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THE SCANDIG-3 MICRODENSITOMETER

by

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CONTENTS

1. SCANDIG-3 MICRODENSITOMETER

1.1 Introduction

The Joyce-Loebl Scandig-3 is a drum scanning microdensitometer which accepts flexible photographic films of any size up to 23 cm × 26 cm and scans at high speed. The Scandig is interfaced to a Data General Nova-3 mini computer and forms part of the SERC's microdensitometer service where digitised data may be processed interactively or written to magnetic tape.

1.2 General description

The Scandig consists of an acrylic drum around which the sample is mounted, and retained with masking tape. An optical carriage moves left or right parallel to the horizontal axis of the drum. One arm of the optical carriage is within the drum and light projected along this arm is focused on the sample. The detecting system is mounted on the other arm of the optical carriage which is outside the drum and directly opposite the illuminated part of the specimen. Light is collected by a lens system, focused onto the scanning aperture (see fig.1) and then to a solid state detector. As the drum rotates the specimen is scanned along the vertical axis with the exact Y position being measured by an optical shaft encoder. The optical carriage is coupled to a stepper motor-driven lead screw (see fig.2). The position along the X-axis (horizontal) is measured by counting the steps of the motor.

1.3 Optical system

The Scandig uses classical microdensitometer optics with a Kohler illumination system. Basically this consists of two microscopes on either side of the sample plane. The input microscope projects a demagnified image of the illuminated primary aperture onto the sample. The output microscope throws a magnified image of the illuminated sample area onto the secondary aperture. Light passing through the secondary aperture is collected by the photodiode detector.

1.4 Photometrics

A solid state planar photodiode is used. This is robust and linear over many decades of light input. A drift free quasi-double beam operation is obtained by resetting zero with each drum rotation.

1.5 Software

The Scandig-3 is interfaced to a Data General Nova-3 which, by means of an assembler interface, can control the scanning pattern and data collection.

1.6 Technical specifications

Specimen size	235 (X) 250 mm (Y) maximum
Scanned area	228 (X) 225 (Y) maximum
Scan increments	25, 50, 100, 200 microns
Scanning apertures	12.5, 25, 50, 100, 200 microns (round and square)
Illuminating apertures	25, 50, 100, 200, 400 (round and square)
Source	Tungsten Halogen
Detector	Silicon photodiode
Scan mode	Transmission
Density range	0-3D (with offsets)
Density quantization	256 levels

2. SOFTWARE INTERFACE BETWEEN THE SCANDIG-3 AND DATA GENERAL

Implemented on the Data General Nova-3 are a set of assembler routines (courtesy A.J. Wonacott) which make it possible to control the scanner's actions. These routines have been modified to allow them to be called using FORTRAN 5 programming language.

The actions of the scanner are basically, movement to the left or right and reading intensity values. The size of a pixel varies depending on the value of the scan increment switch (25, 50, 100 or 200 µm).

The routines that are available are:

SINTD, SPAUS, RINC(INC), SYOFF(IYO), SYLEN(IYL), MOVE(NSTEP), SCAND(IARR,IER), STPSN

<u>SINTD</u> Initalises the scanner; must be called before attempting any action on the scanner.

<u>SPAUS</u> Starts the drum spinning; must be called before a scan or move can take place.

<u>RINC(INC)</u> When this routine is called the value of INC returned is determined from the scan increment switch on the front of the scanner, i.e. INC=1, 2, 4 or 8 for 25, 50, 100, 200 µm respectively. Thus RINC is used in calculating the Y or X lengths in pixels. It should be noted that this switch is the only one that can be read directly via the hardware interface at this present time.

<u>SYOFF(IYO)</u> This tells the scanner where the scan is to start (in pixels) along the Y-axis - at present the range is 0-8 K and IYO must be an integral multiple of 16.

<u>SYLEN(IYL)</u> This determines the Y length of the scan to be performed (in pixels). The range is 16 bytes - 8 Kb with IYL = 16*N. Both IYO and IYL are rounded down to the nearest multiple of 16 if they are not set correctly.

<u>SCAND (IARR,IER)</u> This routine actually performs the scan itself. The buffer of length IYL pixels for a given x position is read into IARR, which must be at least IYL/2 words long (2 bytes = 1 word, 1 pixel = 1 byte). IERR gives an error return code from the scan which is 0 when the scan is initiated, 1 if scan is successful and -1 if the wrong no. words are transferred.

<u>MOVE(NSTEP)</u> Causes the scanner to move 'NSTEP' pixels in x. A positive NSTEP indicates a move to the right, a negative NSTEP indicates a move to the left.

<u>STPSN</u> This stops the Scandig.

3. SCANTM - A GENERAL PURPOSE SCANNING PROGRAM

SCANTM is a Fortran program (implemented on the Data General Nova

3/12) used for controlling scanner actions via the interface in order to write the film data to magnetic tape.

The program consists of a main body with calls to several subroutines each with their own specific function. Basically the program is a tape mount, a set of parameter definitions, a tape write and then a dismount. Figure 3 shows the format of the program as seen by the user. In line with Data General conventions the first file on a tape is file 0. There is provision for a header to be written at the start of each file if so desired. The header contains user name and title and occupies 1 record of 50 words.

Before a scan takes place the appropriate aperture sizes should be selected. We have found that uniform illumination of the secondary aperture occurs when the primary aperture is twice its size, thus with a scanning raster of 50 µm, the primary would be set to 100 µm and the secondary to 50 µm. This overcomes the problem of any slight optical misalignment that may have occurred. The dimensions of the scan are entered at point (a) in fig.3. The format is based around scanning oscillation films with fiducial spots on them.

Your Y-position is ... the y position of the fiducial spot.

Y-offset	how far back from the fiducial spot is the scan to begin
Y-length	the length of the scan
X-offset	X-distance to back-off from the fiducial spot
Lines at 20 scans/mm	length of x scan in pixels
Run fiducial line check?	This is a test to determine whether a slip has occurred in the X-direction during the scan.

In more detail the fiducial in the test is a thin black line placed to the left of a film, usually at the point x = 20 mm. The fiducial test asks the user for the Y-offset of the fiducial and the distance to it.

The Y-offset is merely the Y-position of any point on the line and the distance to it is the distance in x from where the scanner is (immediately before a scan), to a point say 1 mm to the right of the line. On performing the test the scanner moves the specified distance to the fiducial line, stops, and executes a series of scans moving 1 X step at a time through the line. The buffer is tested until a rapid fall from high to low density indicates the edge of the line has been reached. A position that can be repeated for any line of this nature is then calculated via interpolation. During the scan/move function the number of steps taken is recorded and after interpolating a position on the line the scanner returns to the start point and performs the scan.

At the end of the scan the scanner returns to the start point and repeats the search for the fiducial. The program compares the two positions of the line and prints them on the Dasher terminal. A difference of more than 1 pixel means that a slip has occured and the scan should be done again.

