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STANDARDIZATION PROCEDURE FOR TWO INSTRUMENTS FOR COLOR MEASUREMENT

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20. Diano Match-Scan spectrophotometer. Each was interfaced to a mini-computer for collecting data on the test materials. Based on statistical studies of the measurements made on the instruments, two slightly different computer programs were developed which provide guidance for the operator of the instrument through the standardization procedure and make comparisons of the current measured data to previously established norms and tolerances for the same material. The computer programs are "fail-safe" in the sense that the instrument cannot be used to perform routine tests unless all of the standardization criteria are met.

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PREFACE

The work reported was performed as part of Phase II of a project to develop a color measuring system to be used for instrument judgment of color of textile fabrics procured by the Defense Department. The heart of the system is a spectrophotometer to be controlled by a computer that also performs required colorimetric calculations.

Phase I was limited to an evaluation of commercially available spectrophotometers, each with a small microprocessor. The evaluation was performed under Contract DAAK60-77-C-0093 by Rensselaer Polytechnic Institute and published as NATICK/TR-79/044. All three instruments evaluated were judged capable of meeting the color requirements. Because the system also must be capable of measuring infrared reflectance, however, one of the three instruments was dropped from further consideration in the system development.

The purpose of Phase II was to design the color measurement system to meet the needs of the program. One step in the design was the development of a mathematical means for expressing acceptability of slight deviations from standard shade. This work was performed under Contract DAAK60-78-C-0084 by Lehigh University and published as NATICK/TR-80-0036. A second step was development of a rigid system calibration procedure, which is the subject of this report. The work was performed under Contract DAAK60-79-C-0096 by Clemson University. The third step under Phase II was design and procurement of a prototype, two-unit system.

Support of the program was provided by the Manufacturing Testing Technology program. The Project Officer throughout both Phase I and Phase II was Alvin O. Ramsley; Alternate Project Officer was Therese R. Commerford.

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TABLE OF CONTENTS

	Page
Preface	1
List of Figures	4
List of Tables	4
Introduction	5
Instrumentation Used In Study	5
Basic Calibration Methods	6
Routine Calibration	8
Working Calibration Method	10
Observations	11
Bibliography	12
Appendix A: Computer Program QMSTAT for Match-Scan Statistical Study.	41
Appendix B: Computer Program QMSTAT for Hunter D54 Statistical Study.	45
Appendix C: Computer Program QMSTAN for Standardization Program of Match-Scan.	49
Appendix D: Computer Program QSTANH for Standardization Program of Hunter D54.	53

ILLUSTRATIVE DATA

	Page
Figure 1. Transmission curve of didymium filter for Hunter and Match-Scan instruments.	16
Figure 2. Match-Scan wavelength calibrating filters.	17
Figure 3. Hunter wavelength calibrating filters.	18
Figure 4. Mercury emission lines on the Match-Scan instrument.	19
Figure 5. Reflectance of opal and gray porcelain tiles with Match-Scan.	20
Figure 6. Reflectance of opal and gray porcelain tiles with Hunter D54.	21
Figure 7. Transmittance of amber filter with Match-Scan.	22
Figure 8. Transmittance of amber filter with Hunter D54.	23
Figure 9. Reflectance curves of a pair of tan specimens with the Match-Scan.	24
Figure 10. Reflectance curves of a pair of tan specimens with the Hunter D54.	25
Figure 11. Statistical study for Match-Scan.	26
Figure 12. Statistical study for Hunter D54.	30
Figure 13. Schematic of standardization of Match-Scan.	34
Figure 14. Schematic of standardization of Hunter D54.	35
Figure 15. Standardization test for Match-Scan, typical output from QMSTAN computer program.	36
Figure 16. Standardization test for Hunter D54, typical output from QSTANH computer program.	37
Table 1. Transmission data on NG-9 and NG-3 neutral gray filters calibrated by National Bureau of Standards at 511 nm, measurements at 1-nm intervals.	13
Table 2. Transmission data on NG-4 and NG-5 neutral gray filters calibrated by National Bureau of Standards at 511 nm, measurements at 1-nm intervals.	14
Table 3. Measured values for calibration materials.	15

STANDARDIZATION PROCEDURE FOR TWO INSTRUMENTS FOR COLOR MEASUREMENT

Introduction

The U.S. Army Natick Research and Development Laboratories entered into a contract with Clemson University to have a method developed for the standardization of color measuring instruments. This is one part of the longer range program to evolve an inspection procedure for the acceptance of the color of military fabrics through instrumental measurement rather than by visual estimation. Although there are several problems to be solved before a reliable procedure is achieved, two of the major aspects of the project have been investigated under contract and reported separately. In one of these contracts Billmeyer and Alessi addressed the general reliability of commercial color instruments, and in the other one Allen and Yuhas developed the mathematics of the color acceptability criteria.^{1,2} The present work covers a third aspect which involves the technique that would be used to assure reliability of the instrumental measurement through proper calibration.

Instrumentation used in study

Two instruments were used to develop and test the standardization procedure. Both instruments are commercially available and had been investigated in an earlier contract and had been found in the main to be suitable. One instrument is the Hunter D54 spectrophotometer (Christie and McConnell, 1977) and the other is the Diano Match-Scan spectrophotometer.³ Except for the fact that both instruments involve integrating spheres and diffuse polychromatic illumination, the optical arrangement of the two is quite different. Nevertheless, the measurement data obtained in this study with both instruments were quite comparable although they were not exactly interchangeable. No attempts were made to introduce adjustments to compensate for these small differences in results.

The Hunter spectrophotometer was loaned to Clemson by Natick Laboratories for the purpose of this study. It consisted of three interconnected units: a measuring head, power supply, and a microprocessor push-button controller. In order to collect the large amount of statistical data required in this work, the instrument controller was interfaced to a General Automation SPC-16/45 minicomputer. On occasions when graphical data were needed, the spectrophotometer was connected to a Tektronik 4662 plotter. The SPC-16 was programmed in Fortran to aid in the data collection and the standardization test procedure.

1. F. W. Billmeyer, Jr. and P. J. Alessi (1979, "Assessment of Color-Measuring Instruments for Objective Textile Acceptability Judgement" Technical Report NATICK/TR-79/044, U.S. Natick Research and Development Command, Natick, MA 01760, March 1979.
2. E. Allen, and B. Yuhas (1980), "Investigations to Define Acceptability Tolerance Ranges in Various Regions of Color Space," Technical Report, NATICK/TR-80/036, U.S. Army Natick Research and Development Command, Natick, MA 01760, September 1980.
3. J. S. Christie, and G. McConnell, Color 77, p. 309, Adam Hilger Ltd., Bristol, England, 1977.

The Diano Match-Scan spectrophotometer is part of an integrated instrument computer system called the Match-Mate 3000. The instrument is entirely computer-controlled which means that special test programs were written in Fortran around operating software that was furnished by the manufacturer. The Tektronik 4662 plotter was also interfaced to the Match-Mate 3000 system for drawing special graphs.

Basic calibration methods

Spectrophotometric reflectance data are the basic measurements used for calculating color difference values which in turn express the acceptability of the color of test materials compared to established standards. Therefore, it is necessary to evolve a method that would establish with a fair degree of certainty that the instrumental measurement is reliable in order that a high degree of confidence can be placed on tests performed with the equipment. Such a premise infers that the instrument is set up for operation and then checked according to prescribed methods. It must be relative to some accurately known set of data. If these data are based on fundamental measurement of wavelength and spectral power, then this is an absolute method. Alternatively, the values of a set of calibrating materials can be known relative to a master set of similar materials; when the instrument is performing satisfactorily, the results obtained on a specific set of materials will be within specified tolerances. This is a relative calibration method. In this application, long term repeatability of measurements of a given instrument and reproducibility of measurements between locations are of paramount importance, therefore, the relative calibration method is followed in the present study.

Wavelength scale calibration has been done for many years on several commercial spectrophotometers using the well-known absorption maximum of the Corning 5120 didymium glass. Gibson, and Keegan found that several maxima can be used with spectrophotometers having a constant bandwidth in the range between 2 and 10 nm; this offers a method for checking spectrophotometers that have such resolution.⁴ Although the Match-Scan can be calibrated with didymium, this procedure is inappropriate for the D54 instrument which has a bandwidth that changes from 12 nm at 400 nm to 18 nm to 700 nm, making the didymium filter less suited to this purpose. This is shown in Figure 1. Venable and Eckerele (1979) have described a more advanced method for wavelength calibration with a didymium filter which is suitable for any wavelength bandpass.⁵

4. K. S. Gibson, and H. J. Keegan, J. Opt. Soc. Am. 31, 462 (1941).
5. W. H. Venable, Jr., and K. L. Eckerle, (1979), "Didymium Glass Filters for Calibrating Wavelength Scale of Spectrophotometer-SRM 2009, 2010, 2013 and 2014," NBS Special Publication 260-66. National Bureau of Standards, Washington, DC 20234.

An alternative method for wavelength calibration was described by Van den Akker and adapted for the D54 instrument by Stanziola et al.^{6,7} It requires pairs of glass filters having spectrophotometric curves that cross at a determinable wavelength. In the region of the crossing, it is best that the transmission curves be approximately linear. Two sets of filters have been used to check the wavelength scales around 440 nm and 590 nm which presumes to cover the limits of the visible spectrum. The Van den Akker method is applicable to both the D54 and Match-Scan; curves obtained with each instrument are shown in Figures 2 and 3.

There are caveats to the crossing-filter method. Individual sets of filters give particular wavelength crossings which are dependent as well upon bandwidth and instrument geometry. Different values for the intersection wavelength will also be obtained depending upon what wavelength increment is used to interpolate among the transmission measurements for each pair of filters. The crossing wavelength can be computed with data from any wavelength interval according to the following formula:

$$X = I (t_3 - t_1) / (t_2 + t_3 - t_1 - t_4) + W$$

where,

X is the crossing wavelength

I is the wavelength increment

t_1, t_2 are the transmittances for the first filter at wavelength, W, and wavelength, W + I, respectively

t_3, t_4 are the transmittances for the second filter at the same wavelengths as the first filter

W is the first wavelength

A 10-nm increment is preferred because it is a normal mode of operation for the D54 instrument and this makes for a convenient procedure. Hunterlab makes their determinations at 1-nm intervals, which give slightly more variable data (see below) than with 10-nm intervals. There is a small difference in the crossing wavelength dependent upon the wavelength increment, but as long as the same procedure is used at all times, the resulting values should be consistent.

Another method based on mercury emission lines is suited to the Match-Scan instrument but not the D54. The Match-Scan is provided with a Stand-Alone

6. J. A. Van den Akker, J. Opt. Soc. Am. 33, 257 (1943).

7. R. Stanziola, B. Momiroff, and H. Hemmendinger, Color Research Application 4, 36 (1979).

Program (SAP) which allows for single-beam radiometric measurements at 0.2-nm intervals. The output of a mercury arc lamp can be scanned around the emission peaks at 404.7, 435.7, 546.1, 557-578 to determine whether the instrument wavelength scale is correct. This has been done with the Match-Scan and the results are shown in Figure 4. Although the instrument has not been reset to the correct wavelength, the wavelength error is repeatable over a six-month period indicating that reproducible measurements can be achieved.

The D54 is routinely calibrated by the manufacturer, Hunterlab, using a series of filters of known spectral transmittance values for corresponding wavelengths.⁸ Diano, on the other hand, calibrates the Match-Scan using the didymium filter absorption points. However, the purpose of this procedure is to recognize whether an instrument is performing in the same way that it had been when it was put into service. To that end a simple wavelength check is made with the transmittance of an anber filter at about the middle of the visible spectral range.

Several methods have been cited for wavelength checking but there are not generally accepted methods for establishing the validity of the photometric (reflectance or transmittance) scale for a spectrophotometer. In cooperation with the National Bureau of Standards we have developed a set of four neutral gray glass filters of ascending transmittances from about 0.5% to 31%. These were measured on the NBS high-accuracy spectrophotometer at 511 nm, which is in an area of relatively flat transmittance. Since the high-accuracy spectrophotometer will give transmittance values at least more precise than any commercial instrument, it was felt that these filters would serve as a good reference for both instruments in this study.

The measurements obtained on the instruments are given in Tables 1 and 2. It will be noted that 1-nm data obtained with the D54 are slightly less consistent than data obtained with the Match-Scan. For reasons not known, these data are not in keeping with the 10-nm data obtained on the D54 in other parts of this study. Although the photometric readings on both instruments are not equal to those of the NBS, repeat tests done weeks apart indicate that the departure from the Bureau's values remains constant. One can presume from this that either the method of measurement in the commercial instruments produces a specific bias or that the normal standardization methods for these instruments do not compensate for nonlinearity in the photometric scale. Nonetheless, consistency of results is the overwhelming requirement.

Routine calibration

The calibration method which was finally developed as a result of this investigation considered that the following criteria were important:

a. Physical samples should be measured on the instrument and should be stable, easily cleaned, and of a convenient size.

8. See Reference 3.

9. See Reference 5.

b. Measurements should check the performance of the instrument as for wavelength reliability as well as low range (below 5%) and high range (above 70%) photometric response.

c. Measurements should also check the 100% line and the mid-scale correction in the reflection mode.

d. A final check should be made of the ability of the instrument and computer system to give reproducible color difference values on a pair of samples of known color difference.

e. Backup calibration materials should be available to check the instrument wavelength if there are indications of wavelength uncertainty in the routine test.

These objectives were satisfied by selection of the following materials:

a. A white opal glass, 50 mm square by 10 mm thick which is covered on back and sides with black paper. See Figures 5 and 6.

b. A Corning 3307 Signal Yellow filter, 50 mm square by 2.3 mm thick. See Figures 7 and 8.

c. A gray porcelain enamel plaque, 10.7 cm square. See Figures 5 and 6.

d. A pair of tan polyester gelcoat plaques, 7.8 mm square. See Figures 9 and 10.

e. Four glass filters for wavelength checking. Each is 50 mm square. These filters were obtained through Hunter Associates Laboratory (the Corning description is only given for reference).

Blue-Corning 5851, 2.8 mm thick
Green-Corning 4445, 5.0 mm thick
Yellow-Corning 3387, 3.0 mm thick
Red-Corning 2424, 3.1 mm thick

Six sets of these calibration materials were obtained and checked for similarity. Only one set of materials was used throughout this study; individual values for the remaining five sets are given in Table 3 of this report.

In order to establish the range of expected values that would be obtained when the calibrating materials are measured on each instrument, two Fortran programs were written to assist in the collection and evaluation of the resulting data. The programs are the same in principle, but since each instrument operates differently and is interfaced to its own computer, small changes were made to fit each case. QMSTAT is the program used with the Diano Match-Scan and its Digital Equipment Company LSI-11 computer and QMSTAT is used with the Hunter D54 spectrophotometer and the General Automation SPC-16 computer.

The procedure used for the calibration samples with the Match-Scan, made it simple to measure the samples in sequence:

Opal glass
Amber filter
Gray porcelain enamel tile
Standard tan plastic
Sample tan plastic

Each sample was carefully washed with a 1% solution of Sparkleen (Fisher Scientific Company), rinsed with distilled water and carefully dried with Kimwipes. This was done before every measurement.

In the case of the D54 instrument, a procedure that includes instrument setup was added:

Set up D54 for transmittance:

- a. Press "TRANS" button
- b. Block beam with black cardboard and press "ZERO"
- c. Insert white tile and press "STDZ"

Measure Amber filter

Set up D54 for reflectance:

- a. Press "R-SIN" button
- b. Place black trap over port and press "ZERO"
- c. Place white tile over port and press "STDZ"
- d. Place gray tile over port and press "STDZ"

Measure Opal glass
Measure Gray porcelain enamel tile
Measure Standard tan plastic
Measure Sample tan plastic

Both QUMSTAT and QMSTAL programs provide the necessary prompting so that the operator follows the proper sequence. In the QMSTAT program the paired white opal glasses are assumed to be approximately matched, and all of the subsequent measures are corrected to a value which compensates for any mismatch. A set of measurements and calculations for both instruments are given as Figures 11 and 12. Note that all spectral data lists the results of a single measurement, the average of two measurements and the average of ten measurements. Based on these data and the calculated standard deviation (sigma), it was concluded that the average of two measurements was suitable. Since we were not able to actuate the D54 through the program on the SPC-16 computer, we were obliged to operate the spectrophotometer through the keyboard and collect the resulting data through an ASCII interface to the computer. This was accomplished by first pressing the "READ" button; then when the "BUSY" light went out, the "10 NM" button on spectrophotometer console and the "RETURN" on the computer keyboard were pressed simultaneously.

A "PAUSE" was built into the computer program to allow for these operations to take place. Figure 12 shows that the ten repeat measurements were made with a PAUSE between each set. Analogous data to those shown for the Match-Scan in Figure 11 were obtained for the D54 instrument. In preparing Figure 12, the intermediate PAUSE statements have not been shown.

