U.S. Department of the Interior

Geological Survey

Computer Program Useful for Quality Control of an Image-Processing Laboratory

by
Joseph S. Duval

Open-File Report 84-218
1984

COMPUTER PROGRAM USEFUL FOR QUALITY CONTROL OF AN IMAGE-PROCESSING LABORATORY

by

Joseph S. Duval

INTRODUCTION

Because one important product of an image processing laboratory is a photographic reproduction of an image and because the making of photographic images is complex, a quality control program is essential. The photographic image making process consists of two distinct steps: 1) the data are transformed from a digital format to a film format using a film writing machine, 2) the film is developed using an appropriate chemical process. Each of these steps must be subject to quality control, and appropriate tests must be devised that will make it possible to determine whether an incorrect film product is caused by problems with the film writing machine or the film processing. This report discusses the tests which were devised for quality control and presents the computer program which makes appropriate calculations. Although this report discusses the use of film transparencies, the same general procedures could be used for photographic prints.

FILM PROCESSING

Because both black and white and color images are made in the U.S. Geological Survey (USGS) image processing laboratory in Denver, Colorado, techniques to test both types of film processing are needed. A commonly used technique for controlling film processing is to expose test films with a calibrated light source which produces a series of uniformly exposed rectangular areas. The exposure of successive areas increases by fixed increments. This series of rectangular areas is called a step-wedge. The film density (defined as the logarithm of the ratio of light incident on a film to the light transmitted through the film) measured for each of the steps in the step-wedge gives a curve that can be used to judge the quality of the film processing. The film density is measured using a film densitometer. The film densitometer used in the Denver USGS image processing laboratory has red, green, blue, and visual filters (Kodak wratten filters 92, 93, 94, and 106, respectively) that provide a measurement of the spectral characteristics of the light transmitted through the film. The red, green, and blue filters are designed to approximate the spectral properties of the red, green, and blue emulsion used in many color films. The visual filter is designed to approximate the spectral response of the human eye. For black and white film, the visual filter is used to measure the step-wedge. For color film the red, green, and blue filters are used to provide a measure of the color reproduction.

Before the processing of a particular film can be judged, a standard for comparison must be defined. If all of the film to be used is from a single batch of film, a comparison standard can be defined as the average curve calculated from a number of films with similar data and which are qualitatively acceptable. Figure 1 presents the comparison standard used for a specfic batch of black and white film, and Figure 2 presents the comparison standard used for a specific batch of color film. Comparison to

the standard can be done graphically or by using a goodness-of-fit calculation, which is the sum of the squares of the differences between the standard and the curve being tested divided by the number of data points. Because any problem with film processing will shift the film densities of the entire step-wedge, a goodness-of-fit parameter provides a reasonable measure for judging the quality of the film processing. Table 1 gives some typical goodness-of-fit values calculated to monitor film processing. Our experience has been that values less than 0.01 indicate an acceptable product, but a graphical presentation of the data is more useful, as described below.

Table 1. Typical values of goodness-of-fit parameters calculated to judge the quality of film processing.

DATE	BLACK AND WHITE MACHINE	COLOR MACHINE		
		RED	GREEN	BLUE
01/25/82	.0013	.0018	.0016	.0015
02/01/82	.0006	.0025	.0028	.0003
02/08/82	.0002	.0002	.0005	.0005
02/16/82	.0130	.0034	.0032	.0010
02/22/82	.0026	.0003	.0004	.0016

FILM WRITING MACHINES

The film writing machines used in the Denver USGS image processing laboratory are designed to transform digital data in the value range 0-255 into variable light intensity. The transformation function is proportional to the exponential of the negative value of the data. The digital data are, therefore, proportional to the logarithm of the exposure and can be used to plot a curve used in photography called DlogE. The DlogE curve is film density plotted as a function of the logarithm of the exposure. We can obtain such a curve by defining a step-wedge of areas of constant exposure at intervals in the range 0-255. A standard for comparison would be defined in the same way the process control standards are defined. For black and white film the visual film density is used. For color film the visual film density is also used, but it is measured on a neutral color step-wedge made by overlapping step-wedges using red, green, and blue filters on the film writing machine. Figure 3 shows a comparison standard used for judging proper exposure of film by a black and white film writing machine. Figure 4 presents a comparison standard used for judging proper exposure of film by a color film writing machine. Table 2 lists some typical goodness-of-fit values calculated for exposure control. Values less than 0.01 generally indicate an acceptable exposure.

Table 2. Typical values of goodness-of-fit parameters calculated to judge the quality of film exposure by film writing machines.

DATE	BLACK AND WHITE MACHINE	COLOR MACHINE
01/25/82	.0002	.0021
02/01/82	.0019	.0014
02/08/82	.0002	.0017
02/16/82	.0071	.0005
02/22/82	.0077	.0041

Because the color film used at the Denver USGS image processing laboratory has three emulsions with response functions for different parts of the visible light spectrum, the measurement to judge proper exposure is of no value if the neutral color step-wedge is not truly neutral color. The definition of neutral color used in the Denver laboratory is that the red, green, blue, and visual film densities must all be equal. To test that the step-wedge is neutral color, the red, green, and blue film densities of the step-wedge are measured in addition to the visual film density. By plotting curves of the differences between the visual film density and the red, green, and blue film densities as shown in Figure 5, the quality of the neutral color can be judged. Comparisons of the differences to the ideal values which are also shown in Figure 5 provide a basis analysis of any problems with the color balance. Curve values below the ideal values indicate that the color intensities are low and values above the ideal values indicate that the intensities are high. In the particular example given in Figure 5, both the red and blue light exposures are low. To correct the problem both red and blue exposures could be increased or green exposure could be decreased. In either case the comparison standard for exposure control may have to be redefined. Experience over a period of almost two years suggests that adjustments are not necessary until one or more of the curves deviate from the ideal by as much as 0.1.

COMPUTER PROGRAM

A computer program was written to do the goodness-of-fit calculations and graphically display the data. The program is written in BASIC and uses internal graphics of the Hewlett-Packard 9845T for which it was designed. The program does require that the computer have the graphics and mass-storage ROM's. The basic design of the program provides for permanent storage of the comparison standards as well as selective zeroing of any specific standard to allow for changes in the performance of the film writing machines. Provision is also made for the use of special transfer functions allowed by the machines. In general, these special functions are called film factors and are designed to linearize the film response functions as well as modify the slope of the exposure curve. The program is completely interactive with prompts from the computer for required data or decisions. Appendix I contains a listing of the program.

