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TECHNIQUE AND COMPUTER PROGRAM FOR CALCULATING

PHOTOGRAPHIC FILM DENSITY VARIATIONS

BY Craig W. Ohlhorst

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16. Abstract

Film density data that have been digitalized and recorded in Binary Coded Decimal (BCD) format are converted into a number representing the film density difference between the unexposed film border and any point on a photograph by program CONVERT. The difference between AVERAGE, the BCD number representing the unexposed film area and the BCD number of a specific data point is calculated and then multiplied by three constants to produce the desired film density difference. The angle off the principal axis of the lens is computed for each data point in order that a correction factor be applied to compensate for atmospheric backscattering differences and light intensity fall-off, inherent in the camera lens system in use. The program is capable of plotting the calculated density differences. The percentage of points in specific density ranges can also be computed.

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TECHNIQUE AND COMPUTER PROGRAM

FOR CALCULATING PHOTOGRAPHIC FILM DENSITY VARIATIONS

by Craig W. Ohlhorst

Langley Research Center

SUMMARY

A technique and computer program have been developed to calculate the film density difference between the unexposed film border and any point on a photograph. The program calculates the angle off the principal axis of the camera lens so that a correction can be made for vignetting and atmospheric backscattering. The program also plots the computed values as a function of position on the photograph so that a three-dimensional picture is produced. Ranges of density difference can be predetermined, and the program will place each data point into its corresponding range so that the percentage of points in each range can be calculated.

SYMBOLS

AA	proportionality constant, mm/BCD
AVERAGE	number in BCD format representing the density of the unexposed film area
BB	proportionality constant representing the gradient of the linear density wedge, density/mm
BCD	microdensitometer recorded film density
CT	represents the number of data points recorded from the border line trace
Sum	represents the summation of BCD numbers for the data points recorded from the border line trace
XMM	calculated film density difference, density
ZZ	correction factor for vignetting and atmospheric backscattering
ΔBCD	difference in BCD numbers between any two points
ϕ	angle off the principal axis of the camera lens, degrees

ϕ_{Aj} vertical component of ϕ, degrees

ϕ_{pi} horizontal component of ϕ, degrees

θ camera horizontal half angle, degrees

INTRODUCTION

It takes considerable time and money to collect and analyze water samples to determine the health state of a body of water. Development of an instrument that could remotely determine the water quality of a body of water would be of great benefit to the effort of monitoring the water quality of this nation's rivers and lakes.

The NASA Langley Research Center, in conjunction with other federal agencies, has been working on a program to develop and evaluate instruments that will have the capacity to remotely determine various water quality parameters. One of the instruments being evaluated is a wide-angle lens, aerial photography system with appropriate lens filter combinations. The wide-angle lens is used to get both high spatial resolution and a synoptic view at the same time. Film density of the photographs are then analyzed to see if there is a correlation between radiance intensity and certain water quality parameters. It has been shown in reference 1, for example, that the film density difference between the unexposed film border and a point on a photograph can be correlated to chlorophyll a concentrations.

Data obtained using the wide-angle lens require a mathematical correction to the film densities to compensate for atmospheric backscattering and lens vignetting. The correction needed is a function of location on the photograph (angle off the principal axis of the lens). The principal axis is assumed here to be the same as the perpendicular vertical intersecting the center point of the photograph. Each data point will have a unique angle, so a method to calculate this angle is needed. A microdensitometer, an isodensitracer, and a magnetic tape encoder were combined to digitalize the film densities. This paper presents a technique and computer program to convert digitalized film densities into a number representing the film density difference between the unexposed film border and a point on the photograph.

PROBLEM TASK DESCRIPTION

A National Instruments Laboratories' Isodensitracer and Magnetic Tape Digital Encoder System are used to digitalize film densities obtained from a Joyce, Label and Company Microdensitometer. These are recorded in Binary Coded Decimal (BCD) format. The problem considered in this paper is that of calculating the film density difference between the unexposed film border and any recorded data point.

TECHNIQUE FOR COMPUTING FILM DENSITY DIFFERENCES

The Joyce, Lobel and Company Microdensitometer, Model Mark III C, has been modified electronically to utilize the automatic interval stepper of the isodensitracer so that the microdensitometer can automatically scan a full photograph. The microdensitometer uses a double-beam system in which two light beams from a single source are alternately impinged on a photomultiplier tube.[2] The photomultiplier alternately sees the beam going through the specimen and through a reference linear density wedge, thus providing an electrical signal which causes movements of a servomotor to bring the linear wedge into optical balance with the specimen beam. A pen attached to the linear wedge carriage plots the position of the wedge resulting in a plot of the density. The vertical distance that the tracing pen moves, (see figure 1), equals the distance that the linear wedge is shifted to optically balance the reference and specimen beam. Multiplication of this vertical pen distance by the slope (BB, density/mm) of the linear density wedge will give a film density difference value.

The Magnetic Tape Encoder System is mounted on the rear of the microdensitometer and attached to one of the pulleys driving the linear density wedge. A multicommutator is mounted on the x-axis of the flat bed recorder. This commutator provides 5, 10, 20, 50, or 100 contacts per revolution and is so mounted to provide approximately 10 revolutions for one traverse of the recording table on the X-axis. At each point of contact, density datum is recorded. The encoder provides a BCD output corresponding to one of 175 positions evenly spread out along the length of the linear wedge; thus, there is a direct proportionality between the magnitude of the difference in BCD numbers between any two points and the vertical pen distance between those points.

$$\text{Vertical Pen Distance} = (AA)(\Delta BCD)$$

The proportionality constant (AA) has been hand calculated and stored in the program. (See Appendix A for the calculation of AA.) A mathematical computation subtracting the recorded BCD number for a specific data point from the BCD number representing the unexposed film border (AVERAGE) will give the ΔBCD number for that data point. AVERAGE is calculated by summing up the BCD numbers of the border trace and dividing by the total number of points in that trace.

$$\text{AVERAGE} = \text{Sum}/\text{CT}$$

As previously stated, multiplication of the vertical pen distance by constant BB would give the film density difference for a specific data point. Use of a wide-angle lens requires that a correction for vignetting and atmospheric backscattering be made. The correction must be applied to the vertical pen distance before multiplication by BB. The correction factor (ZZ), can be calculated and applies to each data point, provided the angle ϕ for each point is known (see fig. 2). For the photograph shown in this paper, ZZ was set equal to $\cos^2\phi$. The angle ϕ can be broken up into its horizontal and vertical components with

$$\tan^2\phi = \tan^2\phi_{pi} + \tan^2\phi_{Aj}$$

The angles ϕ_{pi} and ϕ_{Aj} can be calculated since the number of points recorded per scan and the number of scan lines are known.

$$\phi_{pi} = \frac{\text{Camera horizontal half angle}}{1/2(\text{number of points per scan})} \times p_i$$

$$\phi_{Aj} = \frac{\text{Camera horizontal half angle}}{1/2(\text{total number of scan lines})} \times A_j$$

where p_i = ith point from the center of the film

A_j = jth line from the centerline

These angles are calculated by the user, converted to $\tan^2$ values by the user, and stored by Data Statements in the program. The program calls the appropriate $\tan^2\phi_{pi}$ and $\tan^2\phi_{Aj}$ values for each data point, adds them together, and calculates ϕ. Thus, the steps for calculating the film density difference are:

1. Calculation of AVERAGE
2. AVERAGE - BCD = ΔBCD
3. (ΔBCD) X (AA) = Vertical Pen Distance
4. Calculation of ϕ
5. Calculation of ZZ
6. (Vertical Pen Distance)/(ZZ) = Corrected Vertical Pen Distance
7. (Corrected Vertical Pen Distance) X (BB) = XMM

PROGRAM DESCRIPTION

Program CONVERT is written in Fortran IV for the Control Data 6000 series computers. It uses Langley Research Center Library subroutines PSEUDO, CALPLT, AXIS, LINPLT, NFRAME; and Library functions SQRT, ATAN, and COS. The program also uses Subroutine ENCOD, which is not in the Langley Computer Library but was developed by Langley personnel for use with the Magnetic Tape Encoder.

Program CONVERT

Program CONVERT is used for the input and output of data. It initializes the variables. Subroutine ENCOD takes the information off the tape, and the program calculates the corrected film density difference values. Each value is placed in a range of density differences by the program so that the percentage of points in each range can be calculated. The user specifies the desired density difference ranges. Program CONVERT also plots the computed values as a function of position on the photograph so that a three-dimensional picture is produced with the third dimension being the density difference.

A specific order of data input onto the recording tape must be followed for the program to work properly. The specific order needed is explained in Appendix B, and a program listing is given in Appendix C. The flow diagram of program CONVERT is shown on pages 6 and 7.

PROGRAM USAGE

The program is run on the Control Data 6000 series computer under the Scope 3.0 operating system and requires a field length of $60{,}000_8$ storage locations. The Central Processing Unit (CPU) time will depend on the number of data points recorded. A CPU time of 150 seconds will usually be enough to analyze one 70 mm size photograph with 50,000 data points recorded.