After the fiducial test the program causes the scanner to scan across the film and in doing so writes a buffer of length Y-length to tape. The length of the records is the same as the Y-length scanned - where 1 pixel = 1 byte and 1 record is written for each pixel scanned in the X direction. For a typical oscillation film of size 120 mm × 120 mm scanned at 50 µm the file would contain 2400 records of 2400 bytes (1200 words). At the end of a scan a file mark is written to tape and the details of the scan written in hard copy to the Dasher terminal (see fig.4).

A series of help commands are available for such things as header reset, tape rewinds, etc. and are executed at the point where I.D. would have been entered (see fig.5). The normal terminator from a series of scans is *E which writes a double end of file mark on the tape, rewinds it and releases the tape unit from the system.

4. SCANCHECK - A SCANDIG CHECK PROGRAM

4.1 Introduction

A suite of FORTRAN programs has been written and implemented to test every aspect of the scanner that, upon failure or malfunction, would cause incorrrect data to be produced. Density repeatability and positional accuracy are perhaps the most important factors that make up 'good' data and therefore these should be tested regularly. Factors such as vibration would usually be expected to remain constant but must be checked nevertheless.

The check program SCANCHECK is run daily and results are checked both individually and against previous runs.

4.2 The main program

SCANCHECK is a FORTRAN program which initiates scanner control via the Scandig/D.G. interface.

The program consists of a main segment which acts as a calling routine for a collection of subroutines. The calling sequence is a menu-based one, a 4 letter command determining the subroutine to be called (see fig.6). The commands themselves have no parameters, instead the user is asked to supply them via simple dialogue. Each subroutine enables the output to be routed to either the V.D.U. or the hard copy terminal.

At present there are 10 subroutines in the check program, each with a very specific and different function.

There is an option at the beginning to allow the program to be run automatically or to be under user control.

When being run automatically the program uses a data input file which is stored on disk. This file contains the data values for the subroutines DRIV, POSI, SPOT, DENS and WEDG respectively. The black lines, constant density areas and wedge required for this test are permanently taped to the drum away from the usual film scanning area. Hence the automatic test may be run at any time. The results from the auto-test are written to the dasher terminal.

4.3 Subroutines available

DENS

This routine measures the ability of the scanner to produce the same density reading at one particular pixel position on the drum. The test

can be repeated up to 1000 times and the mean and standard deviation of the readings is calculated.

There is an option in this test for an x movement between consecutive readings. This option tests the effect of vibration upon density repeatability. The distance moved is usually 10 pixels and the standard deviation of the readings tends to increase by 15%.

The format of the tests and results are shown in fig.7.

WARM

This is also a DENS test but the repeated readings are taken at timed intervals which are determined by the user. This test determines how long after the initial switch-on it takes for the scanner to produce constant density readings. For a constant density film it has been found that the readings 'increase' as the scanner warms up - usually stabilising after approximately half an hour.

Density variations during the warming-up period are probably caused by changes in the optical alignment of the apertures i.e. expansion due to heat from the bulb. Figure 8 shows the format of the test and the results.

DRIV

DRIV tests the scanner's ability to position itself accurately along the X-axis. The distance between 2 black lines separated in x on the drum is repeatedly measured. Backlash is eliminated at the beginning of the scan by a fast move to the left and right. The scanner then scans from left to right looking for the vertical black lines. Their positions are registered and the test is repeated. To speed the whole process up the scanner performs a fast move once the first black line has been detected. The scanner should be able to reproduce the x-separation measurement to ± 5% as shown in fig.9.

POSI

This tests the ability of the scanner to position itself at a precise position along the Y-axis. This test is basically the same as the x-position test (DRIV) but only 1 black line is used. This line, parallel to the x-axis is scanned through in Y such that the buffer contains the density readings through the line and a few readings of background either side. The Y position of the far edge of the line is then calculated via interpolation, this position being relative to the start of the chosen buffer in pixels.

The test is repeated several times and the mean position of the line is calculated (see fig.10).

WEDG

This enables us to see at a glance that there are no bits in the scanners buffer being permanently set thus giving totally false density readings. This is done by comparing a set of calibrated density step wedges (as supplied by Kodak) with scanner density readings.

The test scans a single buffer along the wedge passing through all 20 fogged areas. The density values are output to the teletype and the scanner density values are plotted against the known Kodak values giving the fitted straight line as seen in fig.11.

SPOT

This was written to enable a rapid scan of a spot or small area of film to be made, thus allowing the profile to be determined.

The user is asked to supply the width and length of the scan whereupon the scanner will scan a buffer from one pixel along X which will contain Y-length number of pixels. This buffer is printed out in 10 I4 format and the process repeated for X length number of pixels. (See fig.12 for test and result format.)

PARA

This routine produces a hard copy of the scanner switch settings at the time of a particular scan. This enables us to run a particular test and see at a glance what apertures, offset and increment were used. The primary and secondary apertures and density range information are entered by the user in a number coded form. The scanner can only read the increment switch via the interface, therefore it is important that the user enters the other information correctly (see fig.13).

DRUM

Over its two and a half years of use the Scandig's acrylic/perspex drum has accumulated several small fine surface scratches. These are not deep and can be removed by using a suitable polishing agent. Because of the appearance of these scratches and patches of dirt (not always obvious at first sight) it was decided to write a routine that will plot a 'map' of a specified area of the drum and print a character to indicate where any high (i.e. > 2) density values are. The map can be plotted on either the V.D.U. or the teletype and therefore the size of the map can vary up to 25 lines of 80 characters on the V.D.U. or any number of lines of 80 characters on the teletype.

The user is asked to specify the area of drum to plot.

Each buffer of data is scanned and averaged to fit into 80 characters. The program asks for a base 'dirt' level, that is a number above which a character is to be printed. When values higher than the base 'dirt level' are encountered, this is reflected in the output by a character between 1 and 9 indicating the number of high readings occurring in each 'averaged' pixel or map point.

Any value > 9 is counted as 9 and where there are no values greater than the base level a . is printed. Figure 14 shows a typically dirty drum and this map can help in the choice of a suitable area of drum for mounting films (scratches and dirt cause false readings in the scanned data).

EXIT

The routine EXIT allows the user to exit from the SCANCHECK program and return to the control of the CLI.

HELP

Help simply lists the menu again.

5. FEATURES OF THE SCANDIG-3

5.1 Densitometric accuracy

The aim was to measure the RMS deviation of successive Scandig measurements as a function of scan aperture size and optical density.

The method employed was to take up to 1000 readings of a particular known density from a calibrated Kodak density wedge.

A distribution of the readings was printed (i.e. density readings vs number of occurrences) and the standard deviation calculated via a gaussian fit. These standard deviations were then plotted against density (see fig.15).