Working Calibration Method

The statistical studies with the two instruments were carried on for several months to establish a long term record of performance with the calibrating materials. Based on these experiments, two new programs QMSTAN for the Match-Scan and QMSTANH for the D54 were written to serve as a "fail-safe" calibration procedure that will not permit operation of the instrument if it fails within the limits set for each material. Again there are some differences between the instruments in the procedure itself as well as the specific limits set for each material. Figures 13 and 14 give a diagram of the information needed to effect the calibration of each instrument. Figure 15 shows a set of data obtained with the Match-Scan and Figure 16 shows a set of data obtained with the D54 spectrophotometer.

Observations

Table 3 summarizes the values obtained with each set of materials that are recommended for standardization of any spectrophotometer similar to the D54 or Match-Scan. The tolerances given in the Table reflect the experience obtained from this study. In the main, the tolerance that were determined for acceptable instrument performance in the QMSTAN and QSTANH programs are similar, since both instruments performed in a comparable manner. The data that were obtained on Set #1 were specifically determined on both instruments at $76^{\circ} \pm 1^{\circ}\text{F}$. All of the other data were obtained on the Match-Scan.

Slightly larger tolerances are given for the D54 than the Match-Scan, which allows for the change in transmittance when the D54 is operated at 84°F . Experiments were repeated twice with the temperature in the Clemson Color Science Center laboratory raised to 84°F . When this was done, the transmittance of the amber filter as measured by the D54 was slightly lower than typical results obtained at 76°F . The measurements performed on the Match-Scan at the same time did not show any difference between the two temperatures. If one can assume that the transmittance of the amber filter is approximately linear between 520 and 530 nm, 1% change in transmittance is equivalent to a 0.63 nm wavelength change. Therefore, the tolerance of 0.3% is equivalent to about 0.19 nm for the D54 and 0.13 for the Match-Scan. No statistically significant color differences were determined for the two plastic samples when the data obtained at 76°F were compared to those at 84°F .

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Table 1. Transmission Data on NG-9 and NG-3 Neutral Gray Filters
Calibrated by National Bureau of Standards at 511 nm; measurements
at 1-nm intervals.

SAMPLE NAME?

NG-9 NBS Value 0.807%

AVERAGE READINGS ? [Y/N] Y

NO. OF READINGS TO AVERAGE? 2

D 54

Matchscan

W/L	%R
505.0	0.82
506.0	0.82
507.0	0.82
508.0	0.82
509.0	0.81
510.0	0.82
511.0	0.81
512.0	0.82
513.0	0.81
514.0	0.82
515.0	0.82
516.0	0.82
517.0	0.82
518.0	0.82
519.0	0.82
520.0	0.82

CONTINUE? [Y/N] Y

TRANSMITTANCE

505	.83
506	.84
507	.82
508	.83
509	.84
510	.81
511	.87
512	.84
513	.81
514	.86
515	.83
516	.84
517	.80
518	.80
519	.86
520	.82

SAMPLE NAME?

NG-3 NBS Value 2.693%

AVERAGE READINGS ? [Y/N] Y

NO. OF READINGS TO AVERAGE? 2

D 54

Matchscan

W/L	%R
505.0	2.74
506.0	2.74
507.0	2.74
508.0	2.73
509.0	2.74
510.0	2.74
511.0	2.74
512.0	2.74
513.0	2.74
514.0	2.74
515.0	2.74
516.0	2.75
517.0	2.74
518.0	2.75
519.0	2.75
520.0	2.76

CONTINUE? [Y/N] N

TRANSMITTANCE

505	2.74
506	2.77
507	2.72
508	2.76
509	2.73
510	2.73
511	2.75
512	2.74
513	2.74
514	2.76
515	2.72
516	2.78
517	2.75
518	2.73
519	2.75
520	2.72

Table 2. Transmission Data on NG-4 and NG-5 Neutral Gray Filters
Calibrated by National Bureau of Standards at 511 nm;
Measurements at 1-nm intervals.

SAMPLE NAME?

NG-4 NBS Value 4.384

AVERAGE READINGS ? (Y/N) Y

NO. OF READINGS TO AVERAGE? 2

D 54

Matchscan

W/L %R

TRANSMITTANCE

505.0 4.49
506.0 4.48
507.0 4.48
508.0 4.47
509.0 4.48
510.0 4.47
511.0 4.47
512.0 4.47
513.0 4.47
514.0 4.47
515.0 4.49
516.0 4.49
517.0 4.50
518.0 4.51
519.0 4.52
520.0 4.53

505 4.51
506 4.52
507 4.44
508 4.50
509 4.49
510 4.48
511 4.50
512 4.47
513 4.49
514 4.49
515 4.47
516 4.54
517 4.53
518 4.47
519 4.51
520 4.48

CONTINUE? (Y/N) Y

SAMPLE NAME?

NG-5 NBS Value 31.145%

AVERAGE READINGS ? (Y/N) Y

NO. OF READINGS TO AVERAGE? 2

D 54

Matchscan

W/L %R

TRANSMITTANCE

505.0 31.47
506.0 31.47
507.0 31.47
508.0 31.45
509.0 31.48
510.0 31.46
511.0 31.47
512.0 31.46
513.0 31.47
514.0 31.48
515.0 31.50
516.0 31.51
517.0 31.53
518.0 31.55
519.0 31.55
520.0 31.61

505 31.59
506 31.61
507 31.61
508 31.65
509 31.62
510 31.65
511 31.70
512 31.69
513 31.64
514 31.67
515 31.63
516 31.69
517 31.59
518 31.69
519 31.62
520 31.66

CONTINUE? (Y/N) Y

Table 3. Measured Values for Calibration Materials.

Set Number 1					Mean T or R in % - other sets					
Match-scan					D54					
Mean Length	Mean T or R	Tolerance	Mean T or R	Tolerance	#2	#3	#4	#5	#6	
White Tile	540	100.02*	±0.07	98.36	±0.10	100.08	100.17	99.96	100.03	99.96 %
Amber Filter	420	3.50	±0.03	3.48	±0.03	3.81	3.57	3.39	3.02	2.54 %
	520	39.15	±0.12	38.68	±0.18	40.21	33.36	38.96	37.66	35.86 %
	660	79.97	±0.12	80.20	±0.12	80.06	79.81	79.61	79.19	78.43 %
Gray Porcelain Tile	540	43.90	±0.10	42.96	±0.10	44.66	44.57	43.96	44.33	45.03 %
Tan Plastic -										
CIEL* a* b*	1976	1.89	±0.05	1.88	±0.05	2.06	1.98	1.97	2.10	1.90 Delta E
Wave Length										
Filter Pair										
Dk Blue - Yellow	441.3					441.3	438.9	441.3	440.4	442.2 nm
Red-Blue Green	590.1					590.1	589.3	590.1	591.0	589.6 nm

*Sample versus Standard tile

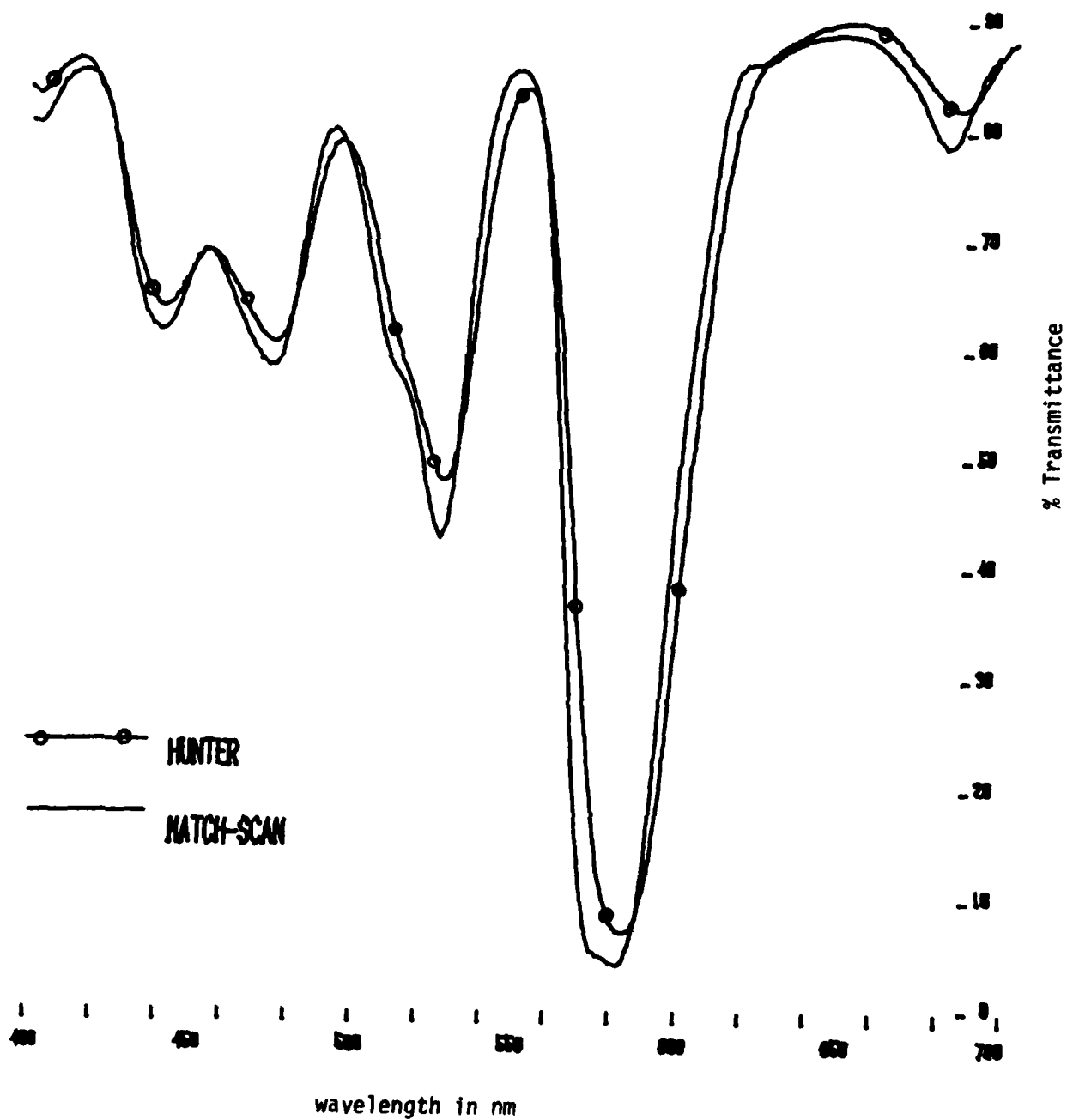


Figure 1. Transmission curves of didymium filter for Hunter D54 and Match-Scan instruments.

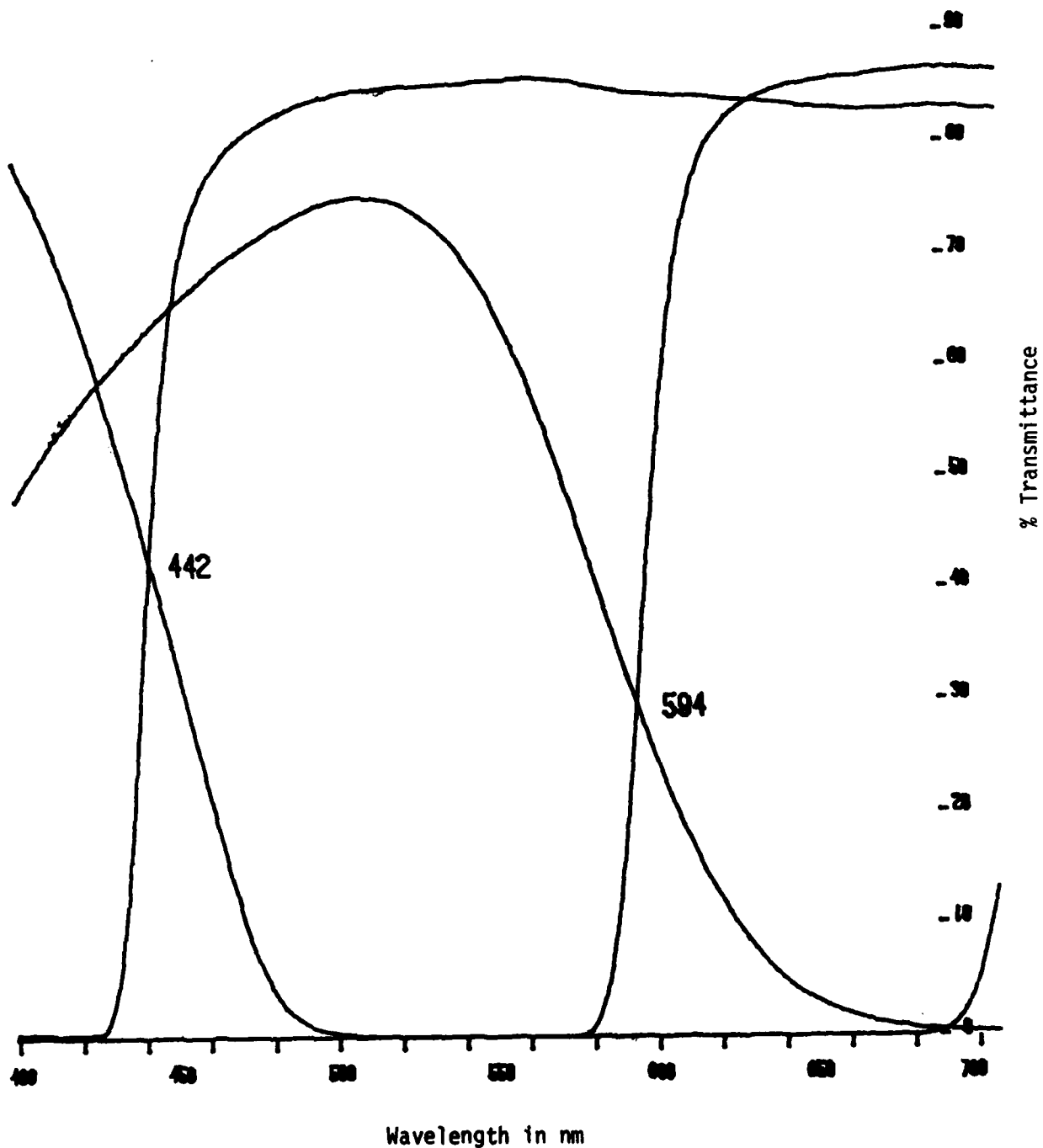


Figure 2. Match-Scan wavelength calibrating filter transmission curves.

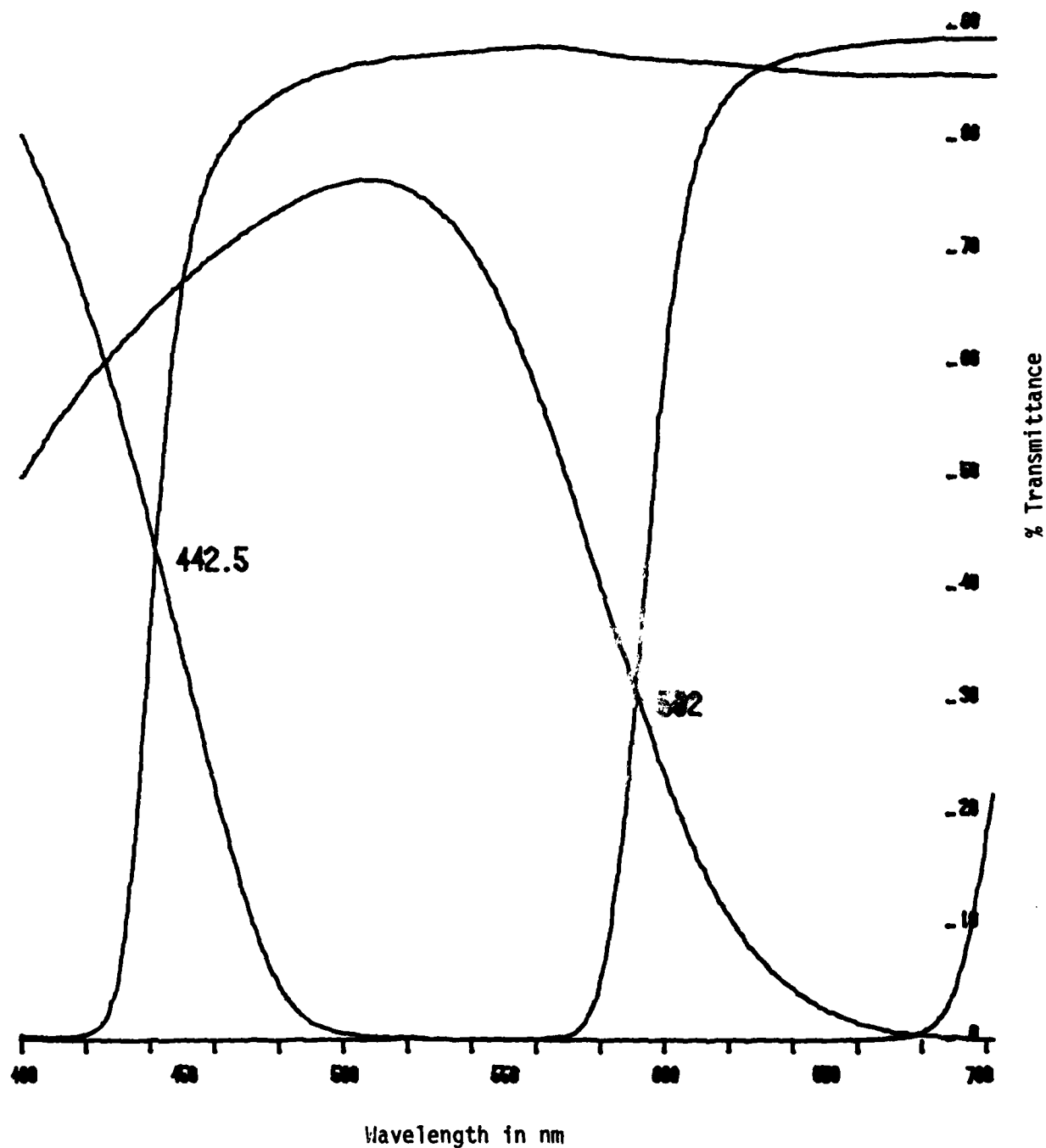


Figure 3. Hunter D54 wavelength calibrating filter transmission curves.