Input Description

Most of the input data comes from the user submitted tape. Other input data terms are as follows:

PPP array of Kodak step wedge densities corresponding to the wedge steps that were traced over by the microdensitometer, inputed by a Data Statement

CFX array of the $\tan^2\phi_{pi}$ values for each data point in a line, inputed by a Data Statement

CFY array of the $\tan^2\phi_{Aj}$ values for each line, inputed by a Data Statement

AA constant, mm/BCD

BB constant, density/mm

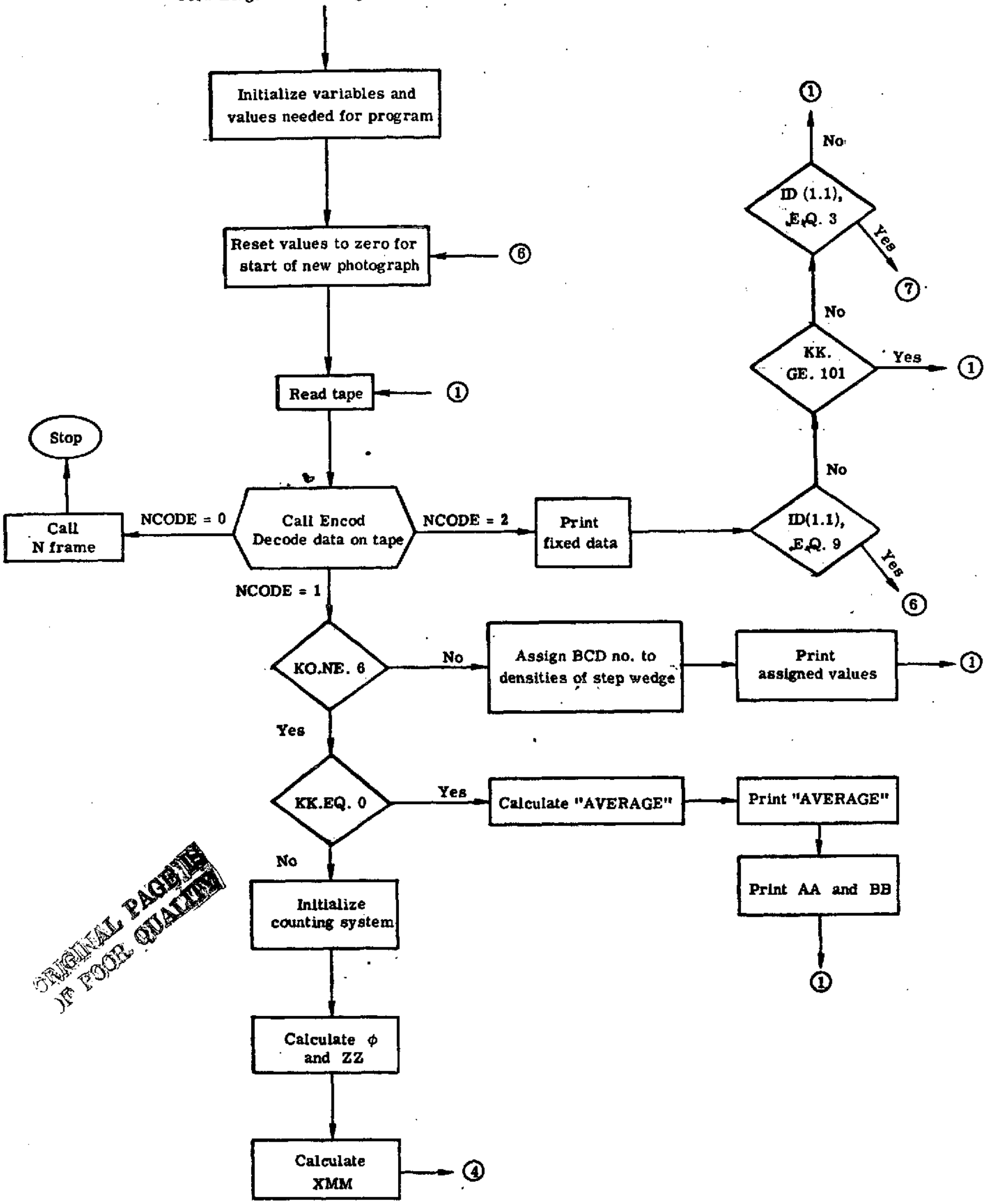
Desired density difference ranges--entered by IF Statements.

Output Description

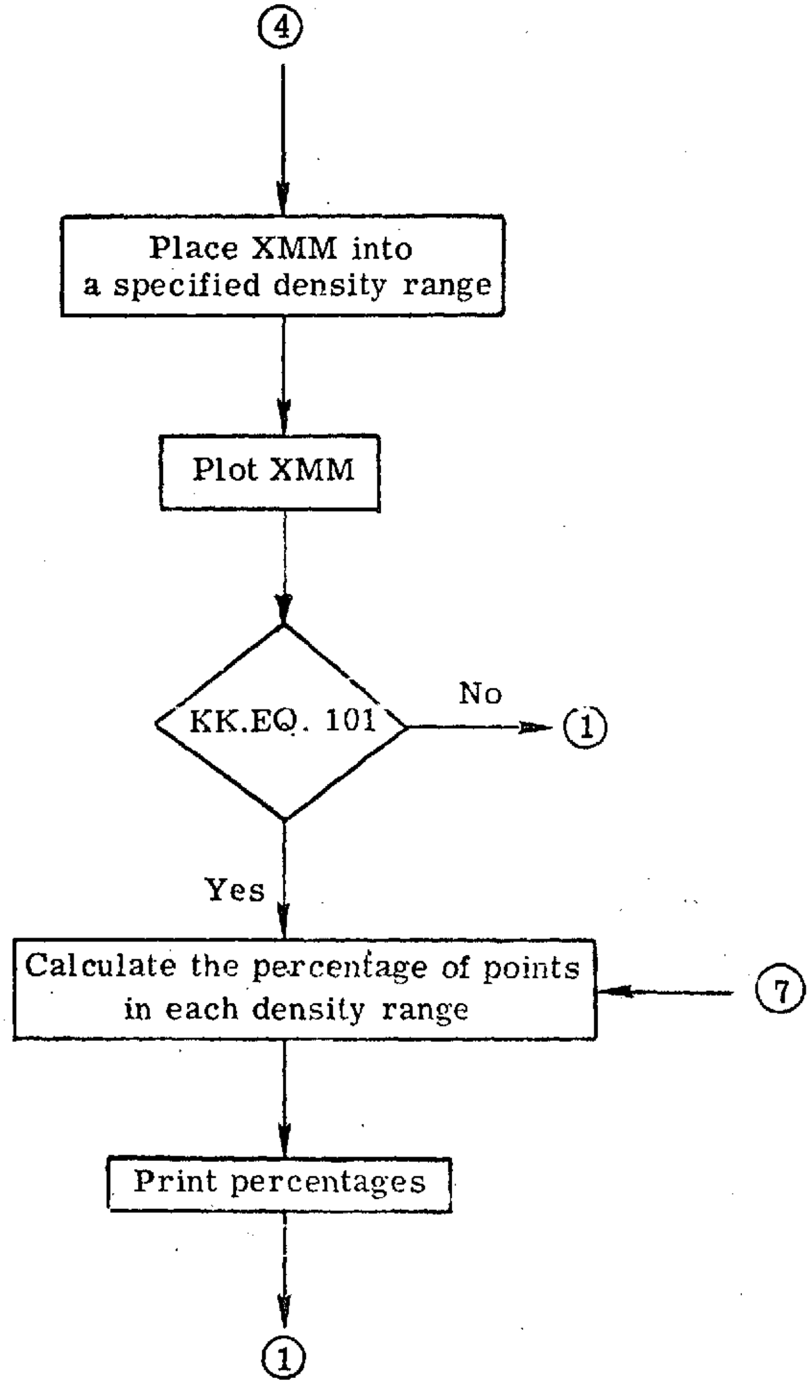
The output for program CONVERT consists of these elements:

1. Five lines of machine setting and other non-density data. See Table I for sample listing. The settings are recorded by the Fixed Data Switches on the Magnetic Tape Encoder (see Appendix D).

Flow Diagram For Program CONVERT



continued Flow Diagram



2. Table of step wedge density versus assigned BCD number. Analysis of the BCD numbers will determine if the microdensitometer is working properly. There should be a constant difference, ±1, between any two BCD numbers. (See Table II.

3. A counter (y-number) specifying what trace the upcoming data represents. A zero means that the border trace is printed next. See top left corner of Table III.

4. The border trace is printed in BCD format so that the user can check the density variation. From these data, AVERAGE is calculated and printed out. See Table III.

5. Calculated density difference values for each scan. There are twelve data points printed per line of printout. See Table IV.

6. Table of density difference range, number of points in each range, and the percentage of total number of data points in each range. See Table V.

CC	represents total number of data points
EA, EB, EC, ED, EE, EF, EG, EH	represent the number of data points in specific difference ranges.
7. Computer plot	The plot is a three-dimensional picture of the calculated film density differences. Each line is plotted from right to left. The actual scales allow for each point on a line to be plotted 2.54 mm (0.1 in.) apart, and the starting point of each successive line is shifted 0.762 mm (0.03 in.) to the left. See figure 3.