There are several problems which had to be overcome in order to produce reliable results. Firstly, the density range was chosen so as to maximise the value being measured, that is, when measuring 0.5 OD a step on the wedge that is less than 0.5/3 × 255 should be chosen (about 38) and the scanner set to the 0-0.5 OD range such that the actual value comes out as 38*6 = 228.

This way a range that would have given density readings of 37-39 now becomes 222-234 and can be measured more accurately. Secondly the r.m.s. deviation cannot be evaluated in the usual way. Suppose the true density is 38.5 and sigma in 0.1 then all 1000 readings are likely to be 38.5±0.3 which means all scanner readings will be 38 and therefore give a r.m.s. deviation of 0. This is why a distribution of the readings is kept and a gaussian fit used to evaluated the r.m.s. deviation.

The test was run for aperture sizes 25, 50, 100, 200 microns and the results plotted as in fig.15. A separate test was run with a movement of 1 pixel in between each density reading, these results are shown by the dotted lines in fig.15.

From the graph it can be seen that the Scandig's densitometric accuracy is best when using the 200 μ sampling aperture and worst when using the 25 μ sampling aperture.

5.2 Density linearity

Photographic suppliers Kodak produce a calibrated neutral density filter which can be used to plot a graph of the Scandig's density linearity. KODAK's wedge is calibrated in diffuse densities whereas the

scanner measures specular densities.

A diffuse density is measured with a 180° collecting angle, while specular density uses almost a 0° collecting angle (see fig.16).

Because of this difference, Scandig and KODAK densities cannot be compared directly. However, a step on the wedge may be taken and the KODAK value plotted against the appropriate observed Scandig value. This gives a line as in fig.11 which tends to level out at step 15 onwards on the wedge. This line can be used as a standard for future density checks; significant deviations indicating a scanner hardware problem.

5.3 Density offset switch

To test the effect of the density offset switch upon density readings, the WEDG test (see SCANCHECK) was run using a calibrated KODAK step wedge whose step values were known. The test was performed with the offset switched OUT, then IN and then at intervals of 0.1 OD from 0.1 to 1.0. The resulting straight lines (see fig.17) were extrapolated to intercept the density axis, whereupon the density intercept for each offset (as a fraction of 3 OD) were plotted against each other. The resulting curve is shown in fig.18.

Thus any required density offset can be selected by reading from the graph the appropriate switch setting.

5.4 Response to density changes

There is no information in the Scandig manual provided by Joyce-Loebl, therefore tests were devised to investigate the scanner's response to density changes. A black line (optical density > 3) was taped to the drum parallel to the x-axis. A scan of 1 pixel width was taken through the line (parallel to the y-axis) and the buffer of data was printed out. When these density values were plotted against pixel position it was evident that it takes 4 or 5 readings for the scanner to "get onto" the line but only 2 readings to come "off". The graph obtained is shown in fig.19. A much more symmetrical graph is obtained from results using the Optronics model P-1000 scanner (see fig.20)

The basic difference between the two scanners is that the Optronics uses a photomultiplier detector, where the Scandig uses a photodiode. The problem with the Scandig-3 appears to be the log amplifier which does not react quickly enough to a change between a high level of light and a low one. A suitable modification is being investigated by the manufacturers.

FIGURE CAPTIONS

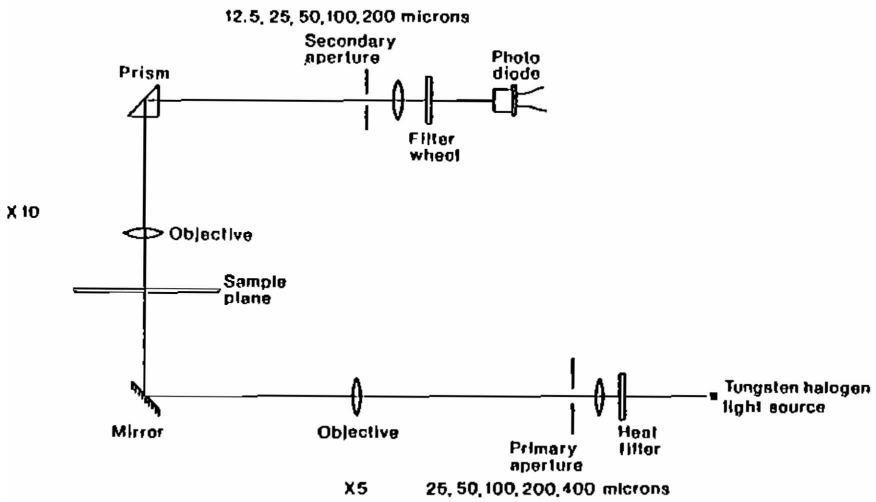

12.5, 25, 50,100,200 microns
Secondary aperture
Prism
Photo diode
Filter wheel
X 10
Objective
Sample plane
Mirror
Objective
Primary aperture
Heat filter
Tungsten halogen light source
X5
25, 50,100,200,400 microns

Fig. 1

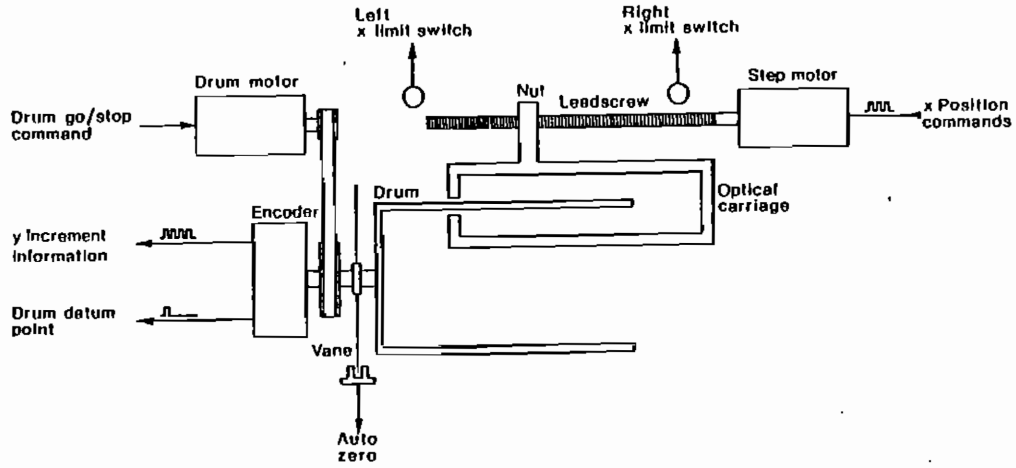

Left x limit switch
Right x limit switch
Drum motor
Nut
Leadscrew
Step motor
Drum go/stop command
x Position commands
Drum
Optical carriage
Encoder
y Increment information
Drum datum point
Vane
Auto zero