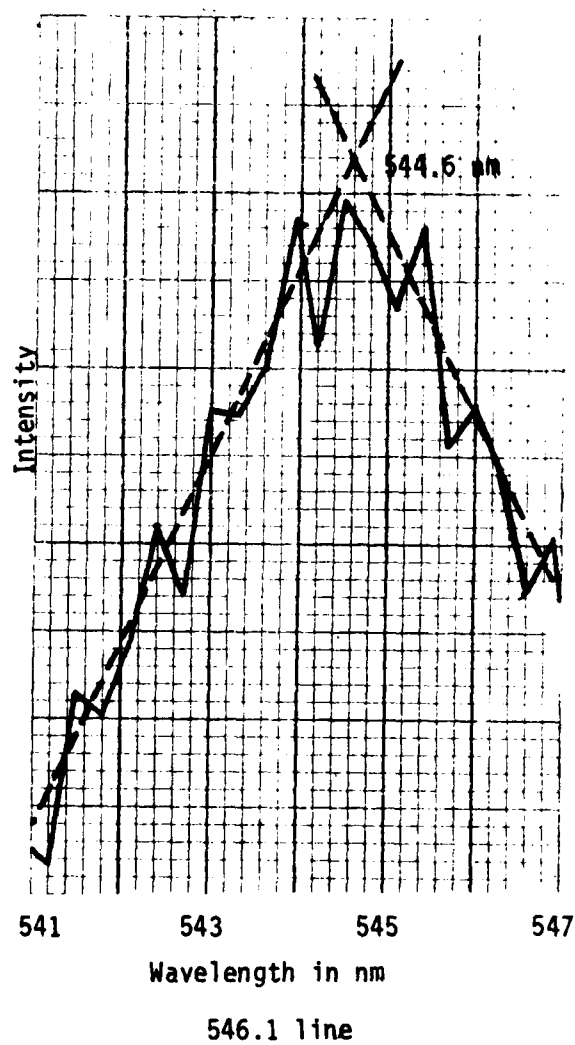
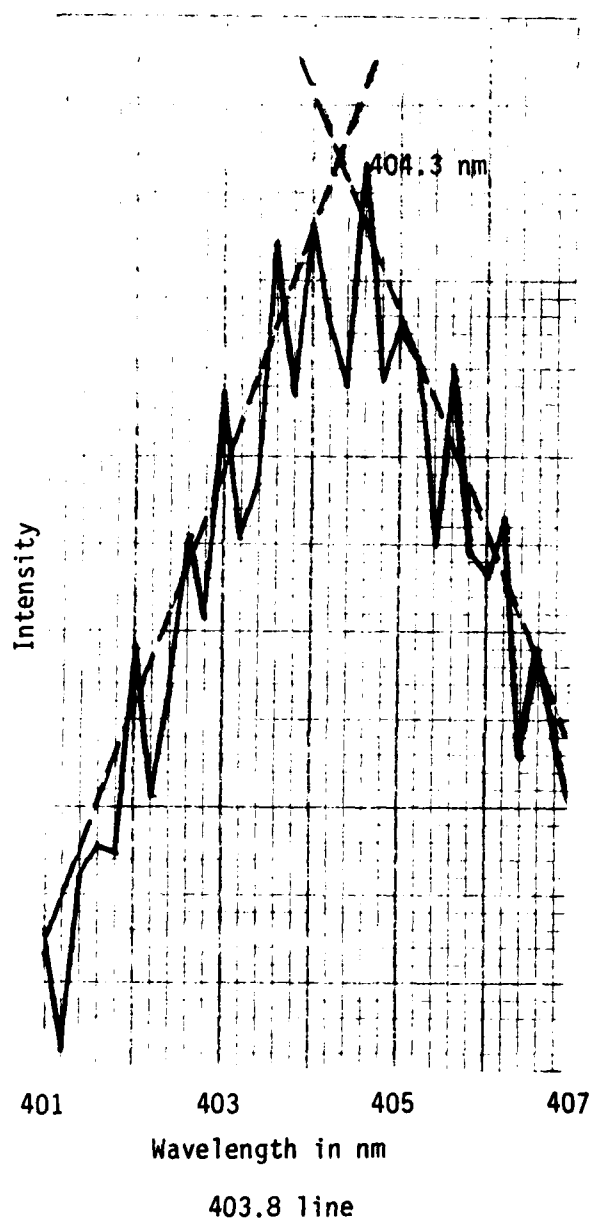


Figure 4. Mercury emission lines on the Match-Scan instrument.

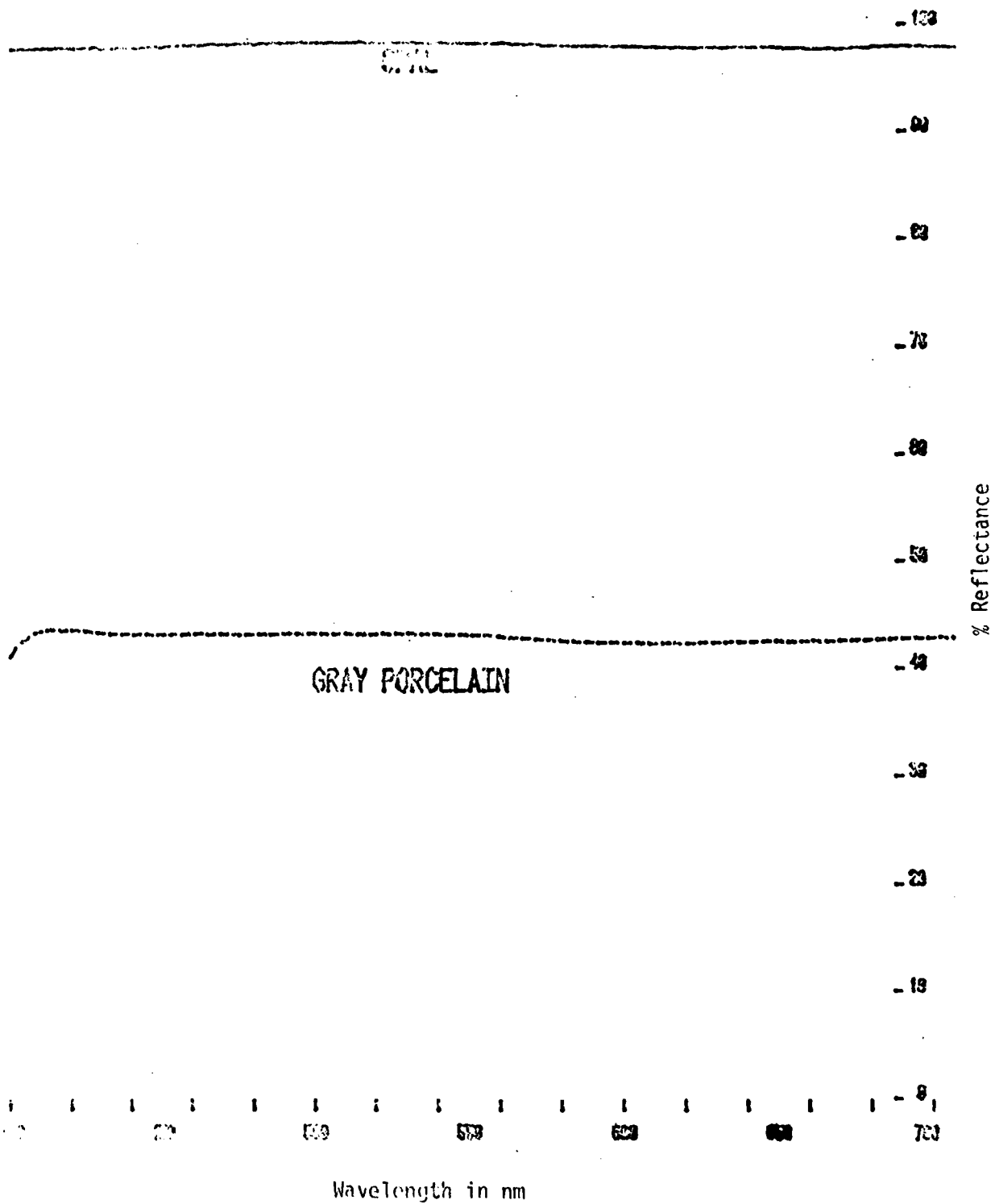


Figure 5. Reflectance of opal and gray porcelain tiles with Match-Scan.

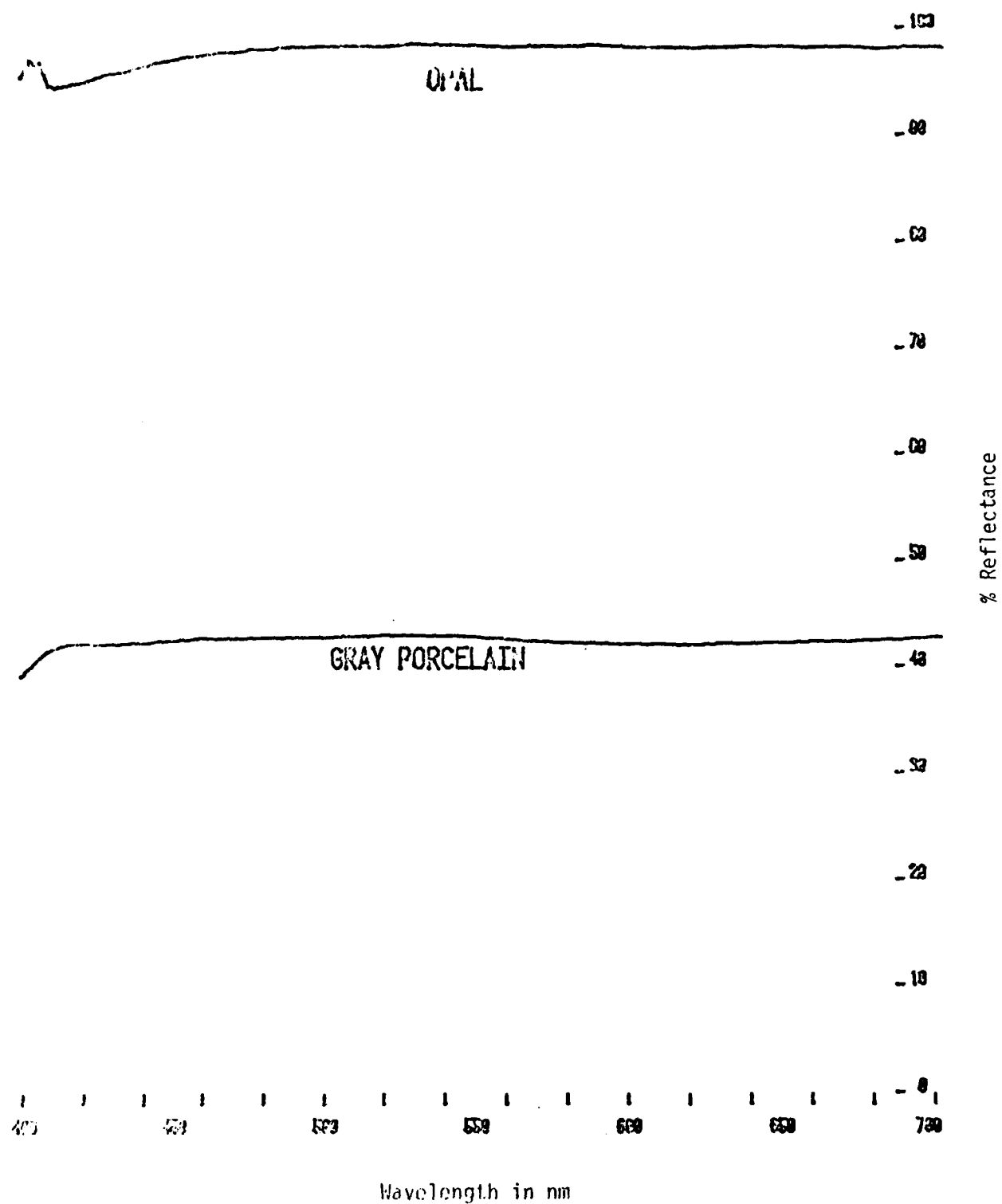


Figure 6. Reflectance of opal and gray porcelain tiles with Hunter D54.

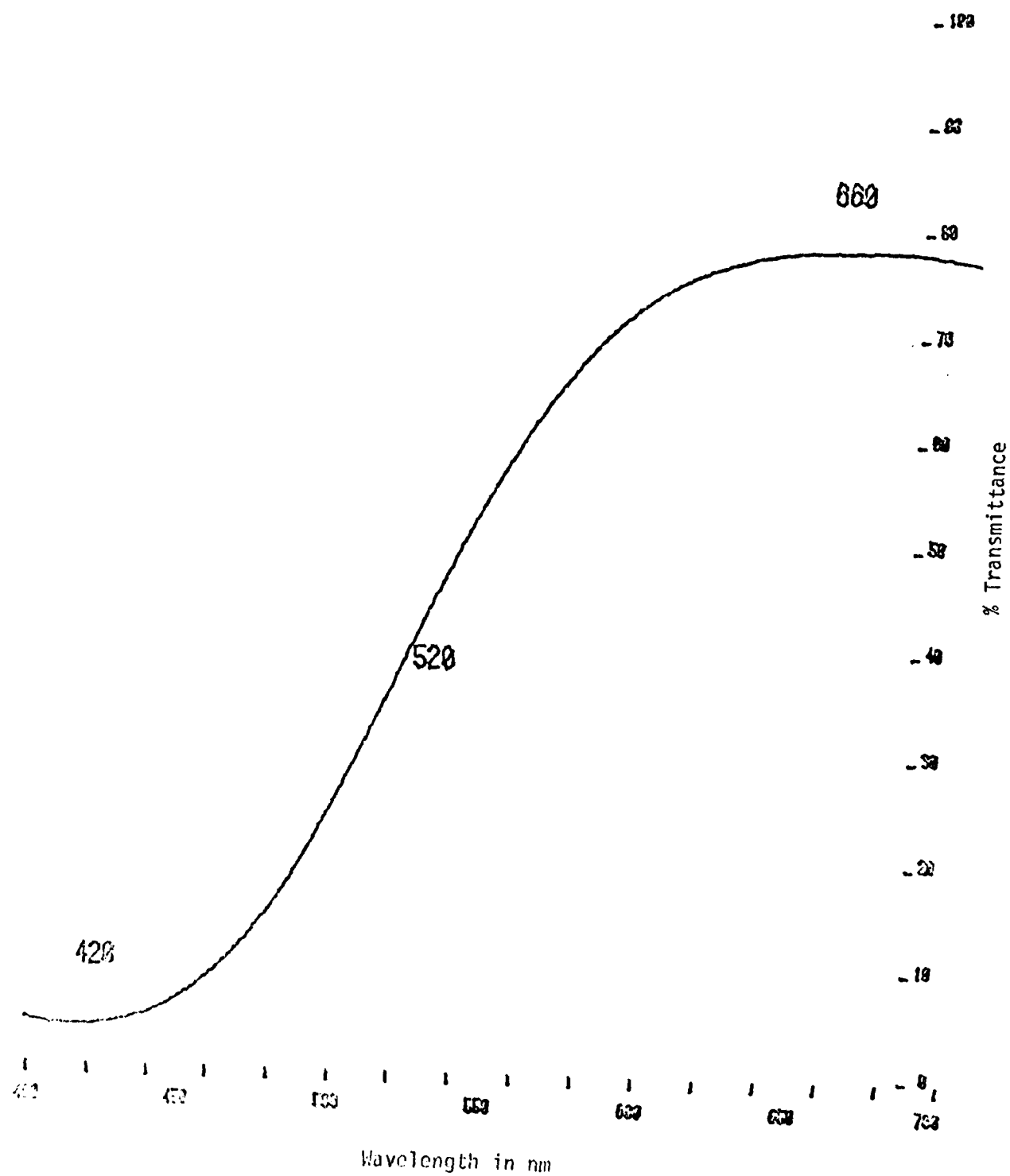


Figure 7. Transmittance of amber filter with Match-Scan.