APPENDIX I

```
10    ! ************************** QCNTRL ***************
20    ! ***
30    ! ***                QUALITY CONTROL PROGRAM
40    ! ***
50    ! ***  This program is designed to make any of the
51    ! ***  various calculations used for quality control
60    ! ***  of the Optronics machines.  The machines
70    ! ***  are designated as:
80    ! ***
90    ! ***  BW = old black & white machine
100   ! ***
110   ! ***  CO = old color machine
120   ! ***
130   ! ***  HSBW = new high speed black & white machine
140   ! ***
150   ! ***  HSCO = new high speed color machine
160   ! ***
170   ! ***  The program is completely interactive and will
180   ! ***  prompt the user for all required data.
190   ! ***
200   ! *** Options available are to calculate a chi-squared
210   ! *** value for either the intensity curve (film density
220   ! *** versus DN) or the Sensomat step wedge.  These
220   ! *** These calculations can be made for no film factor
230   ! *** or any of five film factors in the case of the
240   ! *** intensity curves.
250   ! *** You can also calculate the color balance data
260   ! *** which is the difference from the ideal case where
270   ! *** the color film densities are equal to the
271   ! *** visual film density.
280   ! ***
290   ! ************************************************************************
300   !
310         OPTION BASE 1
320       DIM Stdcrv(4,27,6),Stpwdg(4,11,3),Red(27),Green(27)
321       DIM Blue(27),Visual(27)
322       DIM Dred(27),Dgrn(27),Dblu(27),Ncrvd(4,6),Ncrvw(4,3)
323       DIM Crv(27),Tmp(27)
330       DIM Wdg(11),Stdtot(4,27,6),Stptot(4,11,3),T$(4)
331       DIM File$[15],Ptmp(54)
340   ! ***
350   ! *** STDCRV(I,J,K) - I SELECTS MACHINE TYPE (1=BW, 2=CO,
351   ! ***         3=HSBW, 4=HSCO), J SELECTS THE DN VALUE
360   ! ***         WHERE "X" CORRESPONDS TO UNEXPOSED FILM,
370   ! ***         AND K SELECTS THE FILM FACTORS
380   ! ***
390   ! *** STPWDG(I,J,K) - IS THE STEP WEDGE ON THE FILM
400   ! ***         MADE USING THE SENSOMAT CALIBRATED LIGHT
410   ! ***         SOURCE, I SELECTS THE MACHINE TYPE
420   ! ***         J SELECTS THE STEP LEVEL (1-11)
430   ! ***         K SELECTS THE COLOR (1=RED OR BLACK AND
```

```
431   ! ***         WHITE, 2=GREEN, 3=BLUE)
440   ! ***
450         File$="QCNDAT:H8,0,1"
460         T$(1)="BW"
470         T$(2)="CO"
480         T$(3)="HSBW"
490         T$(4)="HSCO"
491  ! ***
492  ! *** Assign the data file to unit # 1
493  ! ***
500 Assign_it:  ON ERROR GOSUB Chk_file
510         ASSIGN #1 TO File$
520         OFF ERROR
530         GOTO Read_dat
531  ! ***
532  ! *** Check for errors on the file assignment.  If no
533  ! *** file exists, create one.
534  ! ***
540 Chk_file: PRINT ERRM$
550         BEEP
560         IF ERRN=56 THEN S100
570         PAUSE
580         RETURN
581  ! ***
582  ! *** Create a data file, initialize the arrays, and
583  ! *** write the data out to the file
584  ! ***
590 S100:  CREATE File$,80
600         ASSIGN #1 TO File$
610         MAT Stdcrv=ZER
620         MAT Stpwdg=ZER
630         MAT Ncrvd=ZER
640         MAT Ncrvw=ZER
650         MAT Stdtot=ZER
660         MAT Stptot=ZER
670      MAT PRINT #1;Stdcrv,Stpwdg,Ncrvd,Ncrvw,Stdtot,Stptot
680         ASSIGN #1 TO *
690         ASSIGN #1 TO File$
700         RETURN
701  ! ***
702  ! *** Read in the comparison standards
703  ! ***
710 Read_dat:MAT READ #1;Stdcrv,Stpwdg,Ncrvd,Ncrvw,Stdtot,Stptot
720         ASSIGN #1 TO *
730         Ans$="N"
740  INPUT "WANT TO DO ANY SELECTIVE ZEROING OF ARRAYS ?
           (Y/N) DEFAULT=N", Ans$
750         IF Ans$="Y" THEN GOSUB Sel_zero
760         PRINTER IS 16
770         PRINT PAGE,SPA(25),"QUALITY CONTROL PROGRAM"
771 PRINT "THIS PROGRAM CALCULATES QUALITY CONTROL DATA FOR
           OPTRONICS MACHINES."
780 PRINT "YOU WILL BE PROMPTED FOR ALL INPUT DATA"
790         Ntype=1
```

```
800 Start:INPUT "TYPE OF MACHINE ? (1=BW,2=CO,3=HSBW,
                4=HSCO)(DEFAULT=1)",Ntype
810         Ncalc=1
820 Ncalc: INPUT "TYPE OF CALCULATION ? (1=STD CURVE,
2=STEP WEDGE, 3=COLOR BALANCE) (DEFAULT=1)",Ncalc
830         IF ((Ntype=1) OR (Ntype=3)) AND (Ncalc=3)
               THEN Bad_select