Fig. 2

```
SCAN
** NOVA-SCANDIG SCAN SYSTEM 02-22-83 10:02:15 **
=====================================================

PLEASE MOUNT YOUR TAPE. WHEN READY
STRIKE ANY KEY TO CONTINUE

 Scandig to MagTape - Version  3.2
===================================

Initial file NO. :  0

WRITE HEADER INFO TO TAPE ? (Y/N) : Y

HEADER INFORMATION
====================

USERS NAME (20-CHAR): DEMO OUTPUT

TITLE (40-CHAR) : TEST SCAN

APERTURE CODES :
 (INPUT NEGATIVE CODE FOR ROUND, POSITIVE FOR SQUARE.)

2= 25 ;   3= 50 ;   4=100 ;   5=200 ;   6=400 ;
PRIMARY CODE : 4

1= 12 ;   2= 25 ;   3= 50 ;   4=100 ;   5=200 ;
SECONDARY CODE : 3

DENSITY RANGE CODES :
1=0.5 ; 2=1.0 ; 3=1.5 ; 4=2.0 ; 5=3.0  CODE : 4
DENSITY OFFSET : 0
I.D (10-chars), Command (*_) or HELP : A FILM
a YOUR Y-POSITION IS.....(MM)?55.8
Y-Offset (mm) :10.5
Y-Length (mm) :100
X-OFFSET (MM)5
Lines at  20 Scans/mm : 1000
RUN FIDUCIAL CHECK ? (Y/N) : Y
 Y OFFSET OF FIDUCIAL (MM)?215
 HOW FAR BACK IN X TO FIDUCIAL (MM)?14


FILE : 0 (IBM : 1)  SCANNED ON  2/22/83  AT 10: 5:57
====================================================

TEST SCAN

USER : DEMO OUTPUT            SCAN ID : A FILM


SCAN PARAMS :
-----------

NO. LINES      : 1000
RASTER         :   50 (microns)
Y-OFFSET       :  906 (pix)       45.300 (mm)
Y-LENGTH       : 2000 (pix)      100.800 (mm)
DENSITY RANGE : 0.0 - 2.0 (D) - NO OFFSET

SCANNER APERTURES :

 PRIMARY   :  100 (microns) - SQUARE.
SECONDARY :    50 (microns) - SQUARE.
O.K. ?  (Y/N) : Y
```

Fig. 3

```
FINISHED SCAN


FILE : 0 (IBM : 1)  SCANNED ON  2/22/83  AT 10: 5:57
====================================================

TEST SCAN

USER : DEMO OUTPUT            SCAN ID : A FILM


SCAN PARAMS :
-----------

NO. LINES      : 1000
RASTER         :   50 (microns)
Y-OFFSET       :  906 (pix)       45.300 (mm)
Y-LENGTH       : 2000 (pix)      100.800 (mm)
DENSITY RANGE : 0.0 - 2.0 (D) - NO OFFSET.

SCANNER APERTURES :

 PRIMARY   :  100 (microns) - SQUARE.
SECONDARY :    50 (microns) - SQUARE.

FILE FORMAT :
-----------

HEADER -     1 RECORD  OF   50 WORDS,   100 BYTES.
DATA   - 1000 RECORDS OF 1000 WORDS, 2000 BYTES.

****************************************************


REFERENCE POINTS AT 345.24   346.32 PIXELS, SLIP=   1.08
****************** WARNING !!

**************************************************
```

Fig. 4

```
HEADER INFORMATION
===================

USERS NAME (20-CHAR): DEMO RUN

TITLE (40-CHAR) : TEST

APERTURE CODES :
 (INPUT NEGATIVE CODE FOR ROUND, POSITIVE FOR SQUARE.)

2= 25 ;   3= 50 ;   4=100 ;   5=200 ;   6=400 ;
PRIMARY CODE : 4

1= 12 ;   2= 25 ;   3= 50 ;   4=100 ;   5=200 ;
SECONDARY CODE : 3

DENSITY RANGE CODES :
1=0.5 ; 2=1.0 ; 3=1.5 ; 4=2.0 ; 5=3.0   CODE : 4
DENSITY OFFSET : 0
I.D (10-chars), Command (*_) or HELP : HELP

COMMAND LIST
============

COMMAND          ACTION
-------------------------------------------------------------------------
HELP       Lists valid commands.
 *H        Reset title/user/aperture & density range information.
 *D        Reset density range information.
 *L        Complement header flag, changes no-header to header and vise versa.
 *B        Backspace one file on the mag-tape, i.e. overwrite last scan.
 *F        Re-position tape at new file - will reqest file no.
 **        Run next scan with all params as they are.
 *A        Exit from scanfm with no double E-O-F on MT.
 *E        Normal exit, with trailing double E-O-F on MT.
 *R        Read header information off current file.
 *Z        Write double E-O-F, rewind tape, don't exit.

*************************************************************************
I.D (10-chars), Command (*_) or HELP :
```

Fig 5

```
SCANCHECK
 ** SCANCHECK - SCANDIG CHECKER PROGRAM. **
============================================

INITIALISED
DO YOU WANT AUTO-TEST ? (Y/N)
N
ENTER TITLE HERE
DEMO RUN
TITLE   DEMO RUN
 MENU
 ====

 PARA -**HARD COPY RECORD OF SWITCH SETTINGS**

 DENS - **REPEATABILITY OF DENSITY READINGS**

 DRUM - **CHECK OF CLEANLINESS OF DRUM**

 WEDG - **COMPARISON AGAINST CALIBRATED GREY WEDGE**

 MOVX - **DRIVE  UTILITY**

 POSI - **POSITIONAL ACCURACY OF SCANNER**

 DRIV - **ERRORS IN DRIVING FORWARDS/BACKWARDS**

 WARM - **DENSITY CHANGES DURING WARMING UP**

 HELP - **LIST OF AVAILABLE OPTIONS**

 SPOT - **SCAN ACROSS SPOT PROFILE**

 EXIT - **EXIT FROM SCANCHECK**
COMMAND :
```