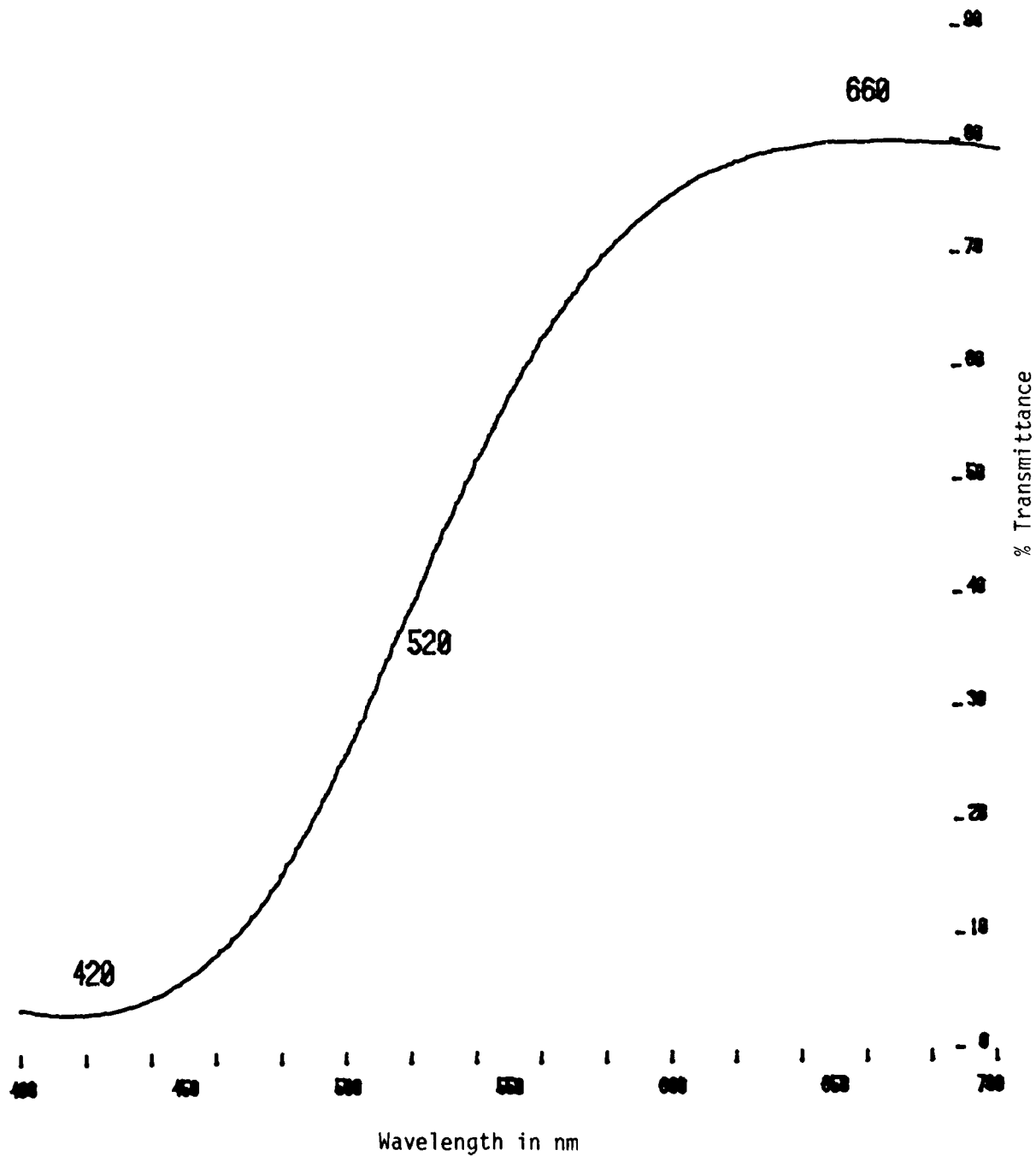


Figure 8. Transmittance of amber filter with Hunter D54.

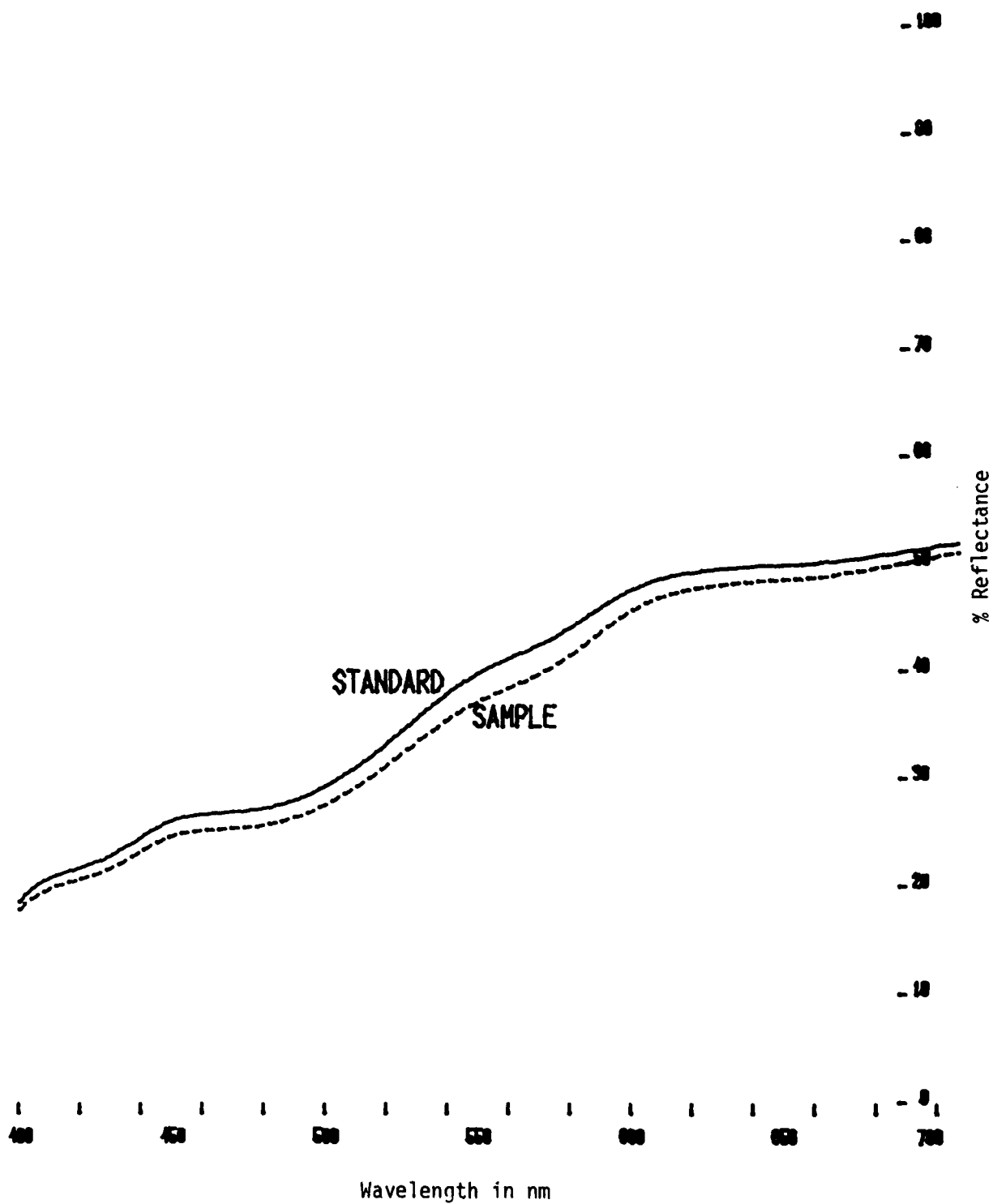


Figure 9. Reflectance curves of a pair of tan specimens with the Match-Scan.

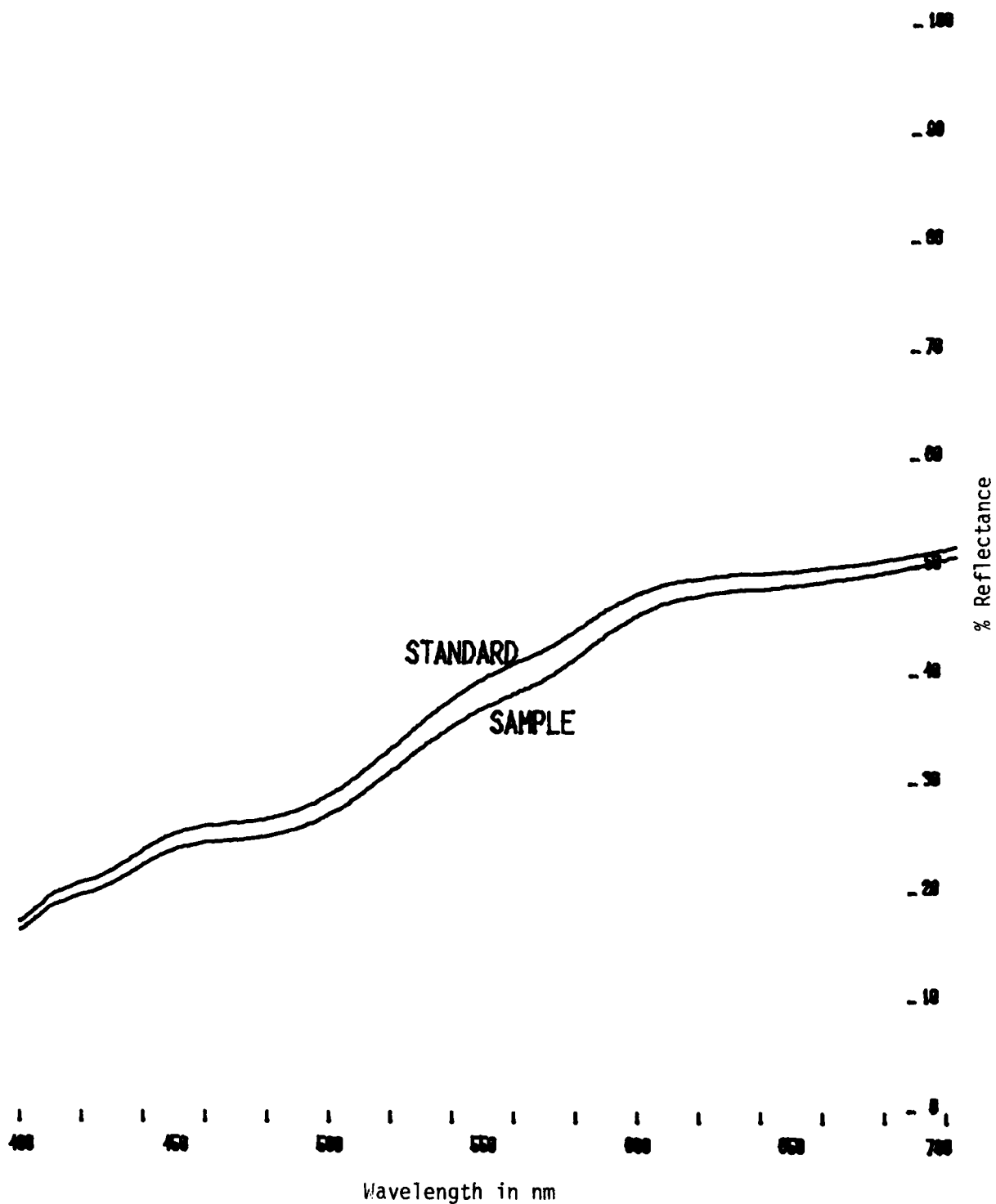


Figure 10. Reflectance curves of a pair of tan specimens with the Hunter D54.

.R QMSTAT

DATE: 10/11/80

BEGIN WITH SAMPLE NO.?(2-5) 2

MEASURE: WHITE TILES INSERT SAMPLE THEN HIT RETURN

PAUSE --

W/L	FIRST	AVG OF 2	AVG OF 10	SIGMA
400	99.56	99.56	99.60	0.046
410	99.64	99.66	99.62	0.037
420	99.70	99.67	99.63	0.039
430	99.69	99.66	99.62	0.044
440	99.66	99.66	99.63	0.029
450	99.61	99.61	99.62	0.024
460	99.67	99.65	99.63	0.030
470	99.66	99.63	99.62	0.027
480	99.59	99.61	99.64	0.032
490	99.63	99.62	99.63	0.013
500	99.63	99.61	99.60	0.013
510	99.59	99.58	99.59	0.018
520	99.59	99.58	99.59	0.014
530	99.61	99.59	99.60	0.019
540	99.57	99.59	99.60	0.020
550	99.62	99.61	99.59	0.022
560	99.59	99.60	99.57	0.023
570	99.57	99.57	99.59	0.013
580	99.61	99.61	99.59	0.024
590	99.58	99.59	99.60	0.021
600	99.59	99.60	99.60	0.020
610	99.63	99.63	99.62	0.023
620	99.58	99.60	99.61	0.023
630	99.62	99.61	99.62	0.025
640	99.57	99.58	99.63	0.028
650	99.66	99.67	99.66	0.021
660	99.65	99.66	99.66	0.020
670	99.70	99.70	99.68	0.030
680	99.74	99.72	99.71	0.041
690	99.63	99.68	99.69	0.041
700	99.74	99.72	99.72	0.048
710	99.79	99.80	99.77	0.049

Figure 11. Statistical study for Match-Scan.

MEASURE: AMBER FILTER

INSERT SAMPLE THEN HIT RETURN

PAUSE --

W/L	FIRST	AVG OF 2	AVG OF 10	SIGMA
400	3.99	3.98	3.98	0.009
410	3.53	3.54	3.53	0.007
420	3.52	3.53	3.52	0.007
430	3.94	3.94	3.95	0.005
440	4.88	4.88	4.88	0.005
450	6.44	6.44	6.44	0.006
460	8.73	8.74	8.74	0.005
470	11.84	11.85	11.86	0.007
480	15.92	15.91	15.90	0.009
490	21.01	21.01	21.01	0.008
500	26.81	26.81	26.81	0.010
510	32.80	32.81	32.82	0.010
520	39.17	39.18	39.20	0.012
530	45.61	45.63	45.62	0.011
540	51.84	51.83	51.82	0.007
550	57.48	57.49	57.51	0.013
560	62.54	62.53	62.55	0.014
570	66.88	66.86	66.84	0.022
580	70.43	70.43	70.43	0.015
590	73.27	73.27	73.28	0.024
600	75.52	75.51	75.49	0.017
610	77.14	77.13	77.11	0.019
620	78.28	78.27	78.28	0.015
630	79.06	79.07	79.08	0.027
640	79.65	79.63	79.59	0.017
650	79.84	79.84	79.85	0.016
660	79.94	79.96	79.97	0.016
670	79.94	79.95	79.93	0.025
680	79.69	79.71	79.73	0.029
690	79.50	79.47	79.47	0.034
700	79.11	79.08	79.07	0.031
710	78.49	78.53	78.54	0.028

Figure 11. Statistical study for Match-Scan (continued).

MEASURE: GRAY PORCELAIN INSERT SAMPLE THEN HIT RETURN

PAUSE --

W/L	FIRST	AVG OF 2	AVG OF 10	SIGMA
400	42.05	42.07	42.07	0.028
410	44.43	44.39	44.40	0.024
420	44.42	44.45	44.46	0.016
430	44.23	44.24	44.24	0.020
440	44.07	44.08	44.10	0.012
450	44.02	44.03	44.03	0.019
460	43.98	44.00	44.00	0.011
470	43.97	43.97	43.98	0.013
480	44.00	43.98	43.97	0.012
490	43.96	43.98	43.97	0.010
500	43.92	43.93	43.95	0.010
510	43.95	43.94	43.94	0.009
520	43.95	43.97	43.97	0.016
530	43.95	43.95	43.95	0.011
540	43.91	43.90	43.89	0.012
550	43.81	43.80	43.80	0.016
560	43.63	43.63	43.65	0.010
570	43.49	43.49	43.48	0.009
580	43.35	43.35	43.35	0.011
590	43.27	43.26	43.26	0.013
600	43.23	43.23	43.22	0.010
610	43.25	43.25	43.25	0.011
620	43.35	43.35	43.34	0.015
630	43.39	43.42	43.40	0.017
640	43.48	43.47	43.46	0.011
650	43.47	43.48	43.49	0.017
660	43.54	43.52	43.52	0.014
670	43.55	43.53	43.55	0.016
680	43.61	43.62	43.64	0.015
690	43.80	43.78	43.77	0.008
700	43.83	43.87	43.86	0.020
710	44.06	44.05	44.02	0.025

Figure 11. Statistical study for Match-Scan (continued).