Machine Setting Terms are as follows:

A	height of light spot on the aperture plate of the microdensitometer, recorded as two BCD numbers
B	width of light spot on the aperture plate of the microdensitometer, recorded as three BCD digits
G	width of light spot on the photograph, recorded as three BCD digits
condenser	focuses the light beam on the photograph, number represents the lens power, recorded as two BCD digits

wedge	represents density range of the linear wedge, recorded as two BCD digits
commutator	represents the number of segments that the linear wedge is broken up into by the isodensitracer, recorded as two BCD digits
dif. control	an electronic control which varies the amount of feedback signal to the table drive unit, recorded as two BCD digits
pen damping	controls the speed of the tracing pen when the microdensitometer is used in manual mode, recorded as two BCD digits
write-out arm ratio	ratio of recording table movement to specimen table movement, recorded as three BCD digits
pen stop multiplier	number of 125 micron-steps that the isodensitracer recording pen takes between successive scans, used when the system is set to run in automatic mode, recorded as two BCD digits
spec. step multiplier	number of 25 micron-steps that the specimen table is moved between successive scans, used when the system is set to automatic mode, recorded as two BCD digits
objective	focuses light from the specimen table onto the aperture plate of the microdensitometer, number represents the lens power, recorded as two BCD digits
magnification	built into the microdensitometer, number represents lens power recorded as two BCD digits
resolution	number of data points recorded by the magnetic tape encoder system per inch of recording table movement, recorded as three BCD digits
film number	number assigned to distinguish the photograph from others, recorded as five BCD digits
cal. strip number	number specifying the Kodak step wedge used, recorded as five BCD digits

step low density	number of the lowest Kodak density step traced over, recorded as two BCD digits
step high density	number of the highest Kodak density step traced over, recorded as two BCD digits

SAMPLE CASE

A positive transparency of a 70 mm photograph taken above Maryland Point on the Potomac River in October 1972 was used for the sample case. (See figure 1.) The picture was taken by a Hasselblad 500 EL camera at an altitude of 3,048 m (10,000 ft). The camera had a 40 mm focal length and a Wratten 89B filter was attached. An F-stop of 8 was used with a shutter speed of 1/250 seconds. The positive transparency was overdeveloped to bring out the features in the water. The white area covering the top third of the photograph is land. The rest of the picture is water. Ground truth data have shown the water to be heavily concentrated with blue-green algae. Analysis has shown that the white sections in the water are areas with sufficient algae density to produce chlorophyll concentrations greater than 34 $\mu g/\ell$.

Density data on the photograph were measured by the microdensitometer from left to right in the horizontal direction and from bottom to top in the vertical direction. The system was set up so that 406 data points were recorded from each scan with 101 scans evenly spaced and covering the whole photograph.

Sample Input Data

PPP 0.05, 0.20, 0.36, 0.50, 0.64, 0.79, 0.94, 1.09, 1.23, 1.38, 1.53

CFX the array of $\tan^2\phi_{pi}$ values inputed as printed out in the program listing (Appendix C)

CFY the array of $\tan^2\phi_{Aj}$ values inputed as printed out in the program listing (Appendix C)

AA = 1.1530 mm/BCD

BB = 0.0130 density change/mm^3

Density difference ranges $<$0.143, 0.143 - 0.195, 0.195 - 0.260, 0.260 - 0.299, 0.299 - 0.546, 0.546 - 0.650, 0.650 - 1.400, 1.400

Sample Output

The printed output is shown in Tables I through Table V with the computer plot shown in figure 3.

CONCLUDING REMARKS

A technique and computer program have been developed to calculate the film density difference between the unexposed film border and any point on a photograph. The program calculates the angle off the principal axis of the camera lens so that a correction can be made for vignetting and atmospheric backscattering. The program also plots the computed values as a function of position on the photograph so that a three-dimensional picture is produced. Ranges of density difference can be predetermined, and the program will place each data point into its corresponding range so that the percentage of points in each range can be calculated.

APPENDIX A

CALCULATION OF CONSTANT AA

Plotting of a density profile of a Kodak Step Wedge (see figure 4) while at the same time recording the data on tape enables the constant AA to be calculated. The constant is computed by measuring the vertical distance between any two steps of the wedge on the profile and dividing by the difference between the corresponding BCD numbers. The BCD numbers are taken from Table II.

Example:

The distance between steps 3 and 7 of figure A1 = 62.2 mm

The corresponding BCD numbers are 97 for step 3 and 151 for step 7.

$$\Delta BCD = 151-97 = 54$$

$$\frac{62.2 \text{ mm}}{54_{\Delta BCD}} = \frac{1.1518 \text{ mm}}{\Delta BCD}$$

The value of 1.1530 mm/BCD assigned to AA in the sample case came about from the averaging of ten such calculations using the F-140, 2.4 density wedge but should be good for any linear wedge used.

APPENDIX B

ORDER OF DATA INPUT NEEDED FOR PROGRAM CONVERT

To insure that program CONVERT works properly, a specific order of data input onto the recording magnetic tape should be followed.

First - Five lines of machine setting data should be inputed onto the tape. Use the fixed data switches.

2nd - A trace of a Kodak step wedge should be inputed next

3rd - A border trace should then be inputed

After these three steps have been followed, the program is now ready for these film data.

When the user is finished with one photograph, a set of fixed data should be inputed onto the tape with the first switch being set to 3 and then another set of fixed data placed in the tape with the first fixed data switch set at 9. See Appendix D for an explanation of this first switch. When digitalizing a second photograph on the recording tape, the first and second steps from above can be left out.

When the user is finished putting data on a tape, an END OF FILE marker (EOF) should be placed on the tape. The EOF signifies to the computer that there is no more data on this specific tape and thus terminates the program.