Fig. 6

```
       DENS
 DENS - SELECTED
INCREMENT =       50   microns OK ?  (Y/N)
Y
THE X INCREMENT SHOULD BE =       50  microns
DISTANCE BETWEEN READINGS ?(PIXELS)
0
WHICH PIXEL TO TEST (MM) ?
50
HOW MANY REPEATS ?
20
HARD COPY NEEDED ? (Y/N)
Y


ATE =  9: 2:83
IME = 14:44:28
**THIS IS A RUN OF DENS**

THE DISPLACEMENT WITHIN BUFFER IS    8
 THE BUFFER BEGINS AT  992
 95  94  95  95  95  94  94  95  94  95  95  94
 95  94  95  95  94  94  94  95
**THIS IS A RUN OF DENS**

THE NUMBER OF READINGS TAKEN WAS :    20
THE MEAN DENSITY READING IS :     94.55
DISTANCE BETWEEN READINGS WAS    0 PIXELS
THE STANDARD DEVIATION IS :     0.50
THE VARIANCE IS :       0.25
ANOTHER SCAN ?  (Y/N) Y
INCREMENT =       50   microns OK ?  (Y/N)
Y
THE X INCREMENT SHOULD BE =       50  microns
DISTANCE BETWEEN READINGS ?(PIXELS)
10
WHICH PIXEL TO TEST (MM) ?
50
HOW MANY REPEATS ?
20
HARD COPY NEEDED ? (Y/N)
Y


ATE =  9: 2:83
IME = 14:45:12
**THIS IS A RUN OF DENS**

THE DISPLACEMENT WITHIN BUFFER IS    8
 THE BUFFER BEGINS AT  992
 96  94  94  95  95  95  94  94  95  95  94  95
 93  94  95  94  95  95  94  95
**THIS IS A RUN OF DENS**

THE NUMBER OF READINGS TAKEN WAS :    20
THE MEAN DENSITY READING IS :     94.55
DISTANCE BETWEEN READINGS WAS   10 PIXELS
THE STANDARD DEVIATION IS :     0.67
THE VARIANCE IS :       0.45
ANOTHER SCAN ?  (Y/N) N
```

Fig.7

```
 WARM - SELECTED
INCREMENT =       50   microns OK ?  (Y/N)
Y
THE X INCREMENT SHOULD BE =       50  microns
WHICH PIXEL TO TEST (MM) ? 50
HOW MANY REPEATS ? 50
DURATION OF TEST (MINS) ?  5
WHAT TIME INTERVAL 'TWIX READINGS (MIN)?1
HARD COPY NEEDED ? (Y/N)
Y
DATE =  9. 2.83
TIME = 15: 7:15
THE TIME INTERVAL IS    1 MINS
**THIS IS A WARM-UP TEST **
----------------------------------------------------------
 NO. READ      TIME       MEAN       S.D.       VARI
----------------------------------------------------------


    50          1         96.24      0.43       0.18
    50          2         96.40      0.49       0.24
    50          3         96.56      0.50       0.25
    50          4         96.52      0.50       0.25
    50          5         96.64      0.48       0.23
ANOTHER SCAN ?  (Y/N) N
```

Fig.8

```
DRIV - SELECTED
INCREMENT =        50  microns OK? (Y/N)
Y
 ENTER YOFFSET IN MM
210
Y-OFFSET SET TO      4200  pixels
 ENTER NUMBER OF REPEATS
3
 ENTER NUMBER OF QUICK STEPS
3500
HARD COPY NEEDED ? (Y/N)
Y
THIS IS AN X-DRIVE TEST
DATE =  9. 2.83
TIME = 14:47:44
SCAN INCREMENT IS :-     50 MICRONS
NO OF QUICK STEPS WAS     3500
************************
```

REP. NO.	START PT.	END PT.	DELTA
1	51.58	4179.86	4128.28
2	51.52	4180.12	4128.60
3	51.50	4180.06	4128.55

RMS = 0.03 0.11 0.14

Fig.9

```
POSI - SELECTED
INCREMENT=        50 MICRONS OK? (Y/N)
Y
Y-OFFSET IN MM ?
     238
Y-OFFSET SET TO      4752 PIXELS
Y-LENGTH IN MM
6
Y-LENGTH SET TO      128 PIXELS
HOW MANY REPEATS?
20
HARD COPY NEEDED ? (Y/N)
Y
```

DATE= 23. 2.83
TIME= 11:44:24
Y-POSITION OF LINE IS -

11:44:29	1	106.50	0	255255255255255255255255255250	51	14	13	12	11	11
11:44:29	1	106.47	0	255255255255255255255255255237	51	14	13	12	12	11
11:44:29	1	106.48	0	255255255255255255255255255239	52	14	13	12	11	11
11:44:29	1	106.50	0	255255255255255255255255255249	50	14	13	12	11	11
11:44:29	1	106.46	0	255255255255255255255255255237	47	14	13	12	11	11
11:44:29	1	106.48	0	255255255255255255255255255244	49	14	13	12	11	11
11:44:29	1	106.49	0	255255255255255255255255255242	53	14	13	12	11	11
11:44:29	1	106.49	0	255255255255255255255255255246	49	14	13	12	11	11
11:44:29	1	106.46	0	255255255255255255255255255236	51	14	13	12	11	11
11:44:29	1	106.46	0	255255255255255255255255255236	51	14	13	12	11	11
11:44:29	1	106.48	0	255255255255255255255255255245	49	14	13	12	11	11
11:44:29	1	106.48	0	255255255255255255255255255243	49	14	13	12	11	11
11:44:29	1	106.46	0	255255255255255255255255255237	47	14	13	12	11	11
11:44:29	1	106.48	0	255255255255255255255255255244	49	15	13	12	11	11
11:44:29	1	106.49	0	255255255255255255255255255246	49	14	13	12	11	11
11:44:29	1	106.46	0	255255255255255255255255255235	51	14	13	12	11	11
11:44:29	1	106.51	0	255255255255255255255255255252	51	14	13	12	12	11
11:44:29	1	106.47	0	255255255255255255255255255238	51	14	13	12	11	11
11:44:29	1	106.50	0	255255255255255255255255255250	51	14	13	12	11	11
11:44:29	1	106.45	0	255255255255255255255255255231	49	14	12	12	11	11