MEASURE: STD TAN PLASTIC INSERT SAMPLE THEN HIT RETURN
PAUSE ---

MEASURE: SPL TAN PLASTIC INSERT SAMPLE THEN HIT RETURN
PAUSE --

STD	ONE	X=	0.4249	Y=	0.4023	Z=	0.2605
STD	AV2	X=	0.4249	Y=	0.4023	Z=	0.2605
STD	AV10	X=	0.4248	Y=	0.4022	Z=	0.2605
STD	SIG	X=	0.00003	Y=	0.00002	Z=	0.00003
SPL	ONE	X=	0.4050	Y=	0.3801	Z=	0.2459
SPL	AV2	X=	0.4050	Y=	0.3800	Z=	0.2459
SPL	AV10	X=	0.4048	Y=	0.3799	Z=	0.2459
SPL	SIG	X=	0.00010	Y=	0.00010	Z=	0.00007
STD	ONE	L*=	69.63	A*=	6.80	B*=	19.91
STD	AV2	L*=	69.63	A*=	6.79	B*=	19.91
STD	AV10	L*=	69.63	A*=	6.79	B*=	19.91
STD	SIG	L*=	0.002	A*=	0.006	B*=	0.004
SPL	ONE	L*=	68.03	A*=	7.76	B*=	19.57
SPL	AV2	L*=	68.02	A*=	7.76	B*=	19.57
SPL	AV10	L*=	68.01	A*=	7.75	B*=	19.56
SPL	SIG	L*=	0.007	A*=	0.004	B*=	0.008
ONE	DL=	1.61	DC=	0.94	DE=	1.86	
AV2	DL=	1.61	DC=	0.95	DE=	1.87	
AV10	DL=	1.62	DC=	0.94	DE=	1.87	
SIG	DL=	0.006	DC=	0.013	DE=	0.014	
STOP	--						

Figure 11. Statistical study for Match-Scan (continued).

750"STAI

DATE: 10/14/80

BEGIN WITH SAMPLE NO. 2(1-5)

71

1. ON HUNTER PRESS "TRANS", PUT WHITE TILE OVER PORT,
BLOCK BEAM WITH BLACK CARDBOARD
2. PRESS "ZERO". REMOVE CARDBOARD
3. PRESS "STDZ". AFTER "STANDARDIZED" PRINTS OUT ON HUNTER,
4. PRESS "ASCII"; THEN "2"
5. PRESS RETURN ON SPC-16 CONSOLE

PAUSE

?

MEASURE: AMBER FILTER

INSERT SAMPLE, PRESS READ ON HUNTER, THEN 10NM

PAUSE

N/L	FIRST	AVG OF 2	AVG OF 10	SIGMA
400	3.99	3.97	3.96	0.019
410	3.50	3.51	3.51	0.010
420	3.50	3.50	3.50	0.005
430	3.90	3.90	3.89	0.010
440	4.82	4.82	4.82	0.004
450	6.39	6.39	6.39	0.004
460	8.57	8.57	8.57	0.005
470	11.48	11.48	11.48	0.006
480	15.46	15.45	15.46	0.008
490	20.46	20.46	20.45	0.010
500	26.02	26.02	26.02	0.006
510	32.18	32.16	32.16	0.014
520	38.72	38.72	38.70	0.013
530	45.02	45.02	45.03	0.013
540	51.16	51.16	51.15	0.013
550	56.92	56.92	56.90	0.014
560	61.95	61.96	61.95	0.014
570	66.33	66.33	66.33	0.015
580	70.14	70.14	70.12	0.015
590	72.79	72.79	72.78	0.015
600	75.20	75.20	75.19	0.015
610	77.19	77.19	77.19	0.014
620	78.24	78.25	78.24	0.017
630	79.00	79.01	78.99	0.029
640	79.64	79.64	79.65	0.017
650	80.13	80.14	80.12	0.019
660	80.15	80.16	80.15	0.016
670	79.94	79.94	79.95	0.011
680	79.96	79.96	79.97	0.014
690	79.96	79.96	79.93	0.016
700	79.52	79.52	79.50	0.019
710	79.04	79.06	79.06	0.023

Figure 12. Statistical study for Hunter D54.

*** REMOVE AMBER FILTER***

1. ON HUNTER, PRESS "R-SIN"; PUT ZERO TRAP OVER PORT
2. PRESS "ZERO". PUT WHITE PORCELAIN OVER PORT
3. PRESS "STDZ" PUT GRAY PORCELAIN OVER PORT.
4. PRESS "STDZ". AFTER "STANDARDIZED" PRINTS OUT ON HUNTER.
5. PRESS RETURN ON SPC-16 CONSOLE

PAUSE

MEASURE: WHITE TILE

INSERT SAMPLE, PRESS READ ON HUNTER, THEN 10X

W/L	FIRST	AVG OF 2	AVG OF 10	SIGMA
400	95.64	95.63	95.57	0.050
410	94.66	94.65	94.63	0.023
420	94.95	94.94	94.95	0.012
430	95.71	95.70	95.71	0.011
440	96.32	96.32	96.33	0.012
450	96.95	96.94	96.95	0.014
460	97.42	97.42	97.41	0.019
470	97.71	97.71	97.69	0.018
480	97.93	97.92	97.92	0.012
490	98.12	98.12	98.12	0.012
500	98.21	98.20	98.22	0.019
510	98.20	98.21	98.22	0.013
520	98.26	98.26	98.26	0.006
530	98.49	98.49	98.51	0.019
540	98.33	98.33	98.35	0.020
550	98.35	98.35	98.36	0.010
560	98.26	98.24	98.24	0.019
570	98.34	98.33	98.34	0.011
580	98.27	98.26	98.27	0.011
590	98.45	98.45	98.46	0.013
600	98.16	98.14	98.14	0.014
610	98.14	98.14	98.15	0.019
620	98.08	98.06	98.06	0.013
630	98.16	98.14	98.14	0.016
640	98.18	98.17	98.18	0.009
650	98.15	98.14	98.17	0.018
660	98.09	98.08	98.10	0.015
670	98.19	98.19	98.20	0.011
680	97.97	97.97	97.97	0.007
690	98.21	98.21	98.20	0.007
700	98.11	98.10	98.10	0.014
710	97.94	97.94	97.98	0.028

Figure 12. Statistical study for Hunter D54 (continued).

MEASURE: GRAY PORCELAIN INSERT SAMPLE, PRESS READ ON HUNTER, THEN 10.00
 RANGE

R/L	FIRST	AVG OF 2	AVG OF 10	SIGMA
400	39.25	39.25	39.25	0.042
410	41.76	41.75	41.77	0.019
420	42.20	42.19	42.21	0.018
430	42.19	42.19	42.19	0.007
440	42.31	42.31	42.32	0.007
450	42.47	42.47	42.48	0.014
460	42.70	42.70	42.72	0.013
470	42.68	42.68	42.69	0.012
480	42.76	42.76	42.76	0.005
490	42.84	42.84	42.84	0.008
500	42.87	42.86	42.85	0.011
510	42.87	42.87	42.87	0.011
520	43.01	43.01	43.01	0.008
530	43.04	43.03	43.03	0.011
540	42.92	42.92	42.93	0.017
550	42.85	42.85	42.86	0.019
560	42.68	42.68	42.68	0.006
570	42.42	42.42	42.43	0.014
580	42.28	42.28	42.29	0.010
590	42.28	42.28	42.29	0.010
600	42.14	42.14	42.14	0.006
610	42.14	42.14	42.13	0.013
620	42.10	42.10	42.11	0.011
630	42.25	42.25	42.26	0.013
640	42.23	42.23	42.23	0.013
650	42.33	42.33	42.34	0.009
660	42.39	42.39	42.40	0.011
670	42.37	42.37	42.37	0.007
680	42.53	42.53	42.55	0.009
690	42.65	42.65	42.66	0.012
700	42.80	42.80	42.79	0.010
710	42.86	42.86	42.87	0.015

Figure 12. Statistical study on Hunter D54 (continued).

MEASURE: STD TAN PLASTIC INSERT SAMPLE, PRESS READ ON HUNTER, THEN 10NM
PAUSE

MEASURE: SPL TAN PLASTIC INSERT SAMPLE, PRESS READ ON HUNTER, THEN 10NM
PAUSE

```

STD  ONE  X= 0.4127 Y= 0.3911 Z= 0.2500
STD  AV2  X= 0.4127 Y= 0.3911 Z= 0.2500
STD  AV10 X= 0.4127 Y= 0.3911 Z= 0.2500
STD  SIG  X=0.00003 Y=0.00002 Z=0.00000
SPL  ONE  X= 0.3927 Y= 0.3689 Z= 0.2358
SPL  AV2  X= 0.3928 Y= 0.3690 Z= 0.2358
SPL  AV10 X= 0.3929 Y= 0.3691 Z= 0.2358
SPL  SIG  X=0.00002 Y=0.00008 Z=0.00005
STD  ONE  L*= 68.83 a*= 6.60 b*= 20.27
STD  AV2  L*= 68.83 a*= 6.61 b*= 20.27
STD  AV10 L*= 68.83 a*= 6.60 b*= 20.28
STD  SIG  L*= 0.001 a*= 0.007 b*= 0.005
SPL  ONE  L*= 67.20 a*= 7.54 b*= 19.89
SPL  AV2  L*= 67.20 a*= 7.54 b*= 19.89
SPL  AV10 L*= 67.21 a*= 7.54 b*= 19.90
SPL  SIG  L*= 0.006 a*= 0.021 b*= 0.005
ONE  DL= 1.63 DC= 0.00 DE= 1.86
AV2  DL= 1.63 DC= 0.00 DE= 1.85
AV10 DL= 1.62 DC= 0.90 DE= 1.85
SIG  DL= 0.006 DC= 0.02 DE= 0.023
STOP

```

Figure 12. Statistical study of Hunter D54 (continued).

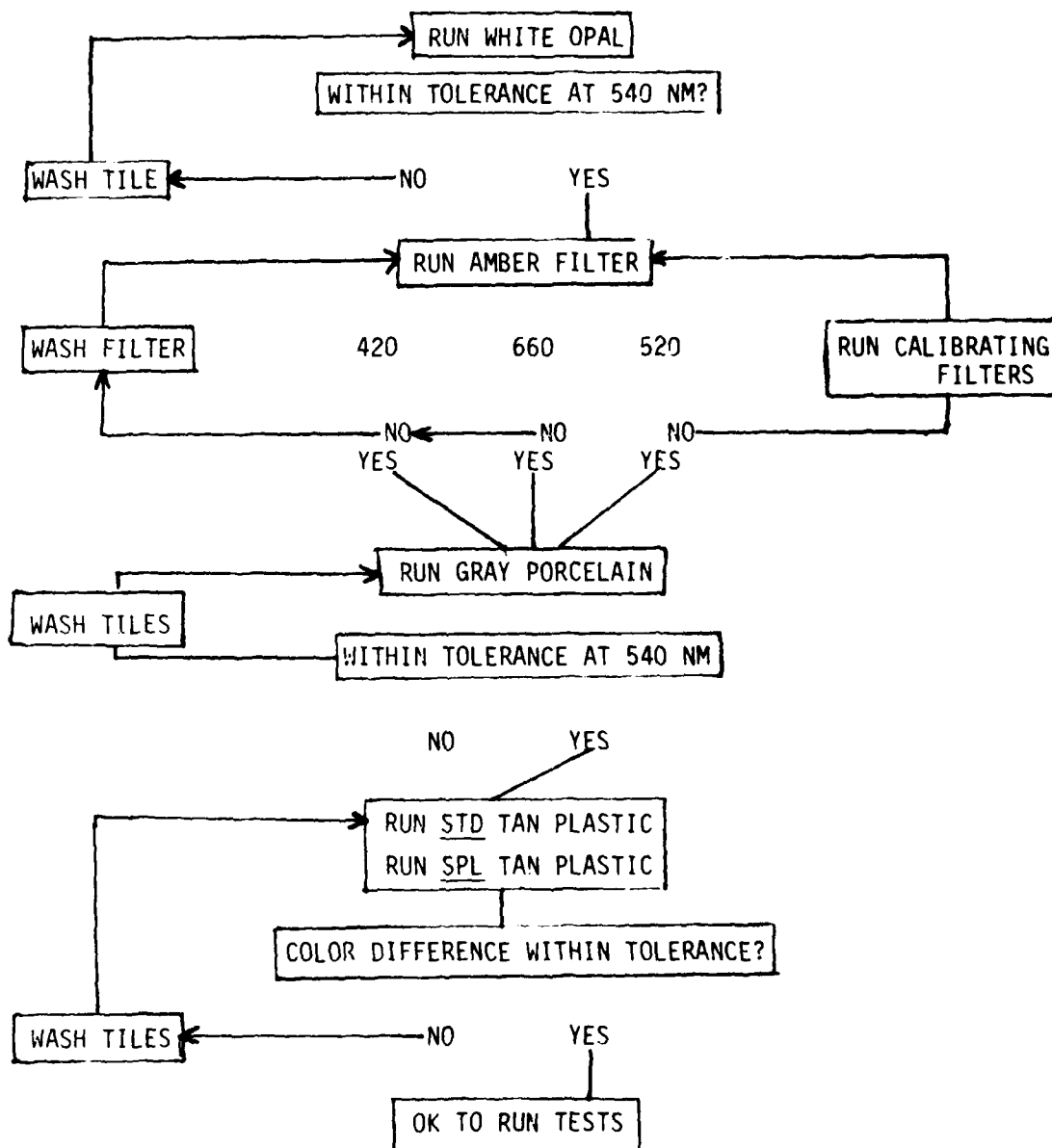


Figure 13. Schematic of standardization of Match-Scan.

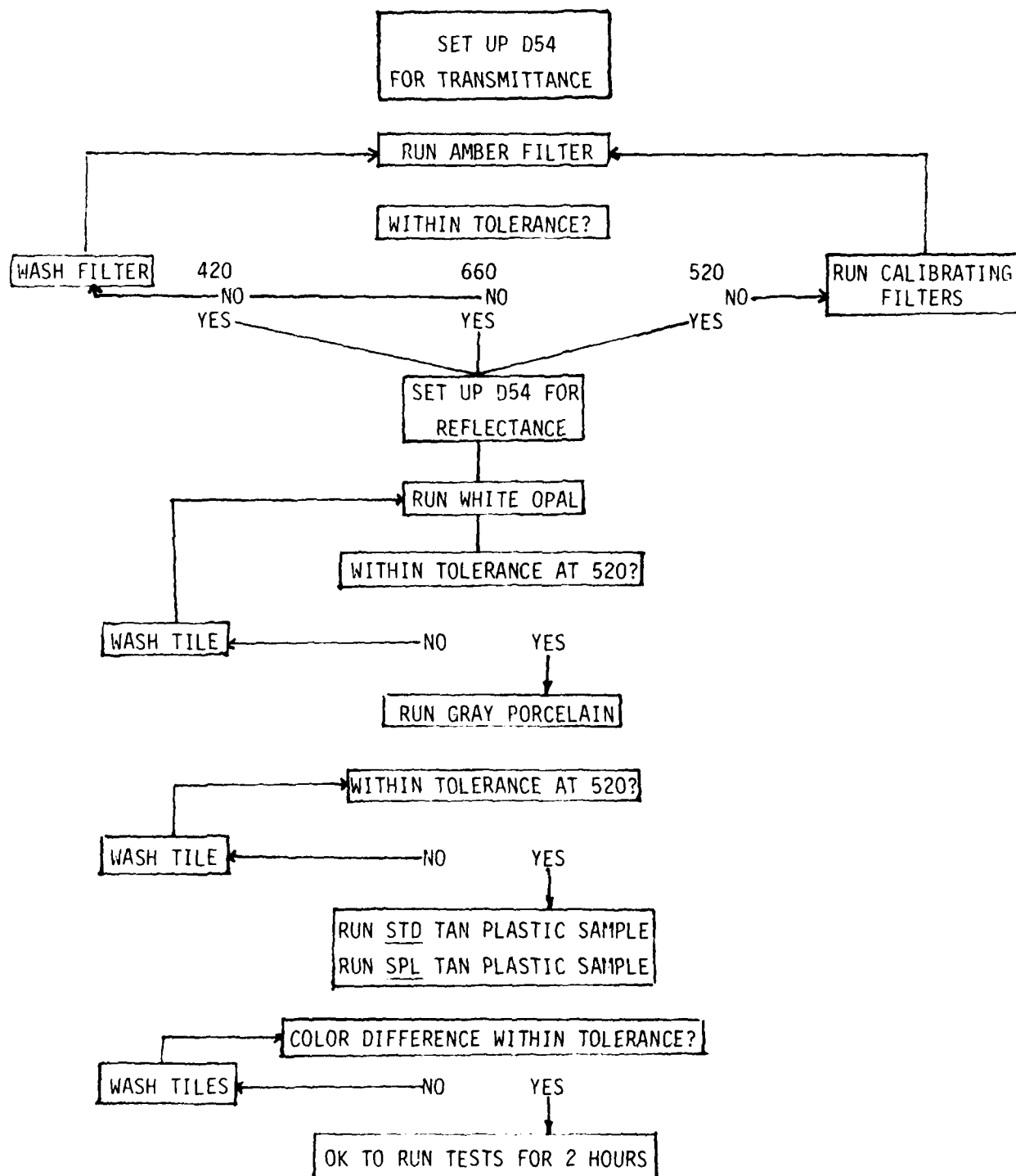


Figure 14. Schematic of standardization of Hunter D54.