840         GOTO Okay
850 Bad_select: BEEP
860 PRINT LIN(2),"NO COLOR BALANCE ON BLACK & WHITE FILM"
870         GOTO Ncalc
880 Okay: ON Ncalc GOTO Std_curve,Step_wedge,Color_balance
881 Std_curve: PRINT PAGE,"ENTER VALUES FOR THE STANDARD CURVE"
,LIN(1),"27 VALUES ARE EXPECTED",LIN(1)
900 PRINT "FIRST 26 VALUES CORRESPOND TO DN's (0,10,20,...,
240,250)",LIN(1),"LAST VALUE CORRESPONDS TO UNEXPOSED FILM"
902       PRINT "THE LAST VALUE IS LOW FOR B&W AND HIGH FOR
COLOR",LIN(1),"DATA CAN BE ON 1 OR SEVERAL LINES"
920         INPUT "",Crv(*)
921   ! ***
922   ! *** Transfer to subroutine which permits the user to
923   ! *** verify that he has entered the data correctly.
924   ! ***
930         GOSUB Chk_crv
940         PRINT PAGE
950         INPUT "DATE OF THE FILM ? (MM/DD/YY)",Date$
960         Ff=0
970 INPUT "FILM FACTOR NUMBER ?(0=NONE,OR 1-5 FOR FACTORS
            1 to 5) (Default=0)",Ff
980         Ff=Ff+1
981   ! ***
982   ! *** Check to see whether a comparison standard exists.
983   ! *** If not, transfer down to ask whether this curve
984   ! *** is to be used in the averaging to get a standard.
985   ! ***
990         IF Ncrvd(Ntype,Ff)=0 THEN No_std
1000        Nchi=27
1001  ! ***
1002  ! *** Go to subroutine which calculates the goodness-
1003  ! *** of-fit parameter
1004  ! ***
1010        GOSUB Nchi
1020        GOTO S110
1030 Nchi:Chi=0
1040        FOR I=1 TO Nchi
1050    IF Ncalc=1 THEN Chi=Chi+(Stdcrv(Ntype,I,Ff)-Crv(I)) 2
1060    IF Ncalc=1 THEN Dred(I)=Stdcrv(Ntype,I,Ff)-Crv(I)
1070    IF Ncalc=2 THEN Chi=Chi+(Stpwdg(Ntype,I,Ff)-Wdg(I)) 2
1080        NEXT I
1090        Chi=Chi/Nchi
1100        RETURN
1110 S110:PRINT PAGE,LIN(10),"CHI-SQUARED FOR ";T$(Ntype);
             " DN CURVE = ";Chi
1120        PRINTER IS 0
```

```
1130        PRINT LIN(2),T$(Ntype);" MACHINE - FILM FACTOR ";
             Ff-1;" -- ";Date$
1140        PRINT "CHI-SQUARED FOR DN CURVE = ";Chi
1141   ! ***
1142   ! *** Transfer to plotting subroutine
1143   ! ***
1150        GOSUB Pltem
1160 F6:  IMAGE 3(7(3D,1X,MD.2D,1X)/),6(3D,1X,MD.2D,1X)
1170        MAT Ptmp=ZER
1190        J=0
1200        FOR I=1 TO 27
1201        J=J+1
1210        Ptmp(J)=Tmp(I)
1220        J=J+1
1230        Ptmp(J)=Dred(I)
1231        NEXT I
1232        PRINT USING F6;Ptmp(*)
1240        PRINTER IS 16
1250        Ans$="A"
1251   ! ***
1252   ! *** Subprogram to add or subtract step-wedges to the
1253   ! *** comparison standards for exposure control.
1254   ! ***
1260 No_std:INPUT "IS THIS CURVE TO BE ADDED TO, REMOVED FROM
THE STANDARD OR NOT ? (A/R/N)(DEF=A)",Ans$
1270        IF Ans$="N" THEN Query
1280        Xm=1
1290        IF Ans$="R" THEN Xm=-1
1300        Ncrvd(Ntype,Ff)=Ncrvd(Ntype,Ff)+Xm
1310        FOR I=1 TO 27
1320        Stdtot(Ntype,I,Ff)=Stdtot(Ntype,I,Ff)+Crv(I)*Xm
1330    Stdcrv(Ntype,I,Ff)=Stdtot(Ntype,I,Ff)/Ncrvd(Ntype,Ff)
1340        NEXT I
1350        GOTO Query
1351   ! ***
1352   ! *** Section to compare the film processing step-wedges
1353   ! *** to the comparison standards for film processing
1354   ! ***
1360 Step_wedge:PRINT PAGE,"INPUT DATA FOR THE STEP WEDGE"
1370        PRINT "11 VALUES ARE EXPECTED"
1380        PRINT "DATA CAN BE ON ONE OR SEVERAL LINES"
1390        INPUT "",Wdg(*)
1400        GOSUB Chk_wdg
1410        PRINT PAGE
1420        INPUT "DATE OF THE FILM ? (MM/DD/YY)",Date$
1430        Ff=1
1440      INPUT "RED, BLK&W, GREEN, OR BLUE DENSITY ?
(1=RED OR B&W, 2=GREEN, 3=BLUE)(DEFAULT=1)",Ff
1450        IF Ncrvw(Ntype,Ff)=0 THEN No_stp
1460        Nchi=11
1470        GOSUB Nchi
1480        PRINT PAGE,LIN(10),"CHI-QUARED FOR ";T$(Ntype);
              " STEP WEDGE = ";Chi
1490        PRINTER IS 0
```

```
1500        IF (Ntype=1) OR (Ntype=3) THEN X$="B&W"
1510      IF ((Ntype=2) OR (Ntype=4)) AND (Ff=1) THEN X$="RED"
1520    IF ((Ntype=2) OR (Ntype=4)) AND (Ff=2) THEN X$="GREEN"
1530    IF ((Ntype=2) OR (Ntype=4)) AND (Ff=3) THEN X$="BLUE"
1540  PRINT LIN(2),T$(Ntype);" MACHINE ";X$;" STEP WEDGE ";Date$
1550        PRINT "CHI-SQUARED = ";Chi
1560        PRINTER IS 16
1570        Ans$="A"
1571    ! ***
1572    ! *** Subprogram to add or subtract step-wedges to the
1573    ! *** comparison standards for film processing.