MEAN POSITION OF LINE IS   106.48

Fig. 10

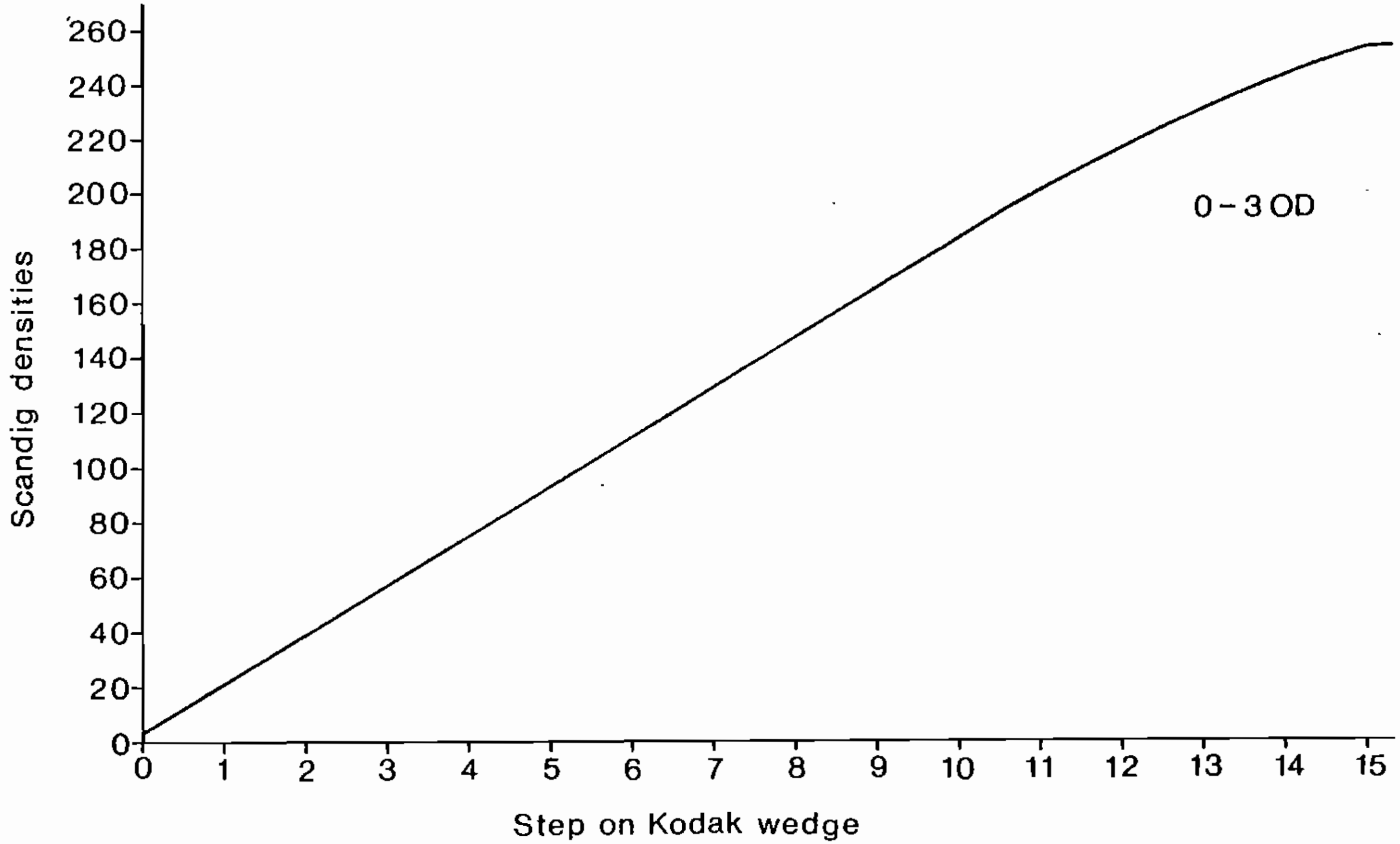

260
240
220
200
180
160
140
120
100
80
60
40
20
0
Scandig densities
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Step on Kodak wedge
0 - 3 OD

Fig. 11

```
SPOT - SELECTED
INCREMENT=        50 MICRONS OK? (Y/N)
Y
Y-OFFSET IN MM ?
50
Y-OFFSET SET TO        992 PIXELS
Y-LENGTH IN MM
1
Y-LENGTH SET TO         32 PIXELS
HOW MANY PIXELS TO SCAN ACROSS ?
10
HARD COPY NEEDED ? (Y/N)
Y
DATE=  9. 2.83
TIME= 15:14:29
  92  92  91  91  93  93  95  93  94  97
  95  96  94  94  94  95  94  95  96  95
  95  94  94  95  95  95  95  94  96  98
  97  96

  91  93  93  91  92  95  97  96  99  99
  95  94  95  95  95  95  94  95  97  94
  93  95  94  95  97  96  96  95  95  95
  96  99

  94  92  92  93  94  94  95  96  96  96
  93  95  94  94  94  95  96  94  94  95
  96  96  96  96  95  94  93  95  97  97
  94  96

  94  96  94  94  96  95  94  93  94  95
  95  97  94  94  95  94  96  95  96  95
  95  98  97  95  95  96  96  95  96  96
  94  94

  94  94  93  95  95  94  94  95  95  93
  93  95  93  93  94  96  97  94  94  97
  96  93  94  95  94  96  96  94  97  96
  98  98

  93  92  93  94  93  94  94  93  92  93
  93  94  94  95  96  98  99  97  95  97
  95  95  94  94  95  97  95  95  95  96
  97  94

  92  93  93  94  93  93  94  96  94  93
  94  96  94  95  95  95  94  94  96  96
  94  95  95  94  94  94  94  93  94  94
  96  96

  92  92  95  93  93  94  94  94  93  94
  95  96  97  95  96  97  98  96  94  97
  98  97  95  95  96  95  95  95  95  97
  96  95

  93  92  93  94  92  93  93  94  94  94
  96  97  95  93  97  95  94  94  96  96
  94  95  96  96  97  96  96  97  97  96
  97  95

  96  94  94  95  94  94  94  94  95  93
  97  97  94  93  94  96  94  94  97  97
  96  98  96  93  93  96  96  97  95  94
  96  96

ANOTHER SCAN ?(Y/N) N
```

Fig. 12

```
          PARA
 PARA - SELECTED
INCREMENT=      50    microns  OK? (Y/N)
Y
 THE X INCREMENT SHOULD BE =      50

APERTURE CODES :
 (INPUT NEGATIVE CODE FOR ROUND, POSITIVE FOR SQUARE. )

2= 25 ;   3= 50 ;   4=100 ;   5=200 ;   6=400 ;
PRIMARY CODE : 4

1= 12 ;   2= 25 ;   3= 50 ;   4=100 ;   5=200 ;
SECONDARY CODE : 3

DENSITY RANGE CODES :
1=0.5 ;2=1.0 ; 3=1.5 ; 4=2.0 ; 5=3.0  CODE : 4
DENSITY OFFSET : 0
HARD COPY NEEDED ? (Y/N)
Y
THE SWITCH SETTINGS ARE AS FOLLOWS :-
THE INCREMENT WAS    50 microns
PRIMARY APERTURE SET TO    100 microns
SECONDARY APERTURE SET TO    50 microns
DENSITY RANGE 0-       2.00 D
```

Fig. 13

```
 DRUM - SELECTED
INCREMENT=       50 MICRONS OK? (Y/N)
Y
Y-OFFSET IN MM ?75
Y-OFFSET SET TO     1500 PIXELS
Y-LENGTH IN MM 30
Y-LENGTH SET TO     608 PIXELS
HOW MANY PIXELS TO SCAN ACROSS ?600
GIVE VALUE FOR BASE DIRT LEVELS
HOW MANY LINES DOWN THE GRAPH ? 30
HARD COPY NEEDED ? (Y/N)
Y


DATE= 10. 2.83
TIME= 14: 0: 4
```