DATE: 1/25/81

BEGIN WITH SAMPLE NO.?(1-5) 1

MEASURE: WHITE TILES INSERT SAMPLE THEN HIT RETURN AFTER PAUSE
AT 540 NM UPPER LIMIT 99.62 LOWER LIMIT 99.48
PAUSE --

W/L	FIRST	AVG OF 2
540	99.54	99.53

MEASURE: AMBER FILTER INSERT SAMPLE THEN HIT RETURN AFTER PAUSE
AT 420 NM UPPER LIMIT 3.53 LOWER LIMIT 3.47
AT 520 NM UPPER LIMIT 39.27 LOWER LIMIT 38.93
AT 660 NM UPPER LIMIT 80.09 LOWER LIMIT 79.85
PAUSE --

W/L	FIRST	AVG OF 2
420	3.49	3.49
520	39.15	39.16
660	80.00	79.96

MEASURE: GRAY PORCELAIN INSERT SAMPLE THEN HIT RETURN AFTER PAUSE
AT 540 NM UPPER LIMIT 44.00 LOWER LIMIT 43.80
PAUSE --

W/L	FIRST	AVG OF 2
540	43.92	43.94

MEASURE: STD TAN PLASTIC INSERT SAMPLE THEN HIT RETURN AFTER PAUSE
COLOR DIFF. UPPER LIMIT 1.94 LOWER LIMIT 1.84
PAUSE --

MEASURE: SPL TAN PLASTIC INSERT SAMPLE THEN HIT RETURN AFTER PAUSE
PAUSE --

AVG OF 2 DL= 1.60 DC= 0.97 DE= 1.87
STOP --

Figure 15. Standardization test for Match-Scan, typical output from QMSTAN computer program.

?SOSTANH

DATE: 1/27/81

DECI" WITH SAMPLE NO. 2 (1-5)

?!

1. ON D54 PRESS "ASCII OUT", THEN "0", THEN "TRANS"
PUT WHITE PORCELAIN OVER PORT,
BLOCK BEAM WITH BLACK CARDBOARD
2. PRESS "ZERO". REMOVE CARDBOARD
3. PRESS "STOZ". AFTER "STANDARDIZED" PRINTS OUT ON D54
4. PRESS "ASCII", THEN "2",
5. PRESS "RETURN" ON SPC-16 CONSOLE PRINTER

PAUSE

?

MEASURE: AMBER FILTER INSERT SAMPLE IN D54;
AFTER A PAUSE IS PRINTED, PRESS "READ" ON D54
AFTER BELL RINGS, PRESS "10NM" AND "RETURN" AT SAME TIME
AT 420 NM UPPER LIMIT 3.51 LOWER LIMIT 3.45
AT 520 NM UPPER LIMIT 38.86 LOWER LIMIT 38.50
AT 660 NM UPPER LIMIT 80.32 LOWER LIMIT 80.08

PAUSE

?

PAUSE

?

W/L	FIRST	AVG OF 2
420	3.49	3.49
520	38.76	38.74
660	80.20	80.20

*** REMOVE AMBER FILTER***

1. ON D54, PRESS "ASCII", THEN "0", THEN "R-SIN" PUT ZERO TRIP
2. PRESS "ZERO". PUT WHITE PORCELAIN OVER PORT
3. PRESS "STOZ". PUT GRAY PORCELAIN OVER PORT
4. PRESS "STOZ". AFTER "STANDARDIZED" PRINTS OUT ON D54,
5. PRESS "ASCII", THEN "2"
6. PRESS "RETURN" ON SPC-16 CONSOLE PRINTER

PAUSE

?

MEASURE: WHITE TILE INSERT SAMPLE IN D54;
AFTER A PAUSE IS PRINTED, PRESS "READ" ON D54
AFTER BELL RINGS, PRESS "10NM" AND "RETURN" AT SAME TIME
AT 540 NM UPPER LIMIT 98.46 LOWER LIMIT 98.26

PAUSE

?

PAUSE

?

W/L	FIRST	AVG OF 2
540	98.40	98.40

Figure 16. Standardization test for Hunter D54, typical output from QSTANH computer program.

MEASURE: GRAY PORCELAIN : INSERT SAMPLE IN D54;
 AFTER A PAUSE IS PRINTED, PRESS "READ" ON D54
 AFTER BELL RINGS, PRESS "10NM" AND "RETURN" AT SAME TIME
 AT 540 NM UPPER LIMIT 43.06 LOWER LIMIT 42.86
 PAUSE
 ?
 PAUSE
 ?

W/L	FIRST	AVG OF 2
540	42.92	42.92

 MEASURE: STD TAN PLASTIC INSERT SAMPLE IN D54;
 AFTER A PAUSE IS PRINTED, PRESS "READ" ON D54
 AFTER BELL RINGS, PRESS "10NM" AND "RETURN" AT SAME TIME
 COLOR DIFFERENCE: UPPER LIMIT 1.93 LOWER LIMIT 1.83
 PAUSE
 ?
 PAUSE
 ?
 MEASURE: SPL TAN PLASTIC INSERT SAMPLE IN D54;
 AFTER A PAUSE IS PRINTED, PRESS "READ" ON D54
 AFTER BELL RINGS, PRESS "10NM" AND "RETURN" AT SAME TIME
 PAUSE
 ?
 PAUSE
 ?

ONE	DL= 1.63	DC= 0.88	DE= 1.85.
AV2	DL= 1.62	DC= 0.87	DE= 1.84

 OK TO MAKE MEASUREMENTS
 STOP

Figure 16. Standardization test for Hunter D54 (continued).

?SOSTANH

DATE: 1/27/81

BEGIN WITH SAMPLE NO. 2 (1-5)

21

1. ON D54 PRESS "ASCII OUT", THEN "0", THEN "TRANS"
PUT WHITE PORCELAIN OVER PORT.
BLOCK BEAM WITH BLACK CARDBOARD
2. PRESS "ZERO". REMOVE CARDBOARD
3. PRESS "STDZ". AFTER "STANDARDIZED" PRINTS OUT ON D54
4. PRESS "ASCII", THEN "2".
5. PRESS "RETURN" ON SPC-16 CONSOLE PRINTER

PAUSE

?

MEASURE: AMBER FILTER INSERT SAMPLE IN D54;
AFTER A PAUSE IS PRINTED, PRESS "READ" ON D54
AFTER BELL RINGS, PRESS "10NM" AND "RETURN" AT SAME TIME
AT 420 NM UPPER LIMIT 3.51 LOWER LIMIT 3.45
AT 520 NM UPPER LIMIT 38.86 LOWER LIMIT 38.50
AT 660 NM UPPER LIMIT 80.32 LOWER LIMIT 80.08

PAUSE

?

PAUSE

?

W/L	FIRST	AVG OF 2
420	3.76	3.77

***READING AT 420NM IS OUT OF SPECS FOR:AMBER FILTER
WASH SAMPLE, THEN

MEASURE: AMBER FILTER INSERT SAMPLE IN D54;
AFTER A PAUSE IS PRINTED, PRESS "READ" ON D54
AFTER BELL RINGS, PRESS "10NM" AND "RETURN" AT SAME TIME
AT 420 NM UPPER LIMIT 3.51 LOWER LIMIT 3.45
AT 520 NM UPPER LIMIT 38.86 LOWER LIMIT 38.50
AT 660 NM UPPER LIMIT 80.32 LOWER LIMIT 80.08

PAUSE

?

PAUSE

?

W/L	FIRST	AVG OF 2
420	3.48	3.48
520	38.74	38.74
660	80.14	80.15

*** REMOVE AMBER FILTER***

1. ON D54, PRESS "ASCII", THEN "0", THEN "R-SIN" PUT ZERO TRAP
2. PRESS "ZERO". PUT WHITE PORCELAIN OVER PORT
3. PRESS "STDZ". PUT GRAY PORCELAIN OVER PORT
4. PRESS "STDZ". AFTER "STANDARDIZED" PRINTS OUT ON D54,
5. PRESS "ASCII", THEN "2"
6. PRESS "RETURN" ON SPC-16 CONSOLE PRINTER

PAUSE

Figure 16. Standardization tests for Hunter D54 (continued).

APPENDICES

	Page
Appendix A. Computer Program QMSTAT for Match-Scan Statistical Study.	41
Appendix B. Computer Program QMSTAT for Hunter D54 Statistical Study.	45
Appendix C. Computer Program QMSTAN for Standardization Program of Match-Scan.	49
Appendix D. Computer Program QSTANH for Standardization Program of Hunter D54.	53

Appendix A

Computer Program QMSTST for Match-Scan Statistical Study.

```

C      PROGRAM QMSTST
C      --- TO CALCULATE STATISTICAL DATA FOR A STANDARDIZATION
C      PROCEDURE APPLICABLE TO THE MATCH-SCAN
C
C      LINK INSTRUCTIONS:
C      ASS DX1 DK
C      R LINK
C      *QMSTAT=QMSTAT,DX0:MSLIB,FISNOV.NEW
C
C      DIMENSION AVGN0(4),CMF(3,32),D65(32),FAC(32,3),FACT(32),PLAST(
C      DIMENSION R(32,10),RC(32,13,2),RG(32),STAR(3,13,2),SPL(4,5)
C      DIMENSION TRI(3,13,2),TRI0(3),VAL(3),USQ(3),AVG(3),CD(3,13)
C      DATA CMF/0.0191,0.0020,0.0860
C      X, 0.0847,0.0088,0.3894
C      X, 0.2045,0.0214,0.9725
C      X, 0.3147,0.0387,1.5535
C      X, 0.3837,0.0621,1.9673
C      X, 0.3707,0.0895,1.9948
C      X, 0.3023,0.1282,1.7454
C      X, 0.1956,0.1852,1.3176
C      X, 0.0805,0.2536,0.7721
C      X, 0.0162,0.3391,0.4153
C      X, 0.0038,0.4608,0.2185
C      X, 0.0375,0.6067,0.1120
C      X, 0.1177,0.7618,0.0607
C      X, 0.2365,0.8752,0.0305
C      X, 0.3768,0.9620,0.0137
C      X, 0.5298,0.9918,0.0040
C      X, 0.7052,0.9973,0.0000
C      X, 0.8787,0.9556,0.0000
C      X, 1.0142,0.8689,0.0000
C      X, 1.1185,0.7774,0.0000
C      X, 1.1240,0.6583,0.0000
C      X, 1.0305,0.5280,0.0000
C      X, 0.8563,0.3981,0.0000
C      X, 0.6475,0.2835,0.0000
C      X, 0.4316,0.1798,0.0000
C      X, 0.2683,0.1076,0.0000
C      X, 0.1526,0.0603,0.0000
C      X, 0.0813,0.0318,0.0000
C      X, 0.0409,0.0159,0.0000
C      X, 0.0199,0.0077,0.0000
C      X, 0.0096,0.0037,0.0000
C      X, 0.0046,0.0018,0.0000/
C      DATA D65/828.,916.,935.,868.,1049.,1171.,1178.,1149.,1159.,1099
C      X, 1094.,1078.,1049.,1077.,1044.,1040.,1000.,964.,957.,886.
C      X, 900.,896.,876.,833.,837.,800.,802.,822.,783.,697.,716.,743./
C
C      DATA SPL/'WHIT','E TI','LES ',' ','AMBE','R FI','LTER','
C      X 'GRAY','FOR','CELA','IN ','STD ','TAN ','PLAS','TIC ','SPL '
C      X 'TAN ','PLAS','TIC '
C      DATA AVGN0,PLAST/'ONE ','AV2 ','AV10','SIG','STD ','SPL '
100  FORMAT(' DATE: 'I2,2(' ','I2))
150  FORMAT('$ BEGIN WITH SAMPLE NO.?(2-5)',6E)

```

Appendix A (continued)

```

200  FORMAT('MEASURE: '4A4,' INSERT SAMPLE THEN HIT RETURN'/)
300  FORMAT(I5,3F10.2,F10.3)
400  FORMAT(1H0,2(2X,A4),' X=',F7.4,' Y=',F7.4,' Z=',F7.4)
450  FORMAT(1H0,2(2X,A4),' X=',F7.5,' Y=',F7.5,' Z=',F7.5)
500  FORMAT(' W/L',5X,'FIRST',4X,'AVG OF 2',2X,'AVG OF 10',4X,'SIGMA')
600  FORMAT(1H0,2(2X,A4),' L*=',F7.2,' A*=',F7.2,' B*=',F7.2)
650  FORMAT(1H0,2(2X,A4),' L*=',F7.3,' A*=',F7.3,' B*=',F7.3)
700  FORMAT(1H0,A4,' DL=',F7.2,' DC=',F7.2,' DE=',F7.2)
750  FORMAT(1H0,A4,' DL=',F7.3,' DC=',F7.3,' DE=',F7.3)

      CALL IDATE(IM,ID,IY)
      WRITE(5,100) IM,ID,IY
      WRITE(5,150)
      READ(5,300) NSAM
      DO 2000 II=1,5
      IF(II.EQ.1) GOTO 960
      IF(II.LT.NSAM) GOTO 2000
960   I=II
      WRITE(5,200) (SPL(M,I),M=1,4)
      PAUSE
      DO 1000 N=1,10
      DO 980 L=1,32
980   FACT(L)=1.
      CALL GMSR(4000,7100,100,1,0,5,0,1,FACT,RG,(ER)
      DO 990 L=1,32
990   R(L,N)=RG(L)
      CALL IDLE(1000)
1000  CONTINUE
      IF(I.LT.4) WRITE(5,500)
      IF(I.GT.1) GOTO 1100
      DO 1040 L=1,32
      FAC(L,2)=0.
      FAC(L,3)=0.
      DELSQ=0.
      DO 1020 N=1,10
      IF(N.EQ.1) FAC(L,1)=R(L,N)
      IF(N.LE.2) FAC(L,2)=R(L,N)*0.5 + FAC(L,2)
      FAC(L,3)=R(L,N)*0.1 + FAC(L,3)
1020  CONTINUE
      DO 1030 N=1,10
1030  DELSQ=(R(L,N)-FAC(L,3))*(R(L,N)-FAC(L,3)) - DELSQ
      SIGMA=SQRT(DELSQ*0.1111)
      WRITE(5,300) 390+L*10,(FAC(L,M),M=1,3),SIGMA
      DO 1035 M=1,3
1035  FAC(L,M)=FAC(L,M)*0.01
1040  CONTINUE
      GOTO 2000
1100  DO 1140 L=1,32
      VAL(2)=0.
      VAL(3)=0.
      DELSQ=0.
      DO 1120 N=1,10
      IF(N.EQ.1) VAL(1)=R(L,N)/FAC(L,1)
      IF(N.EQ.1.AND.I.GE.4) RC(L,1,I-3)=VAL(1)
      IF(N.LE.2) VAL(2)=R(L,N)*0.5/FAC(L,2)+VAL(2)