APPENDIX C

Program Listing

```
JOB,1,0220,60000,01200.          G0000   R3638       100920         RM 11778
USER.OHLHORST, CRAIG W.                   000656390N 67110
LINECNT(11000)
NORFL.
REQUEST,TAPE12,HI,X.     WM36,ROL,
RUN(S,,,,,,,,,1)
REWIND(TAPE12)
SETINDF.
LGO.
RFL(52000)
PLOT.CALPOST,30(XO=1.,YO=1.,FSH=31.,FSV=16.)
CONT.//PAPER 301,GRID COLOR RED,BALLPOINT PEN BLACK,SINGLE MODE//
DROPFIL(TAPE12)
EXIT.
UNLOAD(TAPE12)
      PROGRAM CONVERT(INPUT,OUTPUT,TAPE12,TAPE6)
C     IDEN IS A TWO-DIMENSIONAL ARRAY, CONTAINS DECODED DENSITY INFORMATION
C     ID  TWO-DIMENSIONAL ARRAY, CONTAINS DECODED FIXED DATA INFORMATION
C     CPA   ARRAY OF DATA PTS. TAKEN FROM A MICRODENSITOMETER TRACE
C    1      OF A KODAK STEP WEDGE
C     D ONE-DIMENSION ARRAY CONTAINS SAME INFORMATION AS IDEN
C     RD ARRAY OF DATA POINT..EQ.DELTA BCD
C     XKK ARRAY OF THE LOCATIONS ON THE HORIZONTAL AXIS OF THE GRAPH
C    1    PAPER WHERE THE DATA POINTS ARE TO BE PLOTTED
C     XMM ARRAY OF CALCULATED DENSITY DIFFERENCE VALUES
      DIMENSION IDEN(1,512),ID(1,12),DEN(500),CPA(100),PPP(100),D(512),
     1RD(512),XKK(512),XMM(512),CFX(420),CFY(110)
      INTEGER A(1049)
      DATA(PPP(KB),KB=1,11)/0.05,0.20,0.36,0.50,0.64,0.79,0.94,1.09,
     11.23,1.38,1.53/
C     TAN**2 VALUES FOR EACH DATA PT. IN A LINE, STARTING AT THE LEFT
C     HAND SIDE OF THE PHOTOGRAPH
      DATA(CFX(I),I=1,125)/0.47271,0.46673,0.46081,0.45496,0.44917,
     10.44344,0.43777,0.43214,0.42659,0.42108,0.41565,0.41025,0.40492,
     20.39964,0.39442,0.38925,0.38413,0.37907,0.37405,0.36909,0.36419,
     30.35933,0.35451,0.34975,0.34504,0.34037,0.33576,0.33119,0.32667,
     40.32218,0.31776,0.31338,0.30904,0.30474,0.30048,0.29627,0.29211,
     50.28798,0.28391,0.27987,0.27587,0.27192,0.26799,0.26412,0.26029,
     60.25649,0.25274,0.24901,0.24534,0.24170,0.23810,0.23453,0.23100,
```

```
     70.22751,0.22405,0.22062,0.21724,0.21390,0.21058,0.20731,0.20406,
     80.20085,0.19767,0.19453,0.19142,0.18834,0.18529,0.18229,0.17931,
     90.17636,0.17345,0.17054,0.16770,0.16488,0.16207,0.15931,0.15659,
     A0.15389,0.15123,0.14856,0.14595,0.14338,0.14083,0.13831,0.13579,
     B0.13333,0.13089,0.12848,0.12610,0.12372,0.12140,0.11909,0.11682,
     C0.11457,0.11233,0.11014,0.10796,0.10582,0.10370,0.10160,0.09953,
     D0.09748,0.09546,0.09347,0.09149,0.08954,0.08763,0.08573,0.08386,
     E0.08200,0.08017,0.07837,0.07660,0.07484,0.07310,0.07139,0.06971,
     F0.06804,0.06640,0.06478,0.06318,0.06161,0.06006,0.05853,0.05702/
      DATA(CFX(I),I=126,250)/0.05553,0.05407,0.05262,0.05120,0.04980,
     10.04842,0.04706,0.04572,0.04441,0.04311,0.04184,0.04058,0.03935,
     20.03814,0.03694,0.03577,0.03462,0.03349,0.03237,0.03128,0.03021,
     30.02916,0.02812,0.02711,0.02612,0.02514,0.02419,0.02325,0.02234,
     40.02144,0.02056,0.01970,0.01886,0.01804,0.01724,0.01646,0.01569,
     50.01495,0.01422,0.01351,0.01282,0.01215,0.01150,0.01086,0.01025,
     60.00965,0.00907,0.00851,0.00797,0.00744,0.00693,0.00645,0.00598,
     70.00552,0.00509,0.00467,0.00427,0.00389,0.00353,0.00319,0.00286,
     80.00255,0.00226,0.00198,0.00173,0.00149,0.00127,0.00107,0.00088,
     90.00071,0.00056,0.00043,0.00032,0.00022,0.00014,0.00008,0.00004,
     A0.00001,0.00000,0.00001,0.00004,0.00008,0.00014,0.00022,0.00032,
     B0.00043,0.00056,0.00071,0.00088,0.00107,0.00127,0.00149,0.00173,
     C0.00198,0.00226,0.00255,0.00286,0.00319,0.00353,0.00389,0.00427,
     D0.00467,0.00509,0.00552,0.00598,0.00645,0.00693,0.00744,0.00797,
     E0.00851,0.00907,0.00965,0.01025,0.01086,0.01150,0.01215,0.01282,
     F0.01351,0.01422,0.01495,0.01569,0.01646,0.01724,0.01804,0.01886/
      DATA(CFX(I),I=251,375)/0.01970,0.02056,0.02144,0.02234,0.02325,
     10.02419,0.02514,0.02612,0.02711,0.02812,0.02916,0.03021,0.03128,
     20.03237,0.03349,0.03462,0.03577,0.03694,0.03814,0.03935,0.04058,
     30.04184,0.04311,0.04441,0.04572,0.04706,0.04842,0.04980,0.05120,
     40.05262,0.05407,0.05553,0.05702,0.05853,0.06006,0.06161,0.06318,
     50.06478,0.06640,0.06804,0.06971,0.07139,0.07310,0.07484,0.07660,
     60.07837,0.08017,0.08200,0.08386,0.08573,0.08763,0.08954,0.09149,
     70.09347,0.09546,0.09748,0.09953,0.10160,0.10370,0.10582,0.10796,
     80.11014,0.11233,0.11457,0.11682,0.11909,0.12140,0.12372,0.12610,
     90.12848,0.13089,0.13333,0.13579,0.13831,0.14083,0.14338,0.14595,
     A0.14856,0.15123,0.15389,0.15659,0.15931,0.16207,0.16488,0.16770,
     B0.17054,0.17345,0.17636,0.17931,0.18229,0.18529,0.18834,0.19142,
     C0.19453,0.19767,0.20085,0.20406,0.20731,0.21058,0.21390,0.21724,
     D0.22062,0.22405,0.22751,0.23100,0.23453,0.23810,0.24170,0.24534,
     E0.24901,0.25274,0.25649,0.26029,0.26412,0.26799,0.27192,0.27587,
     F0.27987,0.28391,0.28798,0.29211,0.29627,0.30048,0.30474,0.30904/
      DATA(CFX(I),I=376,420)/0.31338,0.31776,0.32218,0.32667,0.33119,
     10.33576,0.34037,0.34504,0.34975,0.35451,0.35933,0.36419,0.36909,
     20.37405,0.37907,0.38413,0.38925,0.39442,0.39964,0.40492,0.41025,
     30.41565,0.42108,0.42659,0.43214,0.43777,0.44344,0.44917,0.45496,
     40.46081,0.46673,0.47271,13*0.00000/
C     TAN**2 VALUES FOR EACH LINE STARTING AT BOTTOM OF PHOTOGRAPH
      DATA(CFY(KK),KK=1,110)/0.47271,0.44893,0.42610,0.40414,0.38309,
     10.36290,0.34348,0.32490,0.30709,0.29000,0.27362,0.25786,0.24279,
     20.22836,0.21452,0.20125,0.18852,0.17636,0.16472,0.15359,0.14294,
     30.13274,0.12303,0.11376,0.10493,0.09652,0.08851,0.08089,0.07368,
```

```
     40.06685,0.06039,0.05429,0.04854,0.04315,0.03810,0.03339,0.02901,
     50.02494,0.02120,0.01777,0.01466,0.01185,0.00935,0.00715,0.00524,
     60.00364,0.00233,0.00131,0.00058,0.00015,0.00000,0.00015,0.00058,
     70.00131,0.00233,0.00364,0.00524,0.00715,0.00935,0.01185,0.01466,
     80.01777,0.02120,0.02494,0.02901,0.03339,0.03810,0.04315,0.04854,
     90.05429,0.06039,0.06685,0.07368,0.08089,0.08851,0.09652,0.10493,
     A0.11376,0.12303,0.13274,0.14294,0.15359,0.16472,0.17636,0.18852,
     B0.20125,0.21452,0.22836,0.24279,0.25786,0.27362,0.29000,0.30709,
     C0.32490,0.34348,0.36290,0.38309,0.40414,0.42610,0.44893,0.47271,
     D9*0.00000/
      CALL PSEUDO
C     KO INITIALLY SET EQUAL TO ZERO AND THEN REPRESENTS THE NUMBER OF
C    1   TIMES THAT SUBROUTINE ENCOD IS CALLED
C     KK INITIALLY SET TO ZERO,REPRESENTS THE NUMBER OF LINE TRACES TAKEN
C     NO USED AS A COUNTER TO SET KK EQUAL TO ZERO WHEN APPROPRIATE
C     CC = TOTAL NUMBER OF DIGITALIZED DATA POINTS
C     EA,EB ETC. = NUMBER OF DIGITALIZED DATA POINTS IN VARIOUS DEN DIF RANGES
      KO=0
  107 KK=0
      IF(KO.EQ.0) GO TO 110
      CALL CALPLT(4.,-3.,-3)
  110 NO=0
      CC=0.
      EA=0.
      EB=0.
      EC=0.
      ED=0.
      EE=0.
      EF=0.
      EG=0.
      EH=0.
   10 KO=KO+1
C     INCT NUMBER OF RECORDED DATA POINTS IN A LINE
      CALL ENCOD(ICNT,0,IDEN,ID,NSCPTS,NCODE)
      PRINT 25
   25 FORMAT(1HO)
      IF(NCODE.EQ.0) GO TO 40
      IF(NCODE.EQ.2) GO TO 30
      ICNT=NSCPTS
      NXPT=NSCPTS+1
      DO 601 I=1,NXPT
C     CONVERSION OF TWO-DIMENSIONAL ARRAY TO A ONE DIMENSIONAL ARRAY
  601 D(I) = IDEN(1,I)
      IF (KO.NE.6) GO TO 26
C     ASSIGNMENT OF A BCD NO. TO A SPECIFIC KODAK STEP WEDGE DENSITY
      KB=0
      DO 2 NA=5,NXPT,36
      KB=KB+1
      CPA(KB)=D(NA)
    2 CONTINUE
      PRINT 88
```

```
   88 FORMAT(1H1,*DENSITY*10X*BCD NO.*)
      PRINT 89,(PPP(I),CPA(I),I=1,KB)
   89 FORMAT(1H0,F6.2,12X,F3.0)
      GO TO 10
   26 IP=-1
      NO=NO+1
      KK=KK+1
      IF(NO.EQ.1) KK=0
      PRINT 22,KK
   22 FORMAT(1H0,4X,*Y=*,I10//)
      DO 1 I=1,ICNT
C     NEEDED TO NUMERICALLY ORDER THE BCD NUMBERS
      IF(D(I).LT.CPA(I)) D(I)=D(I)+175.
      IF(KK.EQ.0) GO TO 1
C     CALCULATION OF DELTA BCD NUMBERS
      RD(I)=AVERAGE-D(I)
      IF(RD(I).LE.0.) RD(I)=0.
    1 CONTINUE
      IF(ICNT.LT.10) GO TO 350
      IF(KK.GE.1) GO TO 902
      PRINT 200,(D(I),I=1,ICNT)
  200 FORMAT(6X,12F10.2)
      CT=0
      SUM=0
      N1=ICNT-1
C     CALCULATION OF≠AVERAGE≠, THE REFERENCE PT.
      DO 3 I=1,N1
      CT=CT+1
      SUM=SUM+D(I)
    3 CONTINUE
      AVERAGE=SUM/CT
      PRINT 900
  900 FORMAT(58X,7HAVERAGE)
      PRINT 901,AVERAGE
  901 FORMAT(52X,F10.4)
      AA=1.1530
      BB=0.0130
      GO TO 10
  350 KK=KK-1
      PRINT 200,(RD(I),I=1,ICNT)
      GO TO 10
C     CALCULATION OF VERTICAL PEN DISTANCE FROM DELTA BCD NO.
  902 DO 800 I=1,ICNT
      CC=CC+1.
      XMM(I)=RD(I)*AA
  800 CONTINUE
      IF(KK.LT.102) GO TO 803
      PRINT 351
  351 FORMAT(45,*THESE VALUES HAVE NOT BEEN CORRECTED*)
C     OFF-CENTER ANGLE AND CORRECTION FACTOR CALCULATION
  803 DO 802 I=1,ICNT
```