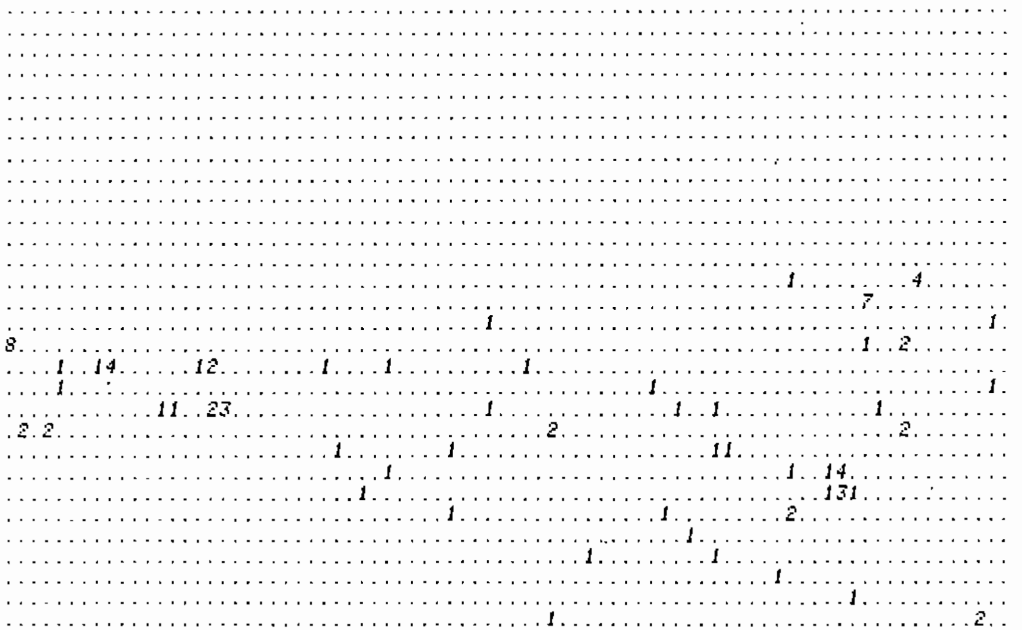
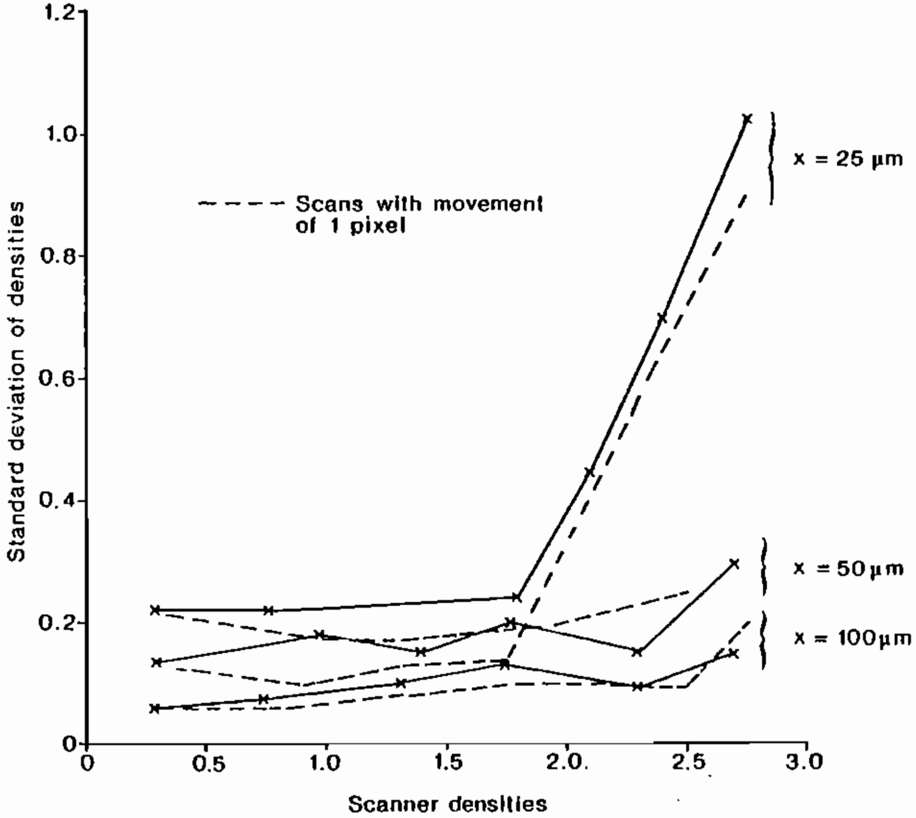
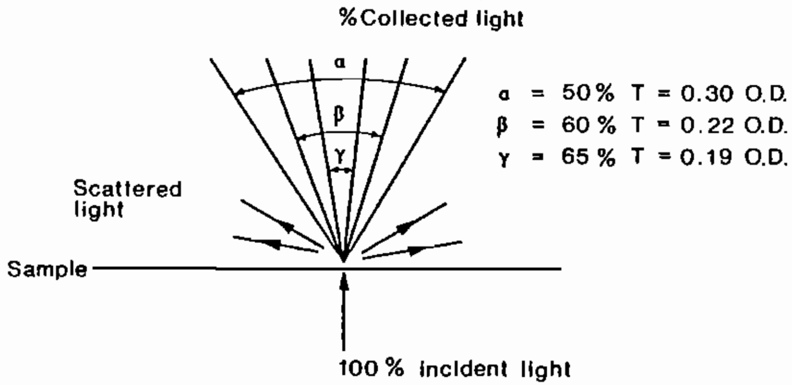


Fig. 14



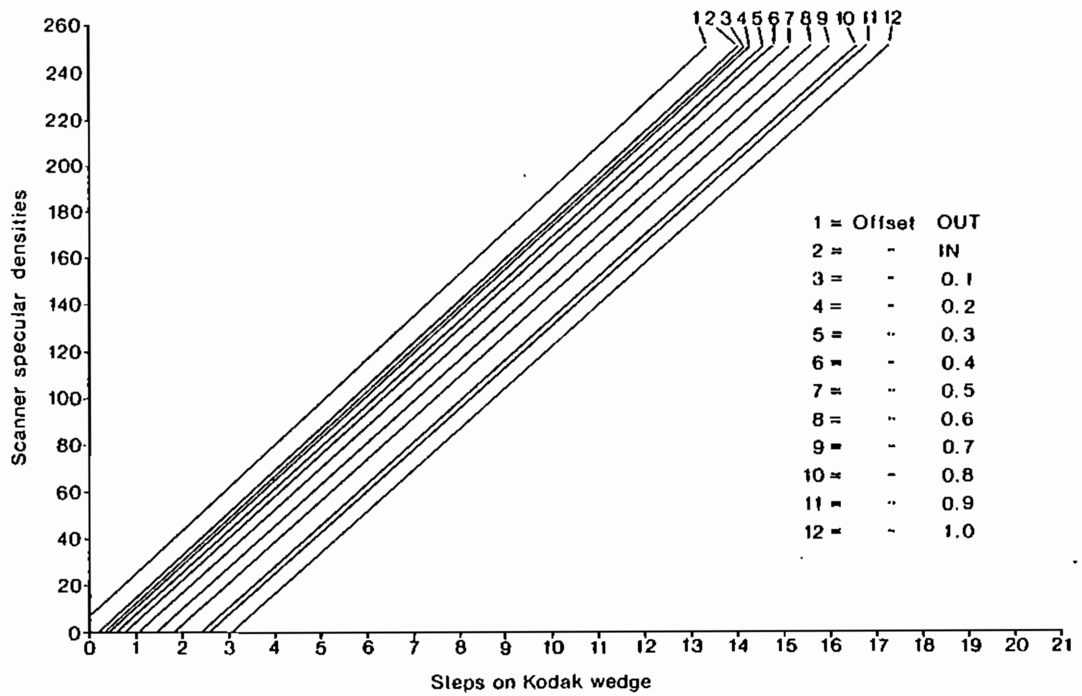
1.2
1.0
0.8
0.6
0.4
0.2
0
Standard deviation of densities
Scans with movement of 1 pixel
x = 25 µm
x = 50 µm
x = 100 µm
0
0.5
1.0
1.5
2.0
2.5
3.0
Scanner densities