1574    ! ***
1580  No_stp:INPUT "ADD, REMOVE CURVE TO STANDARD OR NEITHER ?
(A/R/N) (DEFAULT=A)",Ans$
1590        IF Ans$="N" THEN Query
1600        Xm=1
1610        IF Ans$="R" THEN Xm=-1
1620        Ncrvw(Ntype,Ff)=Ncrvw(Ntype,Ff)+Xm
1630        FOR I=1 TO 11
1640        Stptot(Ntype,I,Ff)=Stptot(Ntype,I,Ff)+Wdg(I)*Xm
1650     Stpwdg(Ntype,I,Ff)=Stptot(Ntype,I,Ff)/Ncrvw(Ntype,Ff)
1660        NEXT I
1670        GOTO Query
1671    ! ***
1672    ! *** Section to perform calculations related to color
1673    ! *** balance of color film.
1674    ! ***
1680  Color_balance:PRINT PAGE,"ENTER THE DATA FOR EACH OF
THE RED, GREEN, BLUE, AND VISUAL FILM DENSITIES"
1690        PRINT "ENTER ALL VALUES FOR EACH CURVE IN
                  THE ORDER GIVEN ABOVE"
1700        PRINT "27 VALUES ARE EXPECTED FOR EACH CURVE",
LIN(1),"FIRST 26 VALUES CORRESPOND TO DN's (0,10,...,240,250)"
1710        PRINT "LAST VALUE CORRESPONDS TO UNEXPOSED FILM",
LIN(1),"THE DATA CAN BE ENTERED ON ONE OR SEVERAL LINES"
1720        INPUT "RED FILM DENSITY ON GREY WEDGE ?",Red(*)
1730        INPUT "GREEN FILM DENSITY ON GREY WEDGE ?",Green(*)
1740        INPUT "BLUE FILM DENSITY ON GREY WEDGE ?",Blue(*)
1750     INPUT "VISUAL FILM DENSITY ON GREY WEDGE ?",Visual(*)
1760        GOSUB Chk_bal
1770        PRINT PAGE
1780  INPUT "DATE OF THE FILM ? (MM/DD/YY) AND FILM FACTOR (0-5)",
          Date$,Ff
1790        MAT Dred=Visual-Red
1800        MAT Dgrn=Visual-Green
1810        MAT Dblu=Visual-Blue
1820        PRINTER IS 0
1830  PRINT T$(Ntype);" MACHINE COLOR BALANCE CURVES - ";Date$;
LIN(1)," FILM FACTOR # ";Ff
1840        PRINT USING F1
1850  F1:IMAGE 2X,"DIFFERENCE FROM VISUAL DENSITY",/,
5X,"DN",5X,"RED",5X,"GREEN",5X,"BLUE"
1860  F2:  IMAGE 4X,3D,2X,MD.DD,5X,MD.DD,4X,MD.DD
1870        X=0
```

```
1880        FOR I=1 TO 27
1890        PRINT USING F2;X,Dred(I),Dgrn(I),Dblu(I)
1900        X=X+10
1910        NEXT I
1920        GOSUB Pltem
1930        PRINTER IS 16
1940 Query: Ans$="Y"
1950 INPUT "WANT TO DO SOMETHING ELSE ? (Y/N) (DEFAULT=Y)",Ans$
1960        IF Ans$="Y" THEN Start
1970        ASSIGN #1 TO File$
1980      MAT PRINT #1;Stdcrv,Stpwdg,Ncrvd,Ncrvw,Stdtot,Stptot
1990        ASSIGN #1 TO *
2000        STOP
2001  ! ***
2002  ! *** Subprogram to plot data
2003  ! ***
2010 Pltem:PLOTTER IS 13,"GRAPHICS"
2020        GRAPHICS
2021  ! ***
2022  ! *** Initialize the plot area and the curve plot area
2023  ! ***
2030        LIMIT 0,184,0,140
2040        LOCATE 30,130,25,95
2050        IF Ncalc<>3 THEN S200
2051  ! ***
2052  ! *** Prepare the blue and green color balance curves
2053  ! *** for plotting by putting in a zero offset.
2054  ! ***
2060        MAT Tmp=Dgrn+(.5)
2070        MAT Dgrn=Tmp
2080        MAT Tmp=Dblu+(1)
2090        MAT Dblu=Tmp
2100 S200: Redmn=0
2110        Grnmn=.5
2120        Blumn=1
2130        X=0
2140        FOR I=1 TO 27
2150        Tmp(I)=X
2160        X=X+10
2170        NEXT I
2180        Xmin=-10
2190        Xmax=270
2200        Ymin=-.5
2210        Ymax=1.5
2220        Xtick=10
2230        Ytick=.25
2240        IF Ncalc=3 THEN S210
2250        Ymax=.5
2260        Ytick=.1
2270 S210: FRAME
2280        SCALE Xmin,Xmax,Ymin,Ymax
2290        Xlen=(Xmax-Xmin)/100
2300        Ylen=(Ymax-Ymin)/50
2310        FOR Xpos=Xmin TO Xmax STEP Xtick
```

```
2320        MOVE Xpos,Ymin
2330        IPLOT 0,Ylen,-1
2340        MOVE Xpos,Ymax
2350        IPLOT 0,-Ylen,-1
2360        NEXT Xpos
2370        FOR Ypos=Ymin TO Ymax STEP Ytick
2380        MOVE Xmin,Ypos
2390        IPLOT Xlen,0,-1
2400        MOVE Xmax,Ypos
2410        IPLOT -Xlen,0,-1
2420        NEXT Ypos
2430        LINE TYPE 4
2440        MOVE 0,Redmn
2450        DRAW 260,Redmn
2460        IF Ncalc<>3 THEN S220
2470        MOVE 0,Grnmn
2480        DRAW 260,Grnmn
2490        MOVE 0,Blumn
2500        DRAW 260,Blumn
2510 S220:  LINE TYPE 1
2520        MOVE Tmp(1),Dred(1)
2530        FOR I=2 TO 27
2540        DRAW Tmp(I),Dred(I)
2550        NEXT I
2560        IF Ncalc<>3 THEN S230
2570        MOVE Tmp(1),Dgrn(1)
2580        FOR I=2 TO 27
2590        DRAW Tmp(I),Dgrn(I)
2600        NEXT I
2610        MOVE Tmp(1),Dblu(1)
2620        FOR I=2 TO 27