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```
      CF=CFY(KK)
      CFF=CFX(I)
      IF(KK.GT.101) GO TO 330
      TANPHI=SQRT(CF+CFF)
      PHI=ATAN(TANPHI)
      ZZ=COS(PHI)**2
      GO TO 331
  330 ZZ=1.
C     CALCULATION OF VERTICAL PEN DISTANCE WITH CORRECTION FACTOR APPLIED
  331 XMM(I)=XMM(I)/ZZ
  802 CONTINUE
      PRINT 203
  203 FORMAT(58X,13HDELTA DENSITY)
C     CALCULATION OF FILM DENSITY DIFFERENCE
      DO 801 I=1,ICNT
      XMM(I)=XMM(I)*BB
  801 CONTINUE
      PRINT 201,(XMM(I),I=1,ICNT)
  201 FORMAT(6X,12F10.4)
      IF(KK.GT.101) GO TO 10
C     ASSIGNMENT OF EACH DATA PT. TO A DENSITY DIFFERENCE RANGE
      DO 301 I=1,ICNT
      IF(XMM(I).GE.0.1430) GOTO302
      EA=EA+1.
      GO TO 301
  302 IF(XMM(I).GT.0.1950) GO TO 303
      EB=EB+1.
      GO TO 301
  303 IF(XMM(I).GT.0.2600) GO TO 304
      EC=EC+1.
      GO TO 301
  304 IF(XMM(I).GT.0.2990) GO TO 305
      ED=ED+1.
      GO TO 301
  305 IF(XMM(I).GT.0.5460) GO TO 306
      EE=EE+1.
      GO TO 301
  306 IF(XMM(I).GT.0.6500) GO TO 308
      EF=EF+1.
      GO TO 301
  308 IF(XMM(I).GT.1.4000) GO TO 309
      EG=EG+1.
      GO TO 301
  309 EH=EH+1.
  301 CONTINUE
C     PLOTTING OF DENSITY DATA
      XKK(1)=0.
      DO 4 I=2,ICNT
      XKK(I)=XKK(I-1)+.025
    4 CONTINUE
      XMM(ICNT+1)=0.
```

```
      XMM(ICNT+2)=1.
      XKK(ICNT+1)=0.
      XKK(ICNT+2)=1.
      IF(KK.GT.1) GO TO 220
      CALL AXES(0.,0.,0.,2.0,0.,1.,1.,10.,4HRDEN,.1,-4)
      CALL AXES(0.,0.,90.,14.,0.,1.,1.,40.,1HX,.1,1)
  220 CALL LINPLT(XMM,XKK,ICNT,1,0,0,0,0)
      CALL CALPLT(.10,.03,-3)
      IF(KK.EQ.101) GO TO 307
      GO TO 10
C     CALCULATION OF PERCENTAGES OF TOTAL PTS. FOR EACH DEN DIF RANGE
C     EAA,EBA ETC. REPRESENT THE PERCENTAGE OF THE TOTAL NUMBER OF DATA
C    1               POINTS IN SPECIFIC DENSITY DIFFERENCE RANGES
  307 EAA=(EA/CC)*100
      EBA=(EB/CC)*100
      ECA=(EC/CC)*100
      EDA=(ED/CC)*100
      EEA=(EE/CC)*100
      EFA=(EF/CC)*100
      EGA=(EG/CC)*100
      EHA=(EH/CC)*100
C     FORMAT STATEMENTS FOR DENSITY DIFFERENCE RANGE TABLE
      PRINT 310
  310 FORMAT(/60X,*DEN DIF RANGE*,10X,*NO. PTS.*,
     110X,*PERCENT AREA*)
      PRINT 311,CC
  311 FORMAT(/20X,2HCC,63X,F6.0)
      PRINT 312,EA,EAA
  312 FORMAT(20X,2HEA,40X,*.LT.0.143*,14X,F6.0,14X,F6.2)
      PRINT 313,EB,EBA
  313 FORMAT(20X,2HEB,39X,11H0.143-0.195,13X,F6.0,14X,F6.2)
      PRINT 314,EC,ECA
  314 FORMAT(20X,2HEC,39X,11H0.195-0.260,13X,F6.0,14X,F6.2)
      PRINT 315,ED,EDA
  315 FORMAT(20X,2HED,39X,11H0.260-0.299,13X,F6.0,14X,F6.2)
      PRINT 316,EE,EEA
  316 FORMAT(20X,2HEE,39X,11H0.299-0.546,13X,F6.0,
     114X,F6.2)
      PRINT 317,EF,EFA
  317 FORMAT(20X,2HEF,39X,11H0.546-0.650,13X,F6.0,
     114X,F6.2)
      PRINT 318,EG,EGA
  318 FORMAT(20X,2HEG,39X,11H0.650-1.400,13X,F6.0,
     114X,F6.2)
      PRINT 319,EH,EHA
  319 FORMAT(20X,2HEH,40X,*.GT.1.400*,14X,F6.0,14X,F6.2)
      GO TO 10
   30 CONTINUE
      DO 21 I=1,12
      IF(ID(I).EQ.13) ID(I)=0
   21 CONTINUE
```

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```
C        CODE=0=INSTRUMENT SETTING
C        CODE=1=CALIBRATION
C        CODE=4=DATA
C        CODE=9=END OF RUN
      IF (KO.NE.1) GO TO 8
C     FORMAT STATEMENTS FOR FIXED DATA PRINTOUT
      PRINT 80
   80 FORMAT(13X4HCODE,13X,1HA,24X,1HB,29X,1HG,19X,9HCONDENSER)
      PRINT 20,(ID(1,I),I=1,12)
   20 FORMAT(6X,12I10)
      GO TO 10
    8 IF(KO.NE.2) GO TO 9
      PRINT 90
   90 FORMAT(13X4HCODE,11X,5HWEDGE,12X10HCOMMUTATOR,9X,3HDIF,2X,7HCONTRO
     1L,8X,3HPEN,2X,7HDAMPING,10X9HWRITE-OUT,1X,5HRATIO,1X,3HARM)
      PRINT 20,(ID(1,I),I=1,12)

      GO TO 10
    9 IF(KO.NE.3) GO TO 12
      PRINT 91
   91 FORMAT(13X4HCODE,3X,3HPEN,1X,4HSTEP,1X,10HMULTIPLIER,4X,4HSPEC,
     11X,4HSTEP,1X,10HMULTIPLIER,3X,9HOBJECTIVE,9X,13HMAGNIFICATION,13X,
     210HRESOLUTION)
      PRINT 20,(ID(1,I),I=1,12)
      GO TO 10
   12 IF(KO.NE.4) GO TO 16
      PRINT 92
   92 FORMAT(13X4HCODE,23X,4HFILM,1X,6HNUMBER,27X,5HMONTH,16X,3HDAY,
     116X,4HYEAR)
      PRINT 20,(ID(1,I),I=1,12)
      GO TO 10
   16 IF(KO.NE.5) GO TO 17
      PRINT 95
   95 FORMAT(13X4HCODE,20X,3HCAL,1X,5HSTRIP,1X,6HNUMBER,19X,4HSTEP,
     11X,3HLOW,1X,7HDENSITY,4X,4HSTEP,1X,4HHIGH,1X,7HDENSITY)
      PRINT 20,(ID(1,I),I=1,12)
      GO TO 10
   17 IF(ID(1,1).EQ.0) GO TO 108
      PRINT 93
   93 FORMAT(9X,4HCODE,24X,8HY-NUMBER)
      PRINT 20,(ID(1,I),I=1,12)
C     SPECFIC USES OF THE 1ST SWITCH OF THE 12 FIXED DATA SWITCHES
      IF(ID(1,1).EQ.9) GO TO 107
      IF(ID(1,1).EQ.8) GO TO 107
      IF(KK.GE.101) GO TO 10
      IF(ID(1,1).EQ.3)GO TO 307
      GO TO 10
  108 PRINT 92
      PRINT 20,(ID(1,I),I=1,12)
      GO TO 10
   40 CALL NFRAME
```

```
      CALL CALPLT(0.,0.,999)
      STOP
      END
      SUBROUTINE ENCOD(ICNT,KSKIP,DEN,ID,NSCPTS,NCODE)
      INTEGER DEN(500),ID(12),A(1049)
      INTEGER CON(15),LM(5),LL(5)
      MFD1=00000000000000000060
      MASK2=00000000000000000017
      MASK3=07700770077007700700
      IF (KSKIP .EQ. 0) GO TO 999
      DO 998 J=1,KSKIP
  950 ICNT = IVAR(12,A,5,1050)
      IF (ICNT .EQ. 0) GO TO 998
      GO TO 950
  998 CONTINUE
      KSKIP=0
  999 CONTINUE
      ICNT = IVAR(12,A,5,1050)
  150 FORMAT (2X,*ICNTIS*I10)
      IF (ICNT .EQ. 0) GO TO 77
      A(2)=A(2) .O. MASK3
      DECODE (10,20,A(2)) (LL(MM),MM=1,5)
   20 FORMAT (5(1X,R1))
      L1=MFD1 .A. LL(3)
      IF (L1 .EQ. 0.OR.L1.EQ.40B) GO TO 70
      I=0
      L=0
    1 DO 10 J=1,3
      I=I+1
      IF (I .GT. ICNT) GO TO 14
      A(I)=A(I) .O. MASK3
      DECODE (10,20,A(I)) (LL(MM),MM=1,5)
      DO 99 K=1,5
      M=5*(J-1)+K
      CON(M)=LL(K) .A. MASK2
      IF (CON(M) .EQ. 13) GO TO 27
      IF (CON(M) .EQ. 10) CON(M)=0
   99 CONTINUE
   10 CONTINUE
   27 LJ=M/3
      IF (LJ .EQ. 0) GO TO 15
      DO 11 J=1,LJ
      K=3*(J-1)
      L=L+1
      DEN(L)=100*CON(K+1)+10*CON(K+2)+CON(K+3)
   11 CONTINUE
      IF (LJ .LT. 5) GO TO 15
      GO TO 1
   14 WRITE(6,101)
  101 FORMAT(//10HREAD ERROR///)
   15 NSCPTS=L-1
```

```
      NCODE=1
      RETURN
C
C     FIXED DATA
C
   70 L=0
      DO 50 J=1,3
      A(J)=A(J) .O. MASK3
      DECODE (10,20,A(J)) (LL(MM),MM=1,5)
      DO 50 K=1,5
      L=L+1
      IF (L .EQ. 13) GO TO 60
      ID(L)=LL(K) .A. MASK2
   50 CONTINUE
   60 NCODE=2
      RETURN
   77 NCODE=0
      RETURN
      END
```

APPENDIX D

FIXED DATA SWITCHES

The Fixed Data that is inputed onto the recording magnetic tape is recorded as 12 separate Binary Coded Digits.