Fig. 15



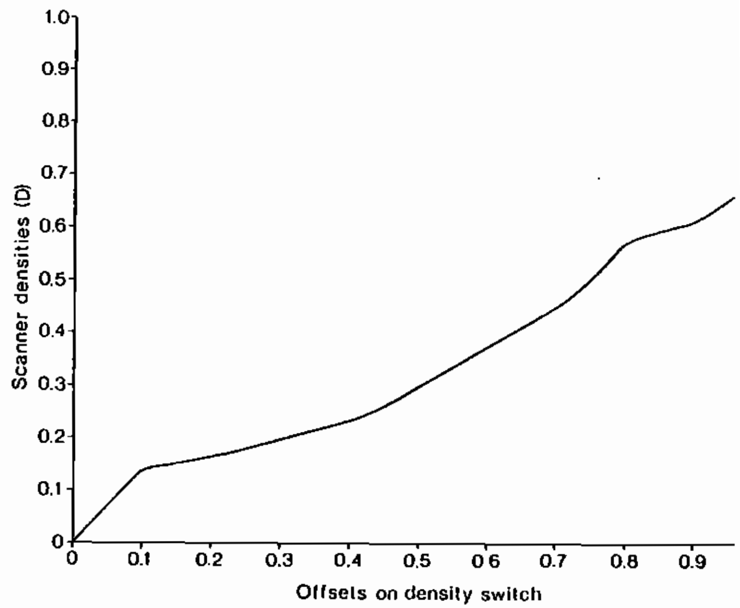
%Collected light
α
β
γ
α = 50% T = 0.30 O.D.
β = 60% T = 0.22 O.D.
γ = 65% T = 0.19 O.D.
Scattered light
Sample
100% incident light

Fig. 16



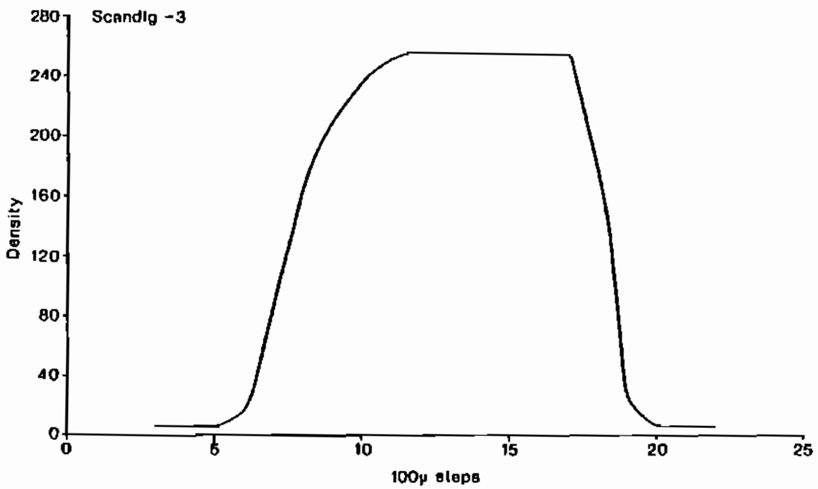
1 2 3 4 5 6 7 8 9 10 11 12
260
240
220
200
180
160
140
120
100
80
60
40
20
0
Scanner specular densities
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Steps on Kodak wedge
1 = Offset OUT
2 = " IN
3 = " 0.1
4 = " 0.2
5 = " 0.3
6 = " 0.4
7 = " 0.5
8 = " 0.6
9 = " 0.7
10 = " 0.8
11 = " 0.9
12 = " 1.0

Fig. 17



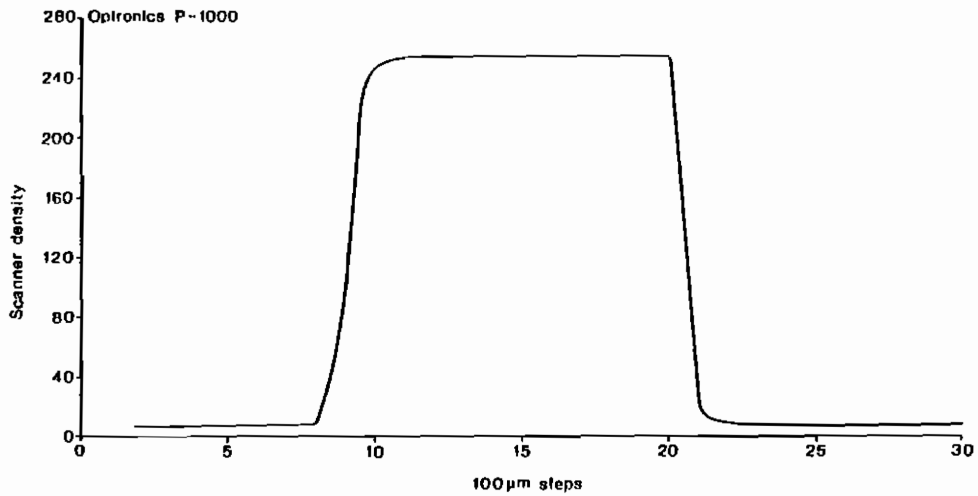
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Scanner densities (D)
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9
Offsets on density switch

Fig. 18



Scandig -3
Density
280
240
200
160
120
80
40
0
0
5
10
15
20
25
100µ steps

Fig. 19



Optronics P-1000
Scanner density
280
240
200
160
120
80
40
0
0
5
10
15
20
25
30
100µm steps

Fig. 20