2630        DRAW Tmp(I),Dblu(I)
2640        NEXT I
2650 S230:  DEG
2660        CSIZE 3
2670        LDIR -90
2680        LORG 1
2690        FOR Xpos=Xmin TO Xmax STEP Xtick
2700        MOVE Xpos,Ymin
2710        LABEL USING "2X,3D";Xpos
2720        NEXT Xpos
2730        LDIR 0
2740        LORG 8
2750        FOR Ypos=Ymin TO Ymax STEP Ytick
2760        MOVE Xmin,Ypos
2770        LABEL USING "MD.DDX";Ypos
2780        NEXT Ypos
2790        LORG 1
2800        IF Ncalc<>3 THEN S240
2810        MOVE 245,.15
2820        LABEL "RED"
2830        MOVE 245,.65
2840        LABEL "GREEN"
2850        MOVE 245,1.15
```

```
2860        LABEL "BLUE"
2870 S240:  SETGU
2880        MOVE 30,10
2890        LABEL "DN VALUES"
2900        MOVE 10,10
2910        LDIR 90
2920        IF Ncalc<>3 THEN LABEL "STD CURVE - TEST CURVE"
2930 IF Ncalc=3 THEN LABEL "VISUAL DENSITY - COLOR DENSITY
            (GREEN AND BLUE OFFSET)"
2940        DUMP GRAPHICS
2950        EXIT GRAPHICS
2960        RETURN
2961  ! ***
2962  ! *** Subprogram for selective zeroing of arrays
2963  ! ***
2970 Sel_zero:PRINTER IS 16
2980        PRINT PAGE,LIN(10),"YOU CAN SELECTIVELY ZERO ANY
OF THE ARRAYS",LIN(1),"ENTER Ntype,Ff,Dtype"
2990      PRINT "WHERE Ntype SELECTS THE MACHINE (1=BW, 2=CO,
3=HSBW, 4=HSCO)",LIN(1),
"   Dtype SELECTS THE DATA TYPE -- (1=DN CURVES, 2=STEP WEDGES)"
3000 PRINT "    Ff IS THE FILM FACTOR (0=NONE, OR 1,2,3,4,5
              FOR FACTORS 1 to 5)"
3010        PRINT "IF Dtype=2 AND THE MACHINE IS B&W, THE
                FILM FACTOR MUST BE 1"
3020 PRINT "IF Dtype=2 AND MACHINE IS COLOR, THE FILM FACTOR
             MUST BE 1,2, OR 3"
3030     PRINT "THE COMPUTER WILL CYCLE ASKING FOR NEW ARRAYS
TO BE ZEROED",LIN(1),"UNTIL ALL ZEROS ARE ENTERED"
3040 Zeroem:INPUT "ENTER Ntype,Ff,Dtype",I,J,K
3050        IF I=0 THEN RETURN
3060        IF K=2 THEN Zero_step
3070        J=J+1
3080        FOR L=1 TO 27
3090        Stdtot(I,L,J)=0
3100        Stdcrv(I,L,J)=0
3110        NEXT L
3120        Ncrvd(I,J)=0
3130        GOTO Zeroem
3140 Zero_step:FOR L=1 TO 11
3150        Stptot(I,L,J)=0
3160        Stpwdg(I,L,J)=0
3170        NEXT L
3180        Ncrvw(I,J)=0
3190        GOTO Zeroem
3191  ! ***
3192  ! *** Subprogram for verifying that the data have been
3193  ! *** entered correctly.  Changes can be made.
3194  ! ***
3200 Chk_crv:PRINT USING F4
3210        FOR I=1 TO 27
3220        PRINT USING F3;I,Crv(I)
3230 F3:IMAGE "POINT #",3D," CURVE VALUE = ",2D.2D
3240 F4: IMAGE "VALUES ENTERED ARE:"
```

```
3250        NEXT I
3260        Ans$="Y"
3270        INPUT "ALL OKAY ? (Y/N) (DEFAULT=Y)",Ans$
3280        IF Ans$="Y" THEN RETURN
3290 Crv_chg:INPUT "ENTER POINT # AND NEW VALUE",I,Crv(I)
3300        Ans$="N"
3310        INPUT "MORE CHANGES ? (Y/N) (DEFAULT=N)",Ans$
3320        IF Ans$="N" THEN Chk_crv
3330        GOTO Crv_chg
3331  ! ***
3332  ! *** Subprogram for verifying that step-wedge data
3333  ! *** for checking film processing have been entered
3334  ! *** correctly.
3335  ! ***
3340 Chk_wdg:PRINT USING F4
3350        FOR I=1 TO 11
3360        PRINT USING F3;I,Wdg(I)
3370        NEXT I
3380        Ans$="Y"
3390        INPUT "ALL OKAY ? (Y/N) (DEFAULT=Y)",Ans$
3400        IF Ans$="Y" THEN RETURN
3410 Wdg_chg:INPUT "POINT # AND NEW VALUE",I,Wdg(I)
3420        Ans$="N"
3430        INPUT "MORE CHANGES ? (Y/N) (DEFAULT=N)",Ans$
3440        IF Ans$="N" THEN Chk_wdg
3450        GOTO Wdg_chg
3460  ! ***
3470  ! *** Subprogram for verifying that color balance data
3480  ! *** were entered correctly.
3490  ! ***
3500 Chk_bal:PRINT USING F4
3510        FOR I=1 TO 27
3520        PRINT USING F5;I,Red(I),Green(I),Blue(I),Visual(I)
3530 F5:IMAGE "POINT #",2D," RED = ",2D.2D," GREEN = ",2D.2D,
       " BLUE = ",2D.2D," VISUAL = ",2D.2D
3540        NEXT I
3550        Ans$="Y"
3560        INPUT "ALL OKAY ? (Y/N) (DEFAULT=Y)",Ans$
3570        IF Ans$="Y" THEN RETURN
3580 Bal_chg:INPUT "ENTER POINT # AND NEW VALUES OF RED,GREEN,
            BLUE, AND VISUAL",I,Red(I),Green(I),Blue(I),Visual(I)
3590        Ans$="N"
3600        INPUT "MORE CHANGES ? (Y/N) (DEFAULT=N)",Ans$
3610        IF Ans$="N" THEN Chk_bal
3620        GOTO Bal_chg
3630        END
```