```

Appendix A (continued)

```

IF(N.EQ.2.AND.1.GE.4) RC(L,2,1-3)=VAL(2)
R(L,N)=R(L,N)/FAC(L,3)
VAL(3)=R(L,N)*0.1 + VAL(3)
IF(1.GE.4) RC(L,3,1-3)=VAL(3)
IF(1.GE.4) RC(L,3+N,1-3)=R(L,N)
1120 CONTINUE
IF(1.GE.4) GOTO 1140
DO 1130 N=1,10
1130 DELSQ=(R(L,N)-VAL(3))*(R(L,N)-VAL(3)) + DELSQ
SIGMA=SQRT(DELSQ*0.1111)
WRITE(5,300) 390+L*10,(VAL(M),M=1,3),SIGMA
1140 CONTINUE
2000 CONTINUE
C I IS THE TRISTIMULUS COUNTER
C J IS THE AVERAGES COUNTER
C K IS THE SAMPLE NUMBER OF THE PLASTIC CHIPS COUNTER
C L IS THE WAVELENGTH COUNTER
DO 2900 I=1,3
TRIO(I)=0.
DO 2900 L=1,32
2900 TRIO(I)=TRIO(I)+100.*CMF(I,L)*D65(L)
TH=1./3.
DO 3070 K=1,2
J1=1
J3=3
DO 2970 I=1,3
2970 AVG(I)=0.
2980 DO 3050 J=J1,J3
DO 3020 I=1,3
TRI(I,J,K)=0.
DO 3000 L=1,32
TRI(I,J,K)=TRI(I,J,K) + RC(L,J,K)*CMF(I,L)*D65(L)
3000 CONTINUE
3020 TRI(I,J,K)=TRI(I,J,K)/TRIO(I)
IF(J1.GT.3) GOTO 3030
WRITE(5,400) PLAST(K),AVGND(J),(TRI(M,J,K),M=1,3)
GOTO 3050
3030 DO 3040 I=1,3
AVG(I)=AVG(I) + TRI(I,J,K)*0.1
3040 CONTINUE
3050 CONTINUE
IF(J1.EQ.4) GOTO 3060
J1=4
J3=13
GOTO 2980
3060 DO 3068 I=1,3
DSQ(I)=0.
DO 3065 J=4,13
3065 DSQ(I)=(TRI(I,J,K)-AVG(I))*(TRI(I,J,K)-AVG(I)) + DSQ(I)
DSQ(I)=SQRT(DSQ(I)*0.1111)
3068 CONTINUE
WRITE(5,450) PLAST(K),AVGND(4),(DSQ(I),I=1,3)
3070 CONTINUE
DO 3080 I=1,3
DO 3080 J=1,13
DO 3080 K=1,2

```

Appendix A (continued)

```

3080   TRI(I,J,K)=TRI(I,J,K)**TH
      DO 3170 K=1,2
      J1=1
      J3=3
      DO 3100 I=1,3
3100   AVG(I)=0.
3110   DO 3150 J=J1,J3
      STAR(1,J,K)=116.0*TRI(2,J,K)-16.0
      STAR(2,J,K)=500.*(TRI(1,J,K)-TRI(2,J,K))
      STAR(3,J,K)=200.*(TRI(2,J,K)-TRI(3,J,K))
      IF(J1.GT.3) GOTO 3130
      WRITE(5,600) PLAST(K),AVGNO(J),(STAR(M,J,K),M=1,3)
      GOTO 3150
3130   DO 3140 I=1,3
3140   AVG(I)=AVG(I)+STAR(I,J,K)*0.1
3150   CONTINUE
      IF(J1.EQ.4) GOTO 3160
      J1=4
      J3=13
      GOTO 3110
3160   DO 3168 I=1,3
      DSQ(I)=0.
      DO 3165 J=4,13
3165   DSQ(I)=(STAR(1,J,K)-AVG(I))*(STAR(I,J,K)-AVG(I)) +DSQ(I)
      DSQ(I)=SQRT(DSQ(I)*0.1111)
3168   CONTINUE
      WRITE(5,650) PLAST(K),AVGNO(4),(DSQ(I),I=1,3)
3170   CONTINUE
      J1=1
      J3=3
      DO 3175 I=1,3
3175   AVG(I)=0.
3180   DO 3250 J=J1,J3
      DO 3200 I=1,3
3200   STAR(I,J,1)=(STAR(I,J,2)-STAR(I,J,1))*(STAR(I,J,2)-STAR(I,J,1))
      CD(1,J)=SQRT(STAR(1,J,1))
      CD(2,J)=SQRT(STAR(2,J,1)*STAR(2,J,1) + STAR(3,J,1)*STAR(3,J,1))
      CD(3,J)=SQRT(CD(1,J)*CD(1,J) + CD(2,J)*CD(2,J))
      IF(J1.GT.3) GOTO 3230
      WRITE(5,700) AVGNO(J),(CD(M,J),M=1,3)
      GOTO 3250
3230   DO 3240 I=1,3
3240   AVG(I)=AVG(I) + CD(I,J)*0.1
3250   CONTINUE
      IF(J1.NE.1) GOTO 3260
      J1=4
      J3=13
      GOTO 3180
3260   DO 3268 I=1,3
      DSQ(I)=0.
      DO 3265 J=4,13
3265   DSQ(I)=(CD(I,J)-AVG(I))*(CD(I,J)-AVG(I)) + DSQ(I)
      DSQ(I)=SQRT(DSQ(I)*0.1111)
3268   CONTINUE
      WRITE(5,750) AVGNO(4),(DSQ(M),M=1,3)
4000   STOP
      END

```

Appendix B.

Computer program QMSTAT for Hunter D54 statistical study.

?\$COPY,DS(QMSTAT),TY

```

C      PROGRAM QMSTAT
C      ---TO CALCULATE STATISTICAL DATA FOR A STANDARDIZED PROCEDURE
C      APPLICABLE TO THE HUNTER D54P SPECTROPHOTOMETER
      DIMENSION AVGN(4),CMF(3,32),D65(32),FAC(32,3),PLAST(2)
      DIMENSION R(32,10),RC(32,13,2),RG(32),STAR(3,13,2),SPL(4,5)
      DIMENSION TRI(3,13,2),TRIO(3),VAL(3),DSQ(3),AVG(3),CD(3,13)
      DIMENSION NUL(32)
      DATA CMF/0.0191,0.0020,0.0860,0.0847,0.0088,0.3894
      -,0.2045,0.0214,0.9725,0.3147,0.0387,1.5535
      -,0.3837,0.0621,1.9673,0.3707,0.0895,1.9948
      -,0.3023,0.1282,1.7454,0.1956,0.1852,1.3176
      -,0.0805,0.2536,0.7721,0.0162,0.3391,0.4153
      -,0.0038,0.4608,0.2185,0.0375,0.6067,0.1120
      -,0.1177,0.7618,0.0607,0.2365,0.8752,0.0305
      -,0.3768,0.9620,0.0137,0.5298,0.9918,0.0040
      -,0.7052,0.9973,0.0000,0.8787,0.9556,0.0000
      -,1.0142,0.8689,0.0000,1.1185,0.7774,0.0000
      -,1.1240,0.6583,0.0000,1.0305,0.5280,0.0000
      -,0.8563,0.3981,0.0000,0.6475,0.2835,0.0000
      -,0.4316,0.1798,0.0000,0.2683,0.1076,0.0000
      -,0.1526,0.0603,0.0000,0.0813,0.0318,0.0000
      -,0.0409,0.0159,0.0000,0.0199,0.0077,0.0000
      -,0.0096,0.0037,0.0000,0.0046,0.0018,0.0000/
      DATA D65/823.,916.,935.,868.,1049.,1171.,1178.,1149.,1159.,1088.,
      -1094.,1078.,1049.,1077.,1044.,1040.,1000.,964.,957.,886.,
      -900.,896.,876.,833.,837.,800.,802.,822.,783.,697.,716.,743./
      DATA SPL/'WHIT','E TI','LES ','','AMBE','R FI','LTER','
      -'GRAY','POR','CELA','IN ','STD ','TAN ','PLAS','TIC','SPL ',
      -'TAN ','PLAS','TIC '//
      DATA AVGN,PLAST/'ONE ','AV2 ','AV10','SIG','STD ','SPL '//
100    FORMAT(' DATE: ',I2,2(' ',I2))
150    FORMAT(' BEGIN WITH SAMPLE NO.?(1-5)',6X)
200    FORMAT('/ MEASURE: '4A4,' INSERT SAMPLE,PRESS READ ON HUNTER,THEN
      - 10MM')
300    FORMAT(I5,3F10.2,F10.3)
350    FORMAT(I3,F11.2)
400    FORMAT(/2(2XA4),/ X=',F7.4,' Y=',F7.4,' Z=',F7.4)
450    FORMAT(/2(2XA4),/ X=',F7.5,' Y=',F7.5,' Z=',F7.5)
500    FORMAT(' W/L',5X,' FIRST',4X,' AVG OF 2',2X,' AVG OF 10',4X,' SIGMA')
600    FORMAT(/2(2XA4),/ L*=',F7.2,' a*=',F7.2,' b*=',F7.2)
650    FORMAT(/2(2XA4),/ L*=',F7.3,' a*=',F7.3,' b*=',F7.3)
700    FORMAT(/A4,' DL=',F7.2,' DC=',F7.2,' DE=',F7.2)
750    FORMAT(/A4,' DL=',F7.3,' DC=',F7.3,' DE=',F7.3)
      CALL DATESB(IY,IM,ID)
      WRITE(5,100) IM,ID,IY
      WRITE(5,150)
      READ(5,350) NSAM
      IF(NSAM.GT.1) GOTO 950
      WRITE(5,150)
950    DO 2000 II=1.5

```

Appendix B (continued)

```

IF(I1.LT.NSAH) GOTO 2000
960 I=11
WRITE(5,200) (SPL(M,1),M=1,4)
DO 1000 N=1,10
PAUSE
DO 980 L=1,32
READ(14,350) NWL(L),RG(L)
980 CONTINUE
DO 935 L=1,32
R(L,N)=RG(L)
935 CONTINUE
1000 CONTINUE
IF (I.LT.4) WRITE(5,500)
IF(I.GT.1) GOTO 1100
DO 1040 L=1,32
FAC(L,2)=0
FAC(L,3)=0
DELSQ=0.
DO 1020 N=1,10
IF(N.EQ.1) FAC(L,1)=R(L,N)
IF(N.LE.2) FAC(L,2)=R(L,N)*0.5+ FAC(L,2)
FAC(L,3)=R(L,N)*0.1 + FAC(L,3)
1020 CONTINUE
DO 1030 N=1,10
DELSQ=(R(L,N)-FAC(L,3))*(R(L,N)-FAC(L,3)) +DELSQ
SIGMA=SQRT(DELSQ*0.1111)
NM=300+L*10
WRITE(5,300) NM,(FAC(L,M),M=1,3),SIGMA
DO 1035 M=1,3
1035 FAC(L,M)=FAC(L,M)*0.01
1040 CONTINUE
GOTO 2000
1100 DO 1140 L=1,32
VAL(2)=0.
VAL(3)=0.
DELSQ=0.
DO 1120 N=1,10
IF(N.EQ.1) VAL(1)=R(L,N)/FAC(L,1)
IF(N.EQ.1.AND.1.GE.4) RC(L,1,I-3)=VAL(1)
IF(N.LE.2) VAL(2)=R(L,N)*0.5/FAC(L,2)+VAL(2)
IF(N.EQ.2.AND.1.GE.4) RC(L,2,I-3)=VAL(2)
R(L,N)=R(L,N)/FAC(L,3)
VAL(3)=R(L,N)*0.1+VAL(3)
IF(1.GE.4) RC(L,3,I-3)=VAL(3)
IF(1.GE.4) RC(L,3+N,I-3)=R(L,N)
1120 CONTINUE
IF(1.GE.4) GOTO 1140
DO 1130 N=1,10
DELSQ=(R(L,N)-VAL(3))*(R(L,N)-VAL(3))+DELSQ
SIGMA=SQRT(DELSQ*0.1111)
NM=300+L*10

```

Appendix B (continued)

```

1140 WRITE(5,300)NM,(VAL(M),M=1,3),SIGMA
      CONTINUE
2000 CONTINUE
C      I IS THE TRISTIMULUS COUNTER
C      J IS THE AVERAGES COUNTER
C      K IS THE SAMPLE NUMBER OF THE PLASTIC CHIPS COUNTER
C      L IS THE WAVELENGTH COUNTER
      DO 2900 I=1,3
        TRIO(I)=0.
        DO 2900 L=1,32
          2900 TRIO(I)=TRIO(I)+100.*CMF(I,L)*D65(L)
              TH=1./3.
              DO 3070 K=1,2
                J1=1
                J3=3
                DO 2970 I=1,3
                  2970 AVG(I)=0.
                  2980 DO 3050 J=J1,J3
                    DO 3020 I=1,3
                      TRI(I,J,K)=0.
                      DO 3000 L=1,32
                        TRI(I,J,K)=TRI(I,J,K)+RC(L,J,K)*CMF(I,L)*D65(L)
                        3000 CONTINUE
                        3020 TRI(I,J,K)=TRI(I,J,K)/TRIO(I)
                        IF(J1.GT.3) GOTO 3030
                        WRITE(5,400) PLAST(K),AVGNO(J),(TRI(M,J,K),M=1,3)
                        GOTO 3050
                  3030 DO 3040 I=1,3
                      AVG(I)=AVG(I)+TRI(I,J,K)*0.1
                  3040 CONTINUE
                  3050 CONTINUE
                  IF(J1.EQ.4) GOTO 3060
                  J1=4
                  J3=13
                  GOTO 2930
                3060 DO 3063 I=1,3
                      DSR(I)=0.
                      DO 3065 J=4,13
                        3065 DSR(I)=(TRI(I,J,K)-AVG(I))*(TRI(I,J,K)-AVG(I))+DSQ(I)
                        DSR(I)=SQRT(DSQ(I)*0.1111)
                  3068 CONTINUE
                  WRITE(5,450) PLAST(K),AVGNO(4),(DSQ(I),I=1,3)
                  3070 CONTINUE
                  DO 3000 I=1,3
                    DO 3000 J=1,13
                      DO 3070 K=1,2
                        3030 TRI(I,J,K)=TRI(I,J,K)**TH
                        DO 3170 K=1,2
                          J1=1
                          J3=3
                          DO 3100 I=1,3

```

Appendix B (continued)

```

3100  AVG(I)=0.
3110  DO 3150 J=J1,J3
      STAR(I,J,K)=116.0*TRI(2,J,K)-16.0
      TRI(2,J,K)=500.*(TRI(1,J,K)-TRI(2,J,K))
      TRI(3,J,K)=200.*(TRI(2,J,K)-TRI(3,J,K))
      IF(J.EQ.3) GOTO 3130
      WRITE(5,600) PLAST(K),AVGNO(J),(STAR(M,J,K),M=1,3)
      GOTO 3150
3130  DO 3140 I=1,3
3140  AVG(I)=AVG(I)+STAR(I,J,K)*0.1
3150  CONTINUE
      IF(J1.EQ.4) GOTO 3160
      J1=4
      J3=13
      GOTO 3110
3160  DO 3165 I=1,3
      DSQ(I)=0.
      DO 3165 J=4,13
3165  DSQ(I)=(STAR(I,J,K)-AVG(I))*(STAR(I,J,K)-AVG(I))+DSQ(I)
      DSQ(I)=SQRT(DSQ(I)*0.1111)
3168  CONTINUE
      WRITE(5,650) PLAST(K),AVGNO(4),(DSQ(I),I=1,3)
3170  CONTINUE
      J1=1
      J3=3
      DO 3175 I=1,3
3175  AVG(I)=0.
3180  DO 3250 J=J1,J3
      DO 3200 I=1,3
3200  STAR(I,J,1)=(STAR(I,J,2)-STAR(I,J,1))*(STAR(I,J,2)-STAR(I,J,1))
      CD(1,J)=SQRT(STAR(1,J,1))
      CD(2,J)=SQRT(STAR(2,J,1)*STAR(2,J,1)+STAR(3,J,1)*STAR(3,J,1))
      CD(3,J)=(CD(1,J)*CD(1,J)+CD(2,J)*CD(2,J))
      IF(J1.EQ.3) GOTO 3230
      WRITE(5,700)AVGNO(J),(CD(M,J),M=1,3)
      GOTO 3250
3230  DO 3240 I=1,3
3240  AVG(I)=AVG(I)+CD(I,J)*0.1
3250  CONTINUE
      IF(J1.EQ.1) GOTO 3260
      J1=4
      J3=13
      GOTO 3180
3260  DO 3265 I=1,3
      DSQ(I)=0.
      DO 3265 J=4,13
3265  DSQ(I)=(CD(I,J)-AVG(I))*(CD(I,J)-AVG(I))+DSQ(I)
      DSQ(I)=SQRT(DSQ(I)*0.1111)
3268  CONTINUE
      WRITE(5,750) AVGNO(4),(DSQ(M),M=1,3)
4000  STOP
      END