Switches

1	2	3	4	5	6	7	8	9	10	11	12

BCD digits, 0-9, can be recorded by each of the twelve switches. Switches two through twelve can be used to record non-density film data, i.e. machine setting data, etc.

Switch 1 is used as a code:

If Switch 1

equals 0 - means that the rest of the fixed data on that same line is non-density film data

equals 1 - means that the next set of non-fixed data represents the microdensitometer trace over a Kodak Step Wedge

equals 3 - tells the computer to go to Fortran Statement number 307 which starts the computation of the number and percentages of data points in specific density ranges up to that point

equals 4 - means that the following data are information collected from the photograph of interest

equals 9 - signifies the end of recorded data for a particular photograph, tells the computer to go to Fortran Statement number 107 which resets all counter variables back to zero for the start of a new piece of film.

REFERENCES

1. Bressette, W. E.; and Lear, D. E., Jr.: The Use of Near-Infrared Reflected Sunlight for Biodegradable Pollution Monitoring, Presented at the Second Conference on Environmental Quality Sensors, National Environmental Research Center, Las Vegas, Nevada, October 10-11, 1973.

2. Instruction Manual For Automatic Recording Microdensitometer Model MK IIIC., Joyce, Loebl and Co. Limited , August 1963.

3. Grolier, Maurice; and Woolbridge, James J.: Specification and Acceptability Tests of the Joyce-Loebl Isodensitracer, Model MK III CS, Series 571, Density Range: 5.6. April 1966.

TABLE I.- MACHINE SETTING

CODE	A			B			C		CONDENSER		
0	6	5	1	5	0	1	5	0	1	6	0
CODE	WEDGE		COMMUTATOR		DIF CONTROL		PEN DAMPING		WRITE-OUT RATIO ARM		
0	2	4	4	8	0	5	0	6	0	0	2
CODE	PEN STEP MULTIPLIER		SPEC STEP MULTIPLIER		OBJECTIVE		MAGNIFICATION		RESOLUTION		
0	0	9	2	2	1	0	0	2	1	0	0
CODE	FILM NUMBER						MONTH		DAY		YEAR
0	1	1	1	1	1	0	6	1	4	7	4
CODE	CAL STRIP NUMBER					STEP LOW DENSITY		STEP HIGH DENSITY			
1	0	5	3	0	5	0	1	1	1	0	0

TABLE II.- STEP WEDGE DENSITY VERSUS "BCD" NUMBER TABLE

Density	BCD No.[a]
0.05	71
.20	85
.36	97
.50	111
.64	124
.79	138
.94	151
1.09	163
1.23	1
1.38	14
1.53	27

[a]BCD numbers go up to 175 and then start over again at 1.

TABLE III.- BORDER TRACE IN BCD FORMAT AND AVERAGE

0

187.00	186.00	187.00	188.00	188.00	189.00	189.00	189.00	190.00	189.00	187.00	187.00
189.00	189.00	188.00	188.00	190.00	190.00	190.00	189.00	189.00	190.00	189.00	189.00
191.00	192.00	190.00	192.00	191.00	190.00	191.00	191.00	190.00	190.00	192.00	194.00
192.00	192.00	192.00	191.00	191.00	192.00	192.00	192.00	192.00	192.00	192.00	192.00
192.00	192.00	192.00	192.00	194.00	193.00	192.00	192.00	192.00	192.00	192.00	192.00
192.00	192.00	192.00	191.00	191.00	191.00	190.00	190.00	190.00	190.00	191.00	191.00
190.00	190.00	190.00	189.00	189.00	189.00	188.00	189.00	190.00	191.00	190.00	190.00
189.00	189.00	188.00	188.00	188.00	188.00	187.00	187.00	187.00	185.00	184.00	188.00
187.00	187.00	187.00	187.00	187.00	187.00	188.00	188.00	187.00	188.00	188.00	188.00
187.00	187.00	187.00	187.00	187.00	188.00	188.00	188.00	188.00	188.00	187.00	187.00
187.00	187.00	187.00	187.00	187.00	187.00	187.00	187.00	187.00	187.00	187.00	187.00
187.00	187.00	187.00	187.00	187.00	187.00	187.00	187.00	187.00	187.00	187.00	187.00
187.00	187.00	187.00	187.00	187.00	187.00	187.00	187.00	188.00	188.00	187.00	187.00
187.00	187.00	187.00	188.00	188.00	188.00	188.00	188.00	188.00	189.00	189.00	189.00
188.00	188.00	188.00	188.00	188.00	188.00	187.00	187.00	188.00	188.00	187.00	187.00
187.00	188.00	188.00	188.00	190.00	190.00	188.00	188.00	188.00	188.00	188.00	188.00
188.00	188.00	189.00	189.00	182.00	116.00	193.00	188.00	188.00	189.00	189.00	189.00
189.00	189.00	189.00	189.00	188.00	187.00	187.00	188.00	188.00	188.00	188.00	189.00
189.00	188.00	189.00	189.00	188.00	189.00	189.00	189.00	189.00	189.00	190.00	190.00
189.00	189.00	189.00	189.00	189.00	189.00	189.00	189.00	189.00	189.00	189.00	189.00
189.00	189.00	189.00	189.00	190.00	189.00	189.00	189.00	190.00	191.00	192.00	191.00
190.00	190.00	190.00	190.00	189.00	189.00	189.00	189.00	189.00	188.00	189.00	188.00
189.00	188.00	188.00	188.00	188.00	188.00	188.00	188.00	188.00	188.00	188.00	188.00
188.00	189.00	189.00	189.00	189.00	189.00	188.00	188.00	188.00	188.00	188.00	188.00
188.00	188.00	188.00	188.00	188.00	188.00	189.00	192.00	192.00	189.00	186.00	188.00
190.00	190.00	189.00	189.00	189.00	189.00	189.00	189.00	189.00	189.00	190.00	189.00
189.00	189.00	189.00	189.00	190.00	190.00	189.00	189.00	190.00	189.00	187.00	190.00
190.00	189.00	189.00	189.00	189.00	189.00	190.00	189.00	189.00	189.00	189.00	189.00
189.00	189.00	189.00	189.00	189.00	189.00	188.00	187.00	188.00	188.00	188.00	188.00
187.00	187.00	187.00	187.00	188.00	188.00	188.00	188.00	187.00	187.00	187.00	188.00
189.00	189.00	188.00	188.00	191.00	197.00	208.00	211.00	422.00			

AVERAGE

188.6848

TABLE IV.- CALCULATED FILM DENSITY DIFFERENCES FOR SCAN 51[a]