FIGURE 1. COMPARISON STANDARD USED FOR JUDGING BLACK AND WHITE FILM PROCESSING

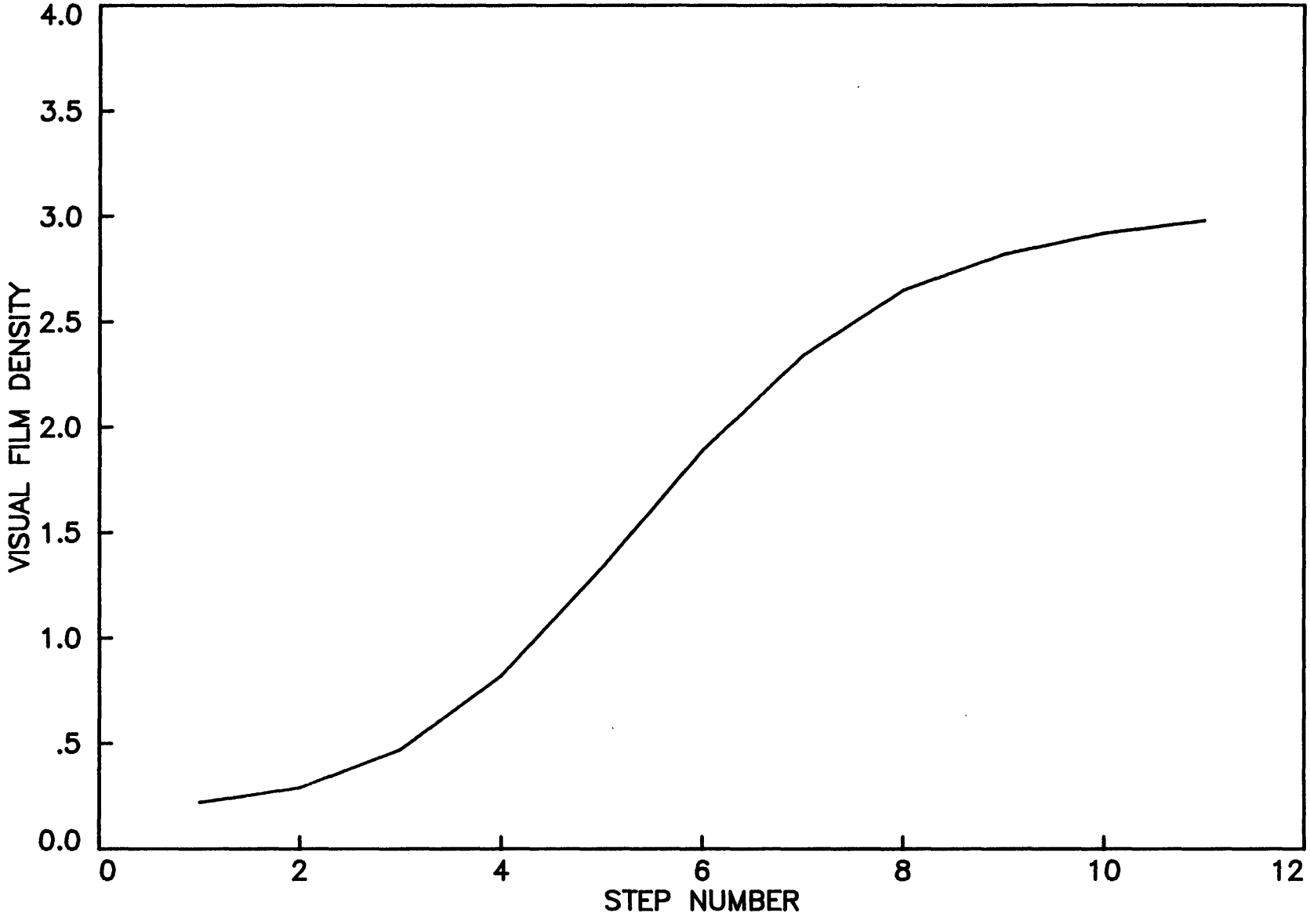
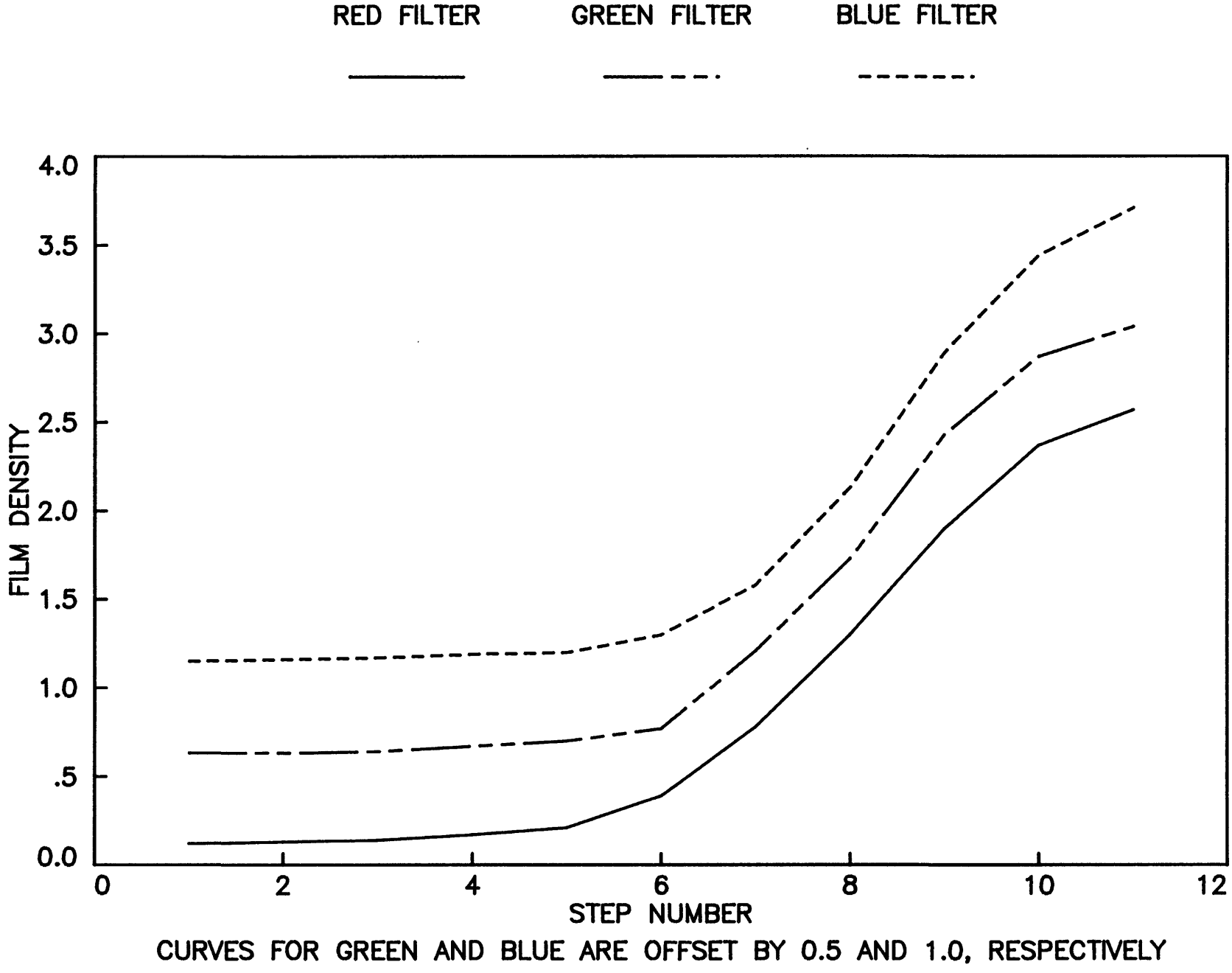


