 microns). The pre-slit should be only slightly larger than the main slit, following regular practice. It is also informative to make runs with larger pre-slits.

(3) In interpreting the results of the scans, the amount of stray light and its influence on fine detail can be inferred from any progressive fall off in recorded density as the sample line width is decreased.

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References:

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2. I.J.Kleinsinger, A.J.Derr, and G.J.Giuffre, "Optical Analysis of a Microdensitometer System," Appl. Opt., 3, 1167-1170, October, 1964.

3. W.N.Charman, "Practical Tests of a Microdensitometer System," Appl. Opt., 4, 289-294, March, 1965.

4. G.H.Snider, Microdensitometer Capability and Interpretation Study, Final Reports I and III, Cornell Aeronautical Laboratory, Inc., December, 1964.

5. H.J.Zweig, "Autocorrelation and Granularity. III. Spatial Frequency Response of the Scanning System and Granularity Correlation Effects Beyond the Aperture," J. Opt. Soc. Am., 49, 238-244, March, 1959.

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7. E.Parzen, "An Approach to Empirical Time Series Analysis," J. Research Natl. Bur. Standards, Rad. Sci., 68D, 937-951, September, 1964.

8. R.C.Jennison, Fourier Transforms and Convolutions for the Experimentalist, Pergamon Press, 1961.

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Appendix 1: <u>Proposed Microdensitometer Test Procedure</u>

1. <u>General</u>

   a. Record name and serial number of instrument.

   b. Describe in detail optical components used in test, including focal length and numerical apertures of all objectives, magnification of eyepieces if used, and magnification of illumination and pickup systems.

   c. Record type of light source and operating conditions.

   d. Record type of photomultiplier.

2. <u>Resolving Power</u>

   a. Purpose: to indicate the resolving power of the microdensitometer in the scanning mode and in the viewing mode.

   b. Procedure:

      (1) Test Object: Photographic, U.S.A.F. 1962 machine readable, frequency range 200 to 1000 lines per millimeter, clear bars on a black surround, high contrast.

      (2) Microdensitometer operating conditions:

         (a) Slit: 0.5 microns by 80 microns.

         (b) Stage rate: 0.025 millimeters per minute.

         (c) Photometer amplifier controls: normal density settings.

      (3) Analog data recording:

         (a) Chart rate: 8 inches per minute.

(b) Zero: Dmin on low part of chart.

(c) Sensitivity: expand recording to place Dmax on high part of chart.

(4) Digital data: not applicable.

(5) Number of repetitions: None. One reading only.

c. Report: Report maximum frequency recorded on chart.

d. Special comments:

(1) Note whether best visual focal setting yields best recorded resolving power.

(2) Note resolving power of viewing system.

3. <u>Modulation Transfer Function</u>

a. Purpose: to estimate the modulation transfer function (optical frequency response) and spread function of the microdensitometer.

b. Procedure:

(1) Test Object: sharp edge exposed by X-rays on Kodak High Resolution Plate. Density range (ΔD) of 0.50 ± 0.10.

(2) Microdensitometer operating conditions:

(a) Slit: 1.0 microns by 80 microns.

(b) Stage rate: 0.0166 mm/min.

(c) Photometer amplifier controls: normal density setting.

(3) Analog data recording (helpful for verification, but not essential):

(a) Chart rate: 8 inches/minute.

(b) Zero: Dmin recording on low part of chart.

(c) Sensitivity: Dmax reading near highest part of chart.

(4) Digital data collection:

(a) Sample rate: 80 samples (3 digits each) per minute.

(b) Scale expansion: adjust controls such that both clear and dark sides of the edge record with 3 digits and there is the largest spread between minimum and maximum values for increased precision.

(5) Number of repetitions: at least six runs over the same edge are necessary to permit averaging.

c. Computation and Report:

(1) Convert digital data to transmission data in computer.

(2) Determine response by Fourier methods at frequency increments of 10 to 20 lines per millimeter to 400 lines/mm.

(3) Plot response versus frequency.

d. Special Comments:

(1) This method yields the estimate of the MTF for the microdensitometer including the slit width function.

(2) The spread function can usually be obtained as part of the computer data reduction.

(3) Scanning from clear to black and black to clear should expose any non-uniform behavior (e.g.: fatigue) in the photometer circuits.

(4) The stage rate and punch rate suggested may not be available on all instruments. Other combinations are equally suitable provided the data point sampling rate is less than 0.300 microns between data points. The stage rate should be slow enough that the response time of the recording equipment does not affect the measurement.

4. Spread Function

a. Purpose: To directly measure the overall optical performance of the microdensitometer by a method simpler than edge trace derivation.

b. Procedure: Currently there is not adequate information for a preliminary test plan. However, once a suitable test object is available, a procedure can be devised.

c. Special comments: While spread function is derivable from edge tracing in the preceding MTF test, a special spread function test should include less error.

5. Power Spectrum

a. Purpose: to determine the approximate power spectral density function of the instrument. Note that this method includes any noise present in the test object.

b. Procedure:

(1) Test Object: a uniformly flashed and processed strip of Kodak 3404 film, density 0.50 ± 0.10.

(2) Microdensitometer Operating Conditions:

(a) Slit: 1 micron by 80 microns.

(b) Stage rate: 0.0166 millimeters per minute.

(c) Photometer amplifier controls: normal density setting.

(3) Analog data recording (not essential):

(a) Chart rate: 2 inches per minute.

(b) Zero control setting: adjust control so that the lowest recording is near zero on the chart.

(c) Sensitivity control setting: expand the density recording to maximum.

(4) Digital data recording:

(a) Punch rate: 80 samples (3 digits) per minute.

(b) Scale expansion: use fullest practical (preserve 3-digit readings) scale expansion to aid retention of significant digits in subsequent computer data reduction.

(5) Number of data points: collect at least 3000 data points per run. Several runs would be desirable to help estimate the precision of this method.

c. Computation and Report:

(1) Convert the digital data to density (or transmission) in the computer.

(2) Determine the autocorrelation function.

(3) Take the Fourier transform of the autocorrelation function.

(4) Plot the power spectrum versus frequency.

d. Special Comments: As in the measurement of modulation transfer function, the stage rate and punch rate may be different than that proposed above, provided that data sampling is taken at rates slow enough to minimize problems associated with the time constants of the recording equipment while still maintaining close data point spacing on the sample.

6. <u>Stray Light Measurement</u>

a. Purpose: to determine the control of stray light (veiling glare) within the microdensitometer.

b. Procedure:

(1) Test Object: a series of black lines of equal density on a clear surround having line widths varying from 5 to 100 microns.

(2) Microdensitometer Operating Conditions:

(a) Slit: 1 micron by 80 microns.

(b) Pre-slit: 5 microns by 85 microns.

(c) Stage rate: 0.050 millimeters per minute.

(d) Photometer controls: normal for density operation.

(3) Analog Data Recording:

(a) Chart rate: 4 inches per minute.

(b) Zero: normal for density calibration.

(c) Sensitivity: normal for density calibration.

(4) Digital Data Collection: not applicable.

(5) Number of repetitions: None. One reading is adequate.

c. Report: The density of the lines recorded on the analog chart is plotted against the width of the lines. The fall-off of density in the narrow lines is a measure of the uncontrolled stray light within the instrument.

d. Special Comments: This test is relative in nature, being dependent on the uniformity of the test object density. Also, the results are a function of the contrast of the dark bar and its surround.