Y = 51

DELTA DENSITY

0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	.0342	.0341
.0340	.0539	.0538	.0735	.0733	.0730	.0728	.0725	.0723	.0721	.0523	.0522
.0520	.0711	.0709	.0707	.0322	.1084	.1271	.1267	.1452	.1636	.1631	.1626
.1621	.1803	.1797	.1792	.1787	.1598	.1410	.1406	.1402	.1398	.1394	.1572
.1567	.1563	.1380	.1376	.1194	.1369	.1543	.1539	.1535	.1531	.1703	.2050
.2220	.2389	.2558	.2726	.2719	.3405	.4432	.4078	.4068	.4402	.4392	.4724
.4543	.3174	.2998	.3160	.2985	.2642	.2468	.2463	.2626	.2954	.2949	.2943
.2937	.2766	.2760	.3085	.3244	.3403	.3561	.3718	.3875	.6154	.8100	1.1829
1.0509	.8707	.5778	.4313	.3661	.3332	.3005	.2679	.2515	.2511	.2507	.2344
.2181	.2337	.2651	.2647	.2643	.2482	.2636	.2790	.2786	.3412	.3879	.4345
.4653	.4334	.4641	.5416	.6190	.4780	.4464	.4303	.4143	.4138	.3669	.3201
.3197	.2885	.2728	.2725	.2723	.2720	.2717	.2561	.2559	.2557	.2401	.2093
.1786	.1937	.1936	.2087	.2390	.2692	.3147	.3601	.4054	.5114	.6931	.6472
.7225	.7675	.7822	.9027	.8720	.9320	.8107	.7046	.6590	.5682	.4926	.4321
.4169	.3565	.2812	.2510	.2659	.2658	.2808	.2657	.2656	.3106	.3856	.4605
.4904	.4903	.4753	.4602	.4451	.4151	.4151	.4600	.4750	.5649	.6998	.7297
.6998	.5649	.5199	.4450	.3851	.3701	.3102	.2802	.1903	.2353	.2354	.2204
.2204	.2355	.2356	.2356	.2658	.2658	.2960	.2961	.2962	.2813	.2814	.2966
.2967	.3119	.3271	.3273	.3879	.3427	.4336	.5397	.4038	.3738	.3589	.3894
.3442	.3140	.2990	.2232	.1930	.1627	.1628	.1629	.1783	.1784	.1786	.1940
.1942	.2097	.2406	.2408	.2410	.2105	.1953	.1955	.1803	.2113	.2425	.2272
.2275	.1657	.1659	.1661	.1663	.1665	.1667	.1669	.1827	.1986	.2145	.2148
.2151	.1839	.1841	.1844	.1846	.1849	.1851	.1854	.1857	.2018	.2021	.2344
.2347	.2351	.2836	.3161	.4131	.4138	.4145	.3667	.3673	.3030	.2548	.2553
.2394	.2398	.2239	.2407	.2411	.2416	.2420	.2260	.2098	.2268	.1941	.1778
.1448	.1451	.1454	.1289	.1292	.1294	.1297	.1300	.1642	.1645	.1649	.1482
.1485	.1660	.1664	.1839	.2189	.2194	.2199	.2030	.1861	.1342	.1170	.0997
.1000	.1002	.1005	.1007	.1010	.1013	.1015	.1376	.1559	.1563	.1567	.1753
.2120	.2490	.3044	.3784	.5079	.7854	.9537	1.0119	.9777	.8131	.7781	.7804
.7827	.8604	.9386	1.0172	1.0203	1.2141	1.3135	1.4136	1.5143	1.4225	1.2721	1.2180
1.1439	1.1672	1.1318	1.1750	1.2579	1.2819	1.3459	1.3705	1.4553	1.5206	1.2638	1.1468
1.1306	1.1346	1.1386	1.1017	1.0439	.9030	.9271	1.1804	1.2475	1.5039	1.5306	1.0925
1.1604	1.2500	1.0197	1.0236	.9630	.9452	.8837	.5910	.5843	.7186	1.0085	

[a]To conserve space only the density difference values for scan 51 are shown. The above is the digitalized data for the pen plot shown in figure 1. These data are read from left to right, top to bottom.

TABLE V.- DENSITY DIFFERENCE RANGES, NUMBER OF POINTS, AND PERCENTAGES

	UG/L CHL.A	DENSITY RANGE	NO. PTS.	PERCENT AREA
			41035	
CC		.LT.0.143	15004	35.56
EA		0.143-0.195	7306	17.80
EB		0.195-0.260	4519	11.01
EC		0.260-0.299	1557	3.79
ED		0.299-0.546	3543	8.63
EE		0.546-0.650	578	1.41
EF		0.650-1.400	1933	4.71
EG		.GT.1.400	6595	15.07
EH				