FIGURE 2. EXAMPLE COMPARISON STANDARDS USED TO JUDGE COLOR FILM PROCESSING



CURVES FOR GREEN AND BLUE ARE OFFSET BY 0.5 AND 1.0, RESPECTIVELY

FIGURE 3. EXAMPLE COMPARISON STANDARD FOR JUDGING EXPOSURE OF BLACK AND WHITE FILM

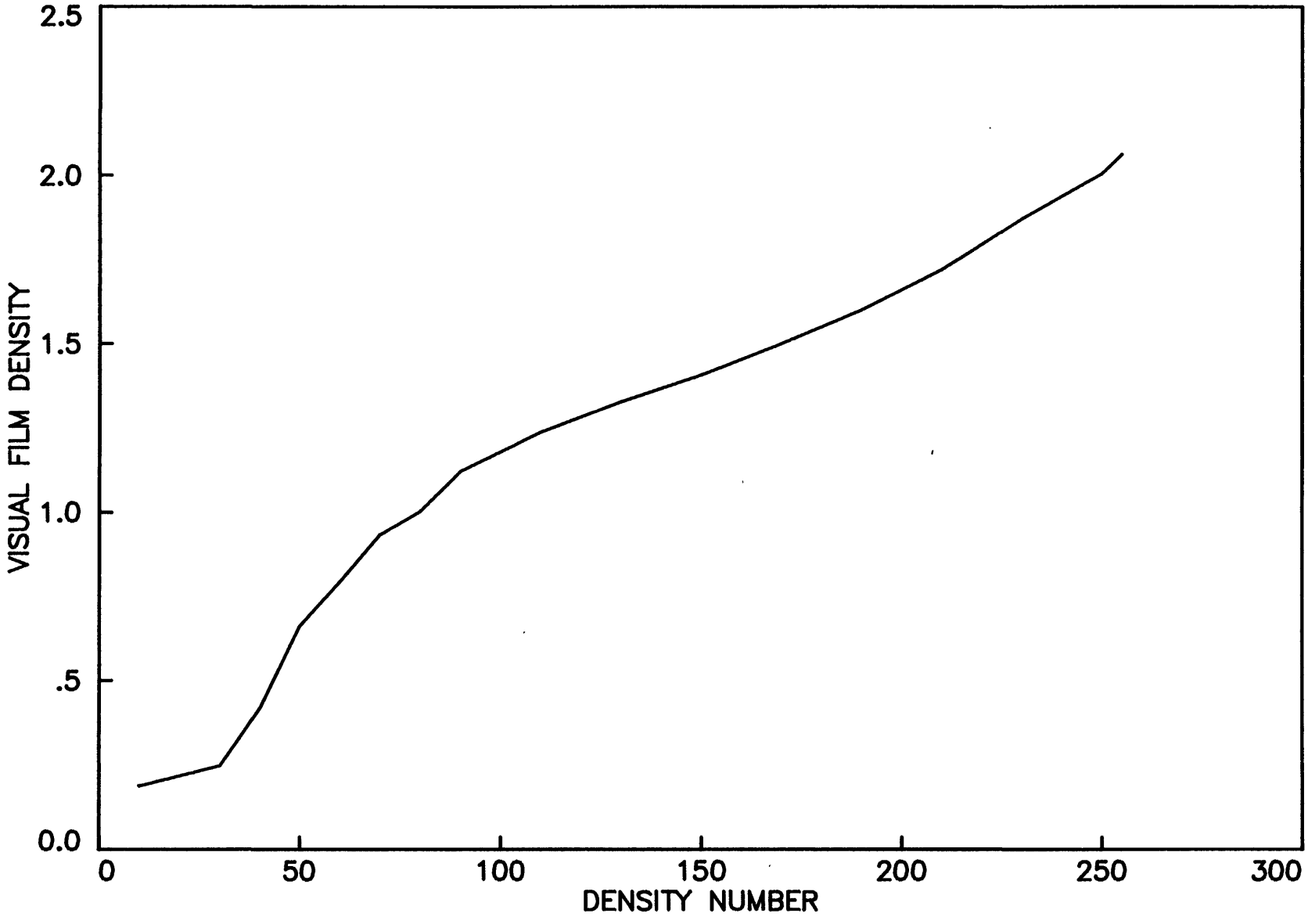