CODE Y-NUMBER

9 1 0 3 5 2 0 0 0 0 0 0

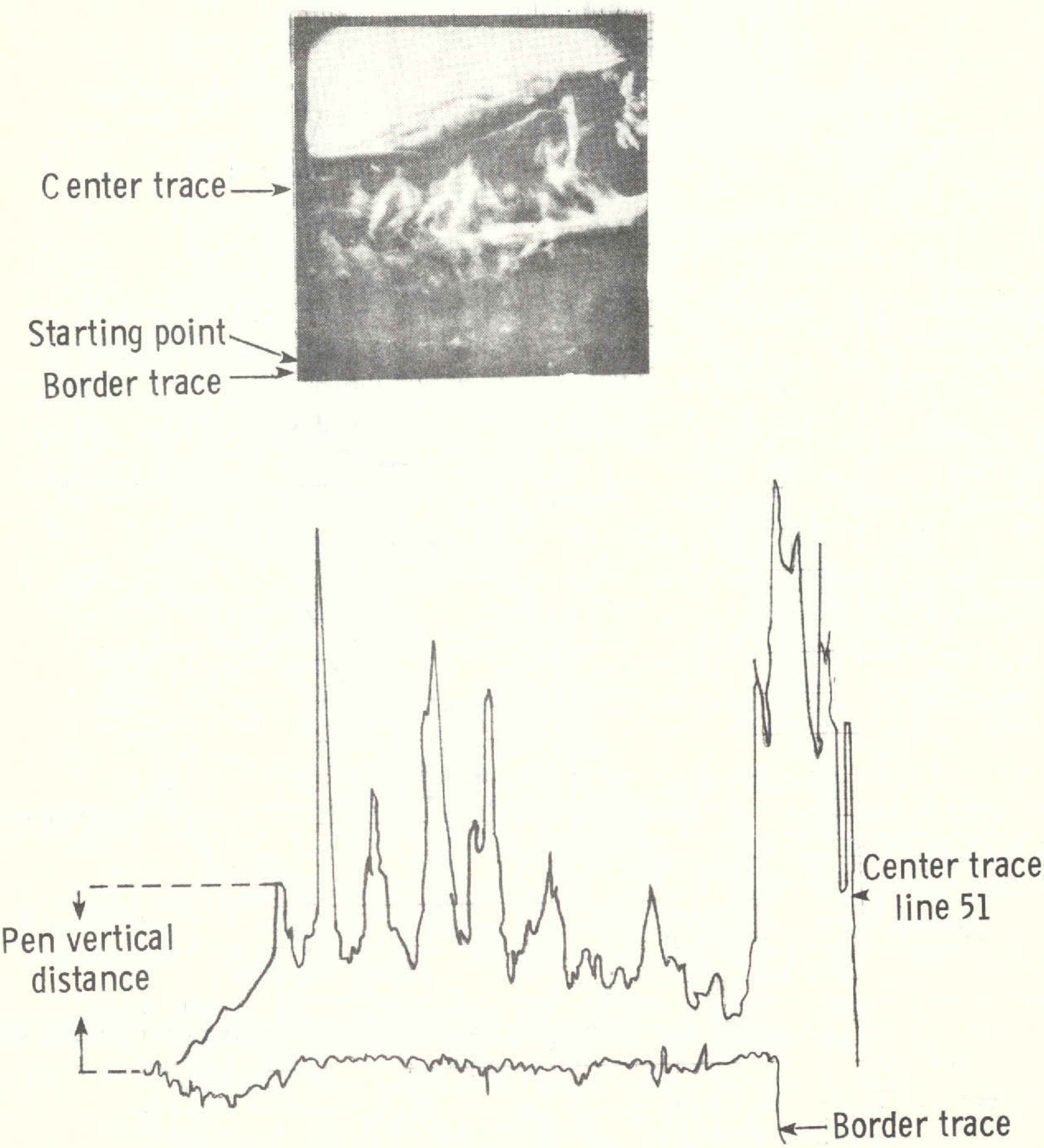


Fig. 1. - Sample photograph and pen plots of line 51 and bottom border

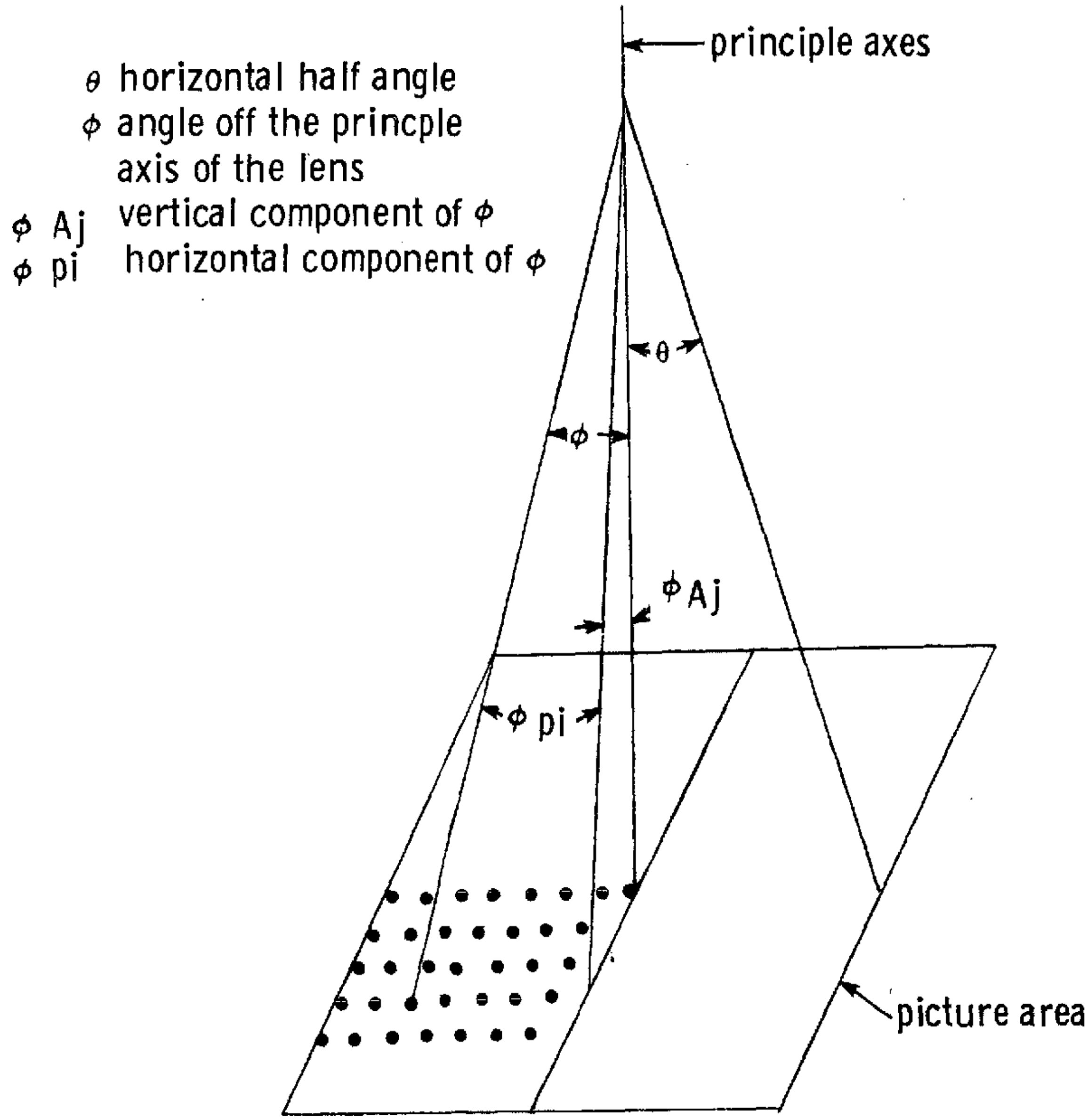


Fig. 2. - Pictorial representation of camera system angles

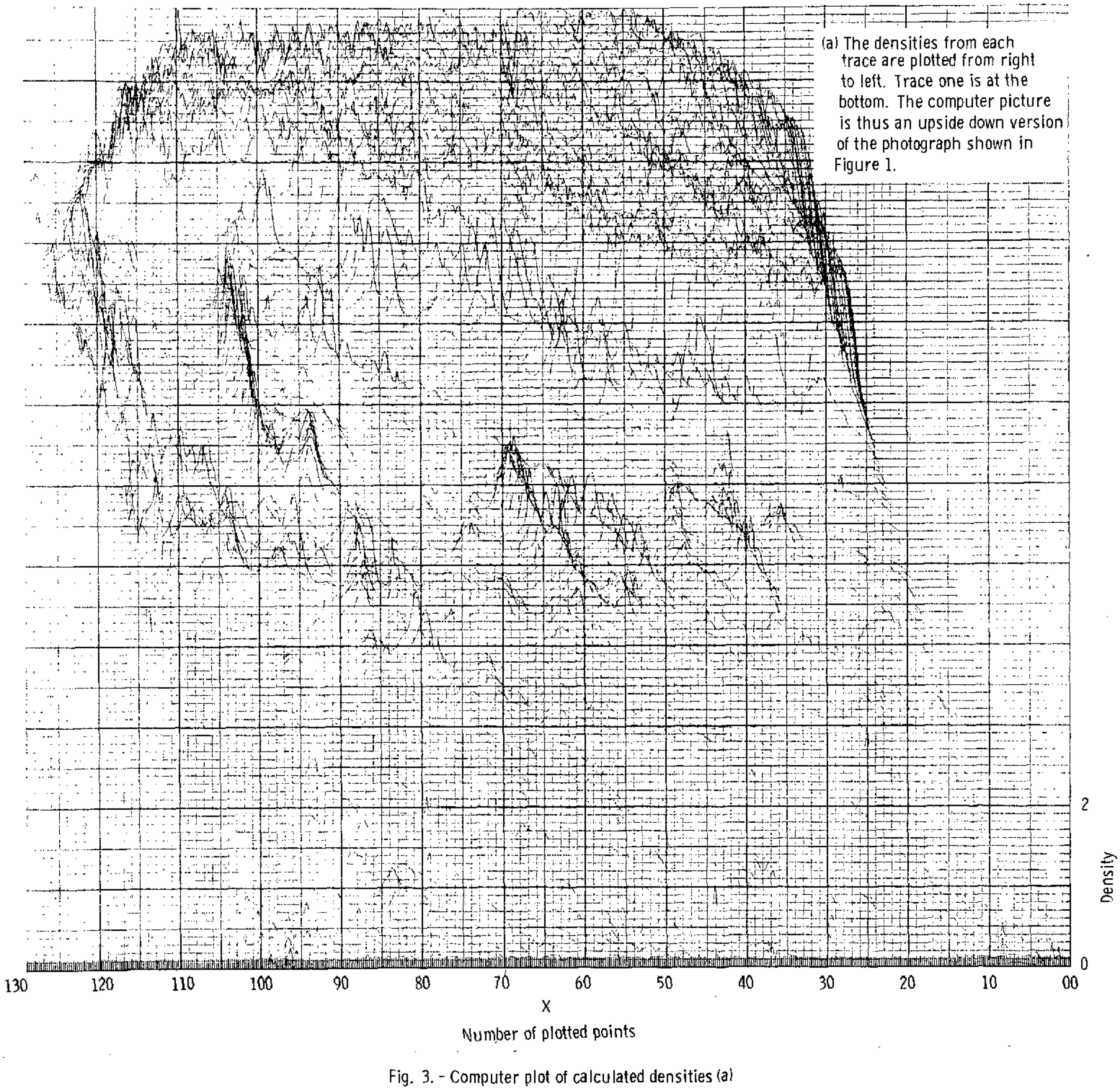
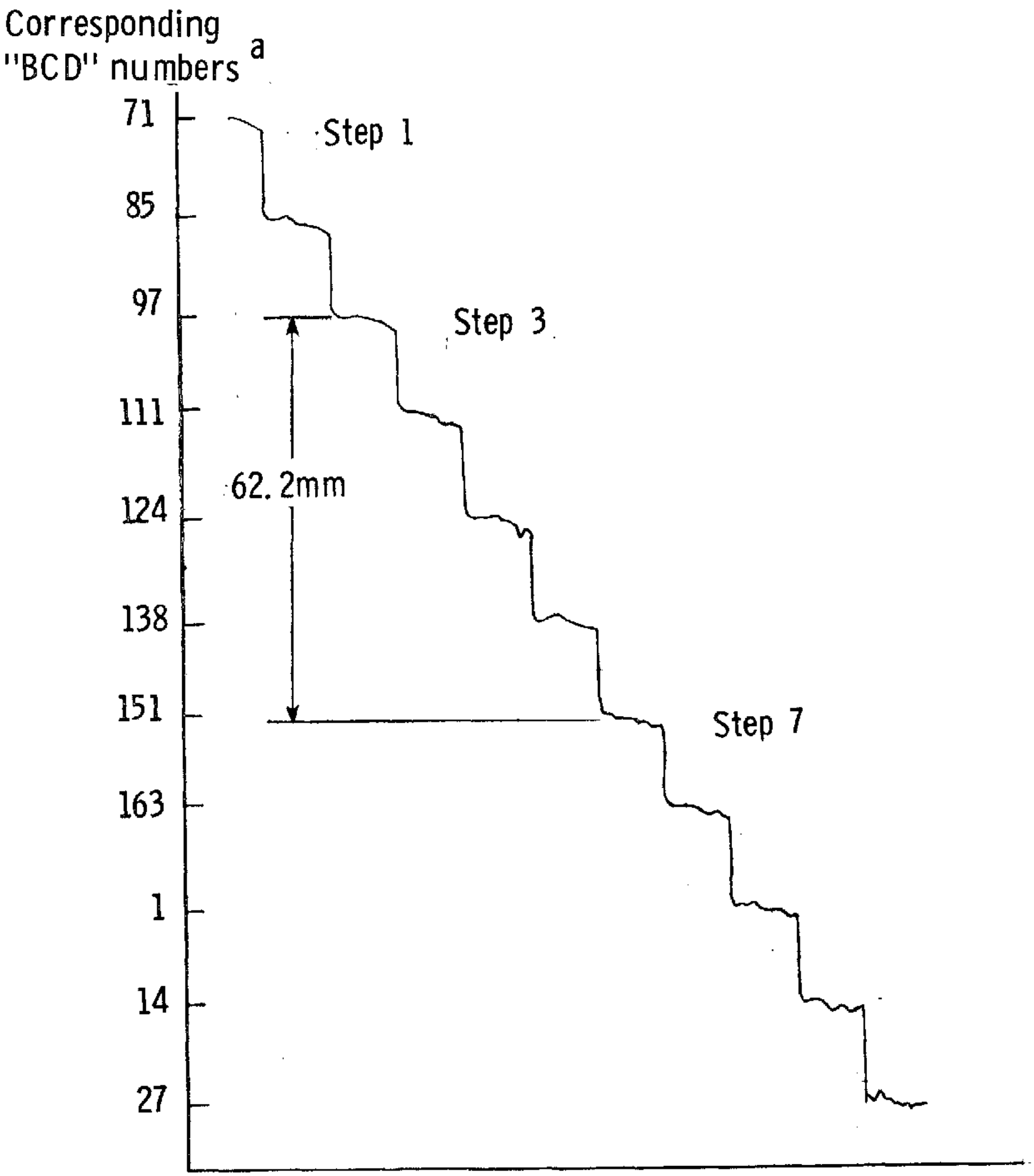


Fig. 3. - Computer plot of calculated densities (a)



[a]BCD numbers go up to 175 and then start over again at 1

Fig. 4 - Microdensitometer pentrace of a Kodak step tablet