FIGURE 4. EXAMPLE COMPARISON STANDARD FOR JUDGING EXPOSURE OF COLOR FILM

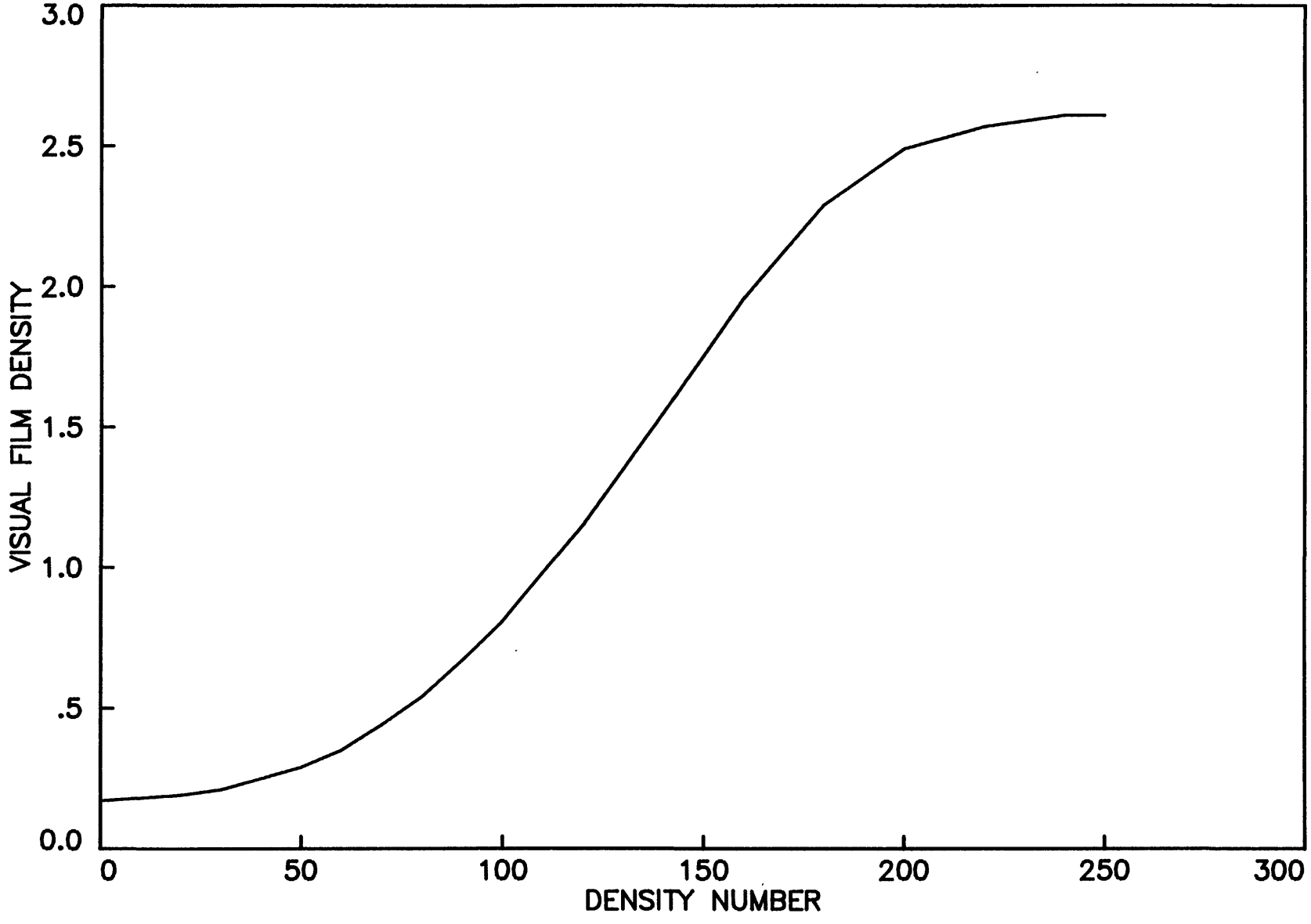
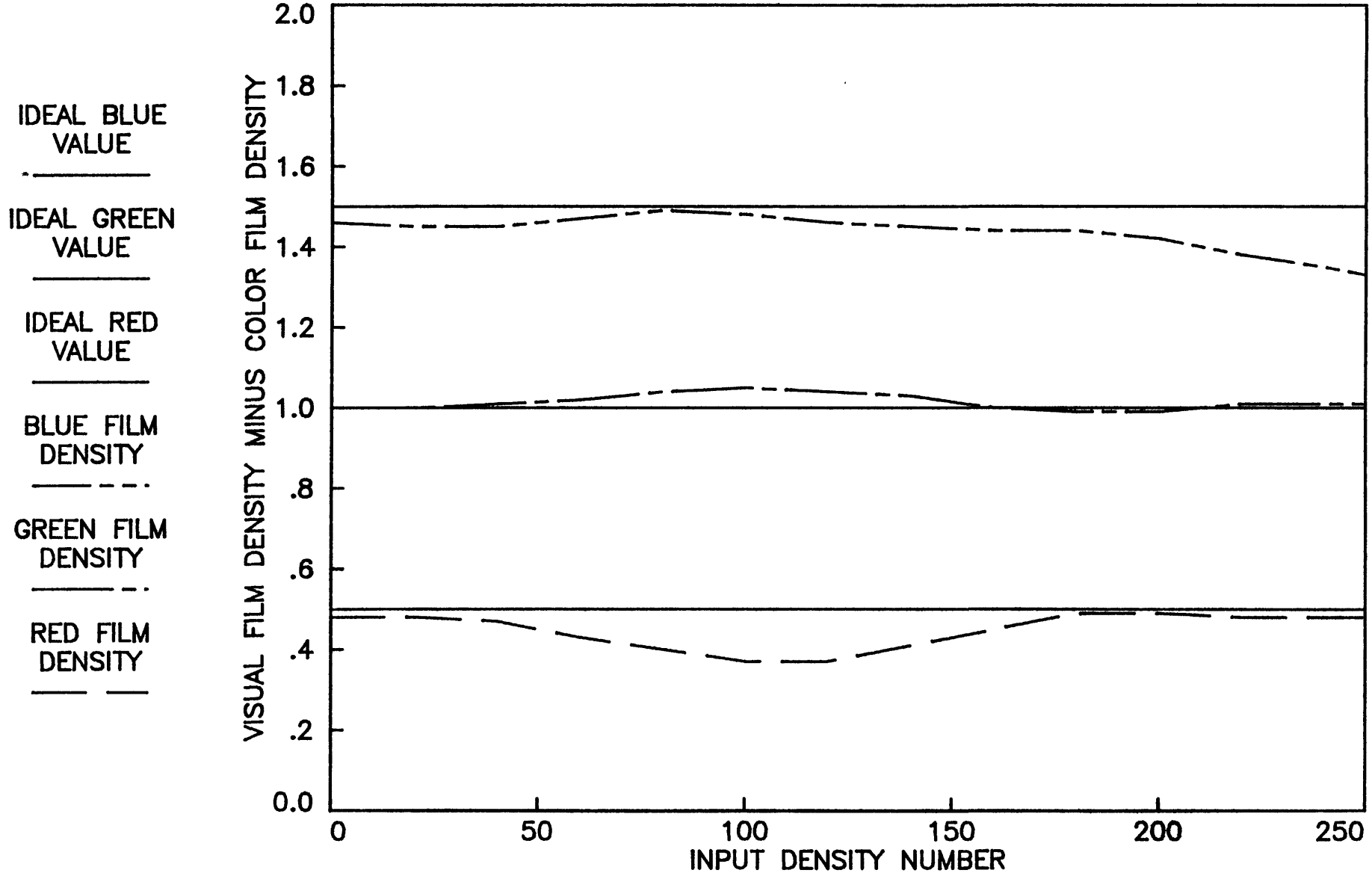


FIGURE 5. SAMPLE DIFFERENCE CURVES USED TO JUDGE COLOR BALANCE OF A FILM WRITING MACHINE



RED,GREEN,AND BLUE ZERO OFFSETS ARE 0.5,1.0,AND 1.5, RESPECTIVELY