```

Appendix C

Computer Program QMSTAN for Standardization Program of Match-Scan.

```

C      PROGRAM QMSTAN
C      ---TO PROVIDE A STANDARDIZATION
C      PROCEDURE APPLICABLE TO THE MATCH-SCAN
C
C      LINK INSTRUCTIONS:
C      ASS DX1 DK
C      R LINK
C      *QMSTAN=QMSTAN,DX0:MSLIB,FISNOV.NEW
C
C
C      DIMENSION CMF(3,32),D65(32),FAC(32,3),FACT(32)
C      DIMENSION R(32,10),RC(32,2,2),RG(32),STAR(3,2,2),SPL(4,5)
C      DIMENSION UL(6),OW(6),NM(5),AC(6)
C      DIMENSION TRI(3,2,2),TRIO(3),VAL(3),CD(3,2)
C
C      DATA CMF/0.0191,0.0020,0.0860
C      X, 0.0847,0.0088,0.3894
C      X, 0.2045,0.0214,0.9725
C      X, 0.3147,0.0387,1.5535
C      X, 0.3837,0.0621,1.9673
C      X, 0.3707,0.0895,1.9948
C      X, 0.3023,0.1282,1.7454
C      X, 0.1956,0.1852,1.3176
C      X, 0.0805,0.2536,0.7721
C      X, 0.0162,0.3391,0.4153
C      X, 0.0038,0.4608,0.2185
C      X, 0.0375,0.6067,0.1120
C      X, 0.1177,0.7618,0.0607
C      X, 0.2365,0.8752,0.0305
C      X, 0.3768,0.9620,0.0137
C      X, 0.5298,0.9918,0.0040
C      X, 0.7052,0.9973,0.0000
C      X, 0.8787,0.9556,0.0000
C      X, 1.0142,0.8689,0.0000
C      X, 1.1185,0.7774,0.0000
C      X, 1.1240,0.6583,0.0000
C      X, 1.0305,0.5280,0.0000
C      X, 0.8563,0.3981,0.0000
C      X, 0.6475,0.2835,0.0000
C      X, 0.4316,0.1798,0.0000
C      X, 0.2683,0.1076,0.0000
C      X, 0.1526,0.0603,0.0000
C      X, 0.0813,0.0318,0.0000
C      X, 0.0409,0.0159,0.0000
C      X, 0.0199,0.0077,0.0000
C      X, 0.0096,0.0037,0.0000
C      X, 0.0046,0.0018,0.0000/
C      DATA D65/828.,916.,935.,868.,1049.,1171.,1178.,1149.,1159.,1088.
C      X, 1094.,1078.,1049.,1077.,1044.,1040.,1000.,964.,957.,886.
C      X, 900.,896.,876.,833.,837.,800.,802.,822.,783.,697.,716.,743./
C      DATA SPL/'WHIT','E TI','LES ','','AMBE','R FI','LTER','
C      X 'GRAY','FOR','CELA','IN ','STD ','TAN ','PLAS','TIC ','SPL '
C      X 'TAN ','PLAS','TIC '/

```

Appendix C (continued)

```

C      1=OPAL@540;2=AMBER@420;3=AMBER@520;4=AMBER@640;5=GRAY@540;6=COL DIF
      DATA NM/540,420,520,660,540/
      DATA UL/99.62,3.53,39.27,80.09,44.00,1.94/
      DATA OW/99.48,3.47,38.93,79.85,43.80,1.84/
      DATA AC/'UPPE','R LI','MIT ','LOWE','R LI','MIT '/
100    FORMAT(' DATE: 'I2,2('/',I2))
150    FORMAT('$ BEGIN WITH SAMPLE NO.?(1-5)',6X)
160    FORMAT(' AT',I4,' NM',2(1X3A4,F6.2))
170    FORMAT(' COLOR DIFF.',2(1X3A4,F6.2))
0175   FORMAT('$ CHANGE LIMITS? 0=NO; 1=YES',4X)
180    FORMAT(2X3A4,'?')
190    FORMAT(F7.2)
200    FORMAT('OMEASURE: '4A4,
X' INSERT SAMPLE THEN HIT RETURN AFTER PAUSE')
210    FORMAT('O***READING AT',I5,' NM IS OUT OF SPECS FOR: ',4A4,/
X' WASH SAMPLE, THEN')
220    FORMAT('*** COLOR DIFFERENCE IS OUT OF SPECS'/
X' WASH PLASTIC TILES, THEN')
300    FORMAT(I5,3F10.2,F10.3)
500    FORMAT(' W/L',5X,'FIRST',4X,'AVG OF 2')
700    FORMAT(1H0,'AVG OF 2 DL=',F7.2,' DC=',F7.2,' DE=',F7.2)
      CALL IDATE(IM,ID,IY)
      WRITE(5,100) IM,ID,IY
      WRITE(5,150)
      READ(5,300) NSAM
950    DO 2000 I=1,5
      IF(I.NE.1.AND.I.LT.NSAM) GOTO 2000
960    WRITE(5,200) (SPL(M,I),M=1,4)
      IF(I.EQ.5) GOTO 975
      IF(I.LE.2) K=0
      IF(I.GE.3) K=2
      IF(I.EQ.4) GOTO 970
965    WRITE(5,160) NM(I+K),(AC(M),M=1,3),UL(I+K),(AC(M),M=4,6),OW(I+K)
970    IF(I.EQ.4) WRITE(5,170) (AC(M),M=1,3),UL(6),(AC(M),M=4,6),OW(6)
      WRITE(5,175)
      READ(5,300) ICH
      IF(ICH.EQ.0) GOTO 972
      WRITE(5,180) (AC(M),M=1,3)
      READ(5,190) UL(I+K)
      WRITE(5,180) (AC(M),M=4,6)
      READ(5,190) OW(I+K)
972    IF(I.NE.2) GOTO 975
      IF(K.LT.3) K=K+1
      IF(K.LT.3) GOTO 965
975    CONTINUE
      PAUSE
      DO 1000 N=1,2
      DO 980 L=1,32
980    FACT(L)=1.
      CALL GMSR(4000,7100,100,1,0,5,0,1,FACT,RG,IER)
      DO 990 L=1,32
990    R(L,N)=RG(L)
      CALL IDLE(1000)
1000   CONTINUE

```

Appendix C (continued)

```

IF(I,LT,4) WRITE(5,300)
IF(I,GT,1) GOTO 1100
DO 1040 L=1,32
FAC(L,2)=0.
DO 1020 N=1,2
IF(N,EQ,1) FAC(L,1)=R(L,N)
IF(N,LE,2) FAC(L,2)=R(L,N)*0.5 + FAC(L,2)
1020 CONTINUE
IF(L,NE,15) GOTO 1030
      WRITE(5,300) 390+L*10,(FAC(L,M),M=1,2)
IF(FAC(15,2).LT,UL(1).AND,FAC(15,2).GT,OW(1)) GOTO 1030
WRITE(5,210) 540,(SPL(M,1),M=1,4)
GOTO 960
1030 DO 1035 M=1,2
1035 FAC(L,M)=FAC(L,M)*0.01
1040 CONTINUE
GOTO 2000
1100 DO 1100 L=1,32
VAL(2)=0.
DO 1120 N=1,2
IF(N,EQ,1) VAL(1)=R(L,N)/FAC(L,1)
IF(N,EQ,1.AND,I,GE,4) RC(L,1,I-3)=VAL(1)
IF(N,LE,2) VAL(2)=R(L,N)*0.5/FAC(L,2)+VAL(2)
IF(N,EQ,2.AND,I,GE,4) RC(L,2,I-3)=VAL(2)
1120 CONTINUE
LL=L/10+2
IF(I-3) 1140,1160,1500
1140 IF(L,EQ,3,OR,L,EQ,13,OR,L,EQ,27) GOTO 1150
GOTO 1500
1150 WRITE(5,300) 390+L*10,(VAL(M),M=1,2)
IF(VAL(2).LT,UL(LL).AND,VAL(2).GT,OW(LL)) GOTO 1500
WRITE(5,210) 390+L*10,(SPL(M,I),M=1,4)
GOTO 960
1160 IF(L,NE,15) GOTO 1500
WRITE(5,300) 540,(VAL(M),M=1,2)
IF(VAL(2).LT,UL(5).AND,VAL(2).GT,OW(5)) GOTO 1500
WRITE(5,210) 540,(SPL(M,3),M=1,4)
GOTO 960
1500 CONTINUE
2000 CONTINUE
C I IS THE TRISTIMULUS COUNTER
C J IS THE AVERAGES COUNTER
C K IS THE SAMPLE NUMBER OF THE PLASTIC CHIPS COUNTER
C L IS THE WAVELENGTH COUNTER
DO 2900 I=1,3
TRIO(I)=0.
DO 2900 L=1,32
2900 TRIO(I)=TRIO(I)+100.*CMF(I,L)*D65(L)
TH=1./3.
DO 3050 N=1,2
DO 3050 J=1,2
DO 3020 I=1,3
TRI(I,J,K)=0.
DO 3000 L=1,32

```

Appendix C (continued)

```

3000 TRI(I,J,K)=TRI(1,J,K) + RC(L,J,K)*CMF(I,L)*DA5(L)
3020 TRI(I,J,K)=TRI(I,J,K)/TRIO(I)
3050 CONTINUE
      DO 3080 I=1,3
      DO 3080 J=1,2
      DO 3080 K=1,2
3080 TRI(I,J,K)=TRI(I,J,K)**TH
      DO 3150 K=1,2
      DO 3150 J=1,2
      STAR(1,J,K)=116.0*TRI(2,J,K)-16.0
      STAR(2,J,K)=500.*(TRI(1,J,K)-TRI(2,J,K))
3150 STAR(3,J,K)=200.*(TRI(2,J,K)-TRI(3,J,K))
      J=2
      DO 3200 I=1,3
3200 STAR(I,J,1)=(STAR(I,J,2)-STAR(I,J,1))*(STAR(I,J,2)-STAR(I,J,1))
      CD(1,J)=SQRT(STAR(1,J,1))
      CD(2,J)=SQRT(STAR(2,J,1)*STAR(2,J,1) + STAR(3,J,1)*STAR(3,J,1))
      CD(3,J)=SQRT(CD(1,J)*CD(1,J) + CD(2,J)*CD(2,J))
      WRITE(5,700) (CD(M,J),M=1,3)
      IF(CD(3,2).LT.UL(6).AND.CD(3,2).GT.OW(6)) GOTO4000
      WRITE(5,220)
      NSAM=4
      GOTO 950
4000 STOP
      END

```

Appendix D

Computer program QSTANH for standardization program of Hunter D54.

```

C      PROGRAM QSTANH
C      ---TO PROVIDE A STANDARDIZATION PROCEDURE
C      APPLICABLE TO THE HUNTER D54P SPECTROPHOTOMETER
      DIMENSION AV(6),AVGNO(4),CD(3,13),CMF(3,32),D65(32)
      DIMENSION TRI(5),RPL(32),PLAST(2)
      DIMENSION RC(32,10),RO(32,13,2),R9(32),SPL(4,5),ST(6)
      DIMENSION STAR(3,13,2),TRI(3,13,2),TRIO(3),VAL(3)
      DATA CMF/0.0191,0.0020,0.0860,0.0847,0.0038,0.3894
      -,0.2045,0.0214,0.9725,0.3147,0.0387,1.5535
      -,0.3437,0.0621,1.9673,0.3707,0.0895,1.9048
      -,0.3223,0.1282,1.7454,0.1956,0.1852,1.3176
      -,0.0805,0.2535,0.7721,0.0162,0.3321,0.4153
      -,0.0038,0.4608,0.2185,0.0375,0.6067,0.1120
      -,0.1177,0.7618,0.0607,0.2365,0.8752,0.0305
      -,0.3768,0.9620,0.0137,0.5298,0.9918,0.0040
      -,0.7052,0.9973,0.0000,0.8787,0.9556,0.0000
      -,1.0142,0.8689,0.0000,1.1185,0.7774,0.0000
      -,1.1240,0.6583,0.0000,1.0305,0.5280,0.0000
      -,0.8563,0.3981,0.0000,0.6475,0.2835,0.0000
      -,0.4316,0.1793,0.0000,0.2683,0.1076,0.0000
      -,0.1526,0.0603,0.0000,0.0813,0.0318,0.0000
      -,0.0409,0.0159,0.0000,0.0199,0.0077,0.0000
      -,0.0026,0.0037,0.0000,0.0046,0.0018,0.0000/
      DATA D65/828.,916.,935.,868.,1049.,1171.,1178.,1149.,1159.,1083.,
      -1094.,1078.,1049.,1077.,1044.,1040.,1000.,964.,957.,886.,
      -900.,896.,876.,833.,837.,800.,802.,822.,783.,697.,716.,743./
      DATA SPL/'AMBER','R FI','LTER','/
      -      'WHIT','E TI','LE'//
      -      'GRAY','POR','CELA','IN'//
      -      'STD','TAN','PLAS','TIC'//
      -      'SPL','TAN','PLAS','TIC'//
      DATA AVGNO,PLAST/'ONE','AV2','AV10','SIG','STD','SPL'//
C      1=AMBER#420;2=AMBER#520;3=AMBER#660;4=OPAL#540;5=GRAY#540;6=COL. DIFF.
      DATA ST/3.48,38.68,80.20,98.36,42.96,1.88/
      DATA AV/0.03,0.18,0.12,0.10,0.10,0.05/
      DATA NM/420,520,660,540,540/
100     FORMAT(' DATE: ',I2,2(' ',I2))
120     FORMAT('// 1. ON D54 PRESS "ASCII OUT", THEN "0", THEN "TRAP"//
      -//      PUT WHITE PORCELAIN OVER PORT,//
      -//      BLOCK BEAM WITH BLACK CARDBOARD//
      -// 2. PRESS "ZERO". REMOVE CARDBOARD//
      -// 3. PRESS "STDZ". AFTER "STANDARDIZED" PRINTS OUT ON D54//
      -// 4. PRESS "ASCII", THEN "2",//
      -// 5. PRESS "RETURN" ON SPC-16 CONSOLE PRINTER//
150     FORMAT(' BEGIN WITH SAMPLE NO. ? (1-5)')
170     FORMAT('*** REMOVE AMBER FILTER***')
      -// 1. ON D54, PRESS "ASCII", THEN "0", THEN "R-SIN"//
      -//      PUT ZERO TRAP OVER PORT//
      -// 2. PRESS "ZERO". PUT WHITE PORCELAIN OVER PORT//
      -// 3. PRESS "STDZ". PUT GRAY PORCELAIN OVER PORT//
      -// 4. PRESS "STDZ". AFTER "STANDARDIZED" PRINTS OUT ON D54,//
      -// 5. PRESS "ASCII", THEN "2"//
      -// 6. PRESS "RETURN" ON SPC-16 CONSOLE PRINTER//
200     FORMAT(' MEASURE: '4A4' INSERT SAMPLE IN D54')

```

Appendix D (continued)

```

-// AFTER A PAUSE IS PRINTED, PRESS "READ" ON 054//
-// AFTER BELL RINGS, PRESS "10NM" AND "RETURN" AT SAME TIME//
210  FORMAT(//***READING AT 15NM IS OUT OF SPECS FOR: 4A4//
-//  WASH SAMPLE, THEN//)
220  FORMAT(' A1',14,' NM UPPER LIMIT',F6.2,' LOWER LIMIT',F6.2)
230  FORMAT(' COLOR DIFFERENCE: UPPER LIMIT',F6.2,' LOWER LIMIT',F6.2)
240  FORMAT(//*** COLOR DIFFERENCE IS OUT OF SPECS FOR: 4A4//
-//  WASH TILES, THEN//)
250  FORMAT(V)
300  FORMAT(15,3F10.2,F10.3)
350  FORMAT(13,F11.2)
450  FORMAT(/2(2XA4), ' X=',F7.5,' Y=',F7.5,' Z=',F7.5)
500  FORMAT(' W/L',5X,' FIRST',4X,' AVG OF 2')
700  FORMAT(/A4, ' DL=',F7.2,' DC=',F7.2,' DE=',F7.2)
800  FORMAT(//***OK TO MAKE MEASUREMENTS***//)
      CALL FREMAT
      CALL DATESB(IY,IM,ID)
      WRITE(5,100) IM,ID,IY
      WRITE(5,150)
      READ(5,250) NSAM
      IF(NSAM.GT.1) GOTO 950
      WRITE(5,120)
      PAUSE
950  DO 2000 II=1,5
      IF(II.LT.NSAM) GOTO 2000
960  I=II
      IF(I.NE.2) GOTO 970
      WRITE(5,170)
      PAUSE
970  WRITE(5,200) (SPL(M,I),M=1,4)
      K=1
      IF(I.NE.1) K=I+2
      IF(I.EQ.5) GOTO 978
975  UL=ST(K)+AV(K)
      OW=ST(K)-AV(K)
      IF(I.EQ.4) WRITE(5,230) UL,OW
      IF(I.EQ.4) GOTO 978
      WRITE(5,220) NM1(K),UL,OW
      IF(I.NE.1) GOTO 978
      IF(K.EQ.3) GOTO 978
      K=K+1
      GOTO 975
978  CONTINUE
      DO 1000 N=1,2
      PAUSE
      DO 980 L=1,32
      R(L,N)=RG(L)
980  READ(14,350) NWL(L),RG(L)
      CONTINUE
      DO 985 L=1,32
      R(L,N)=RG(L)
985  CONTINUE
1000  CONTINUE
      IF(I.LT.4) WRITE(5,500)

```

Appendix D (continued)

```

K=1
IF(I.NE.1) K=I+2
1100 DO 1140 L=1,32
    VAL(2)=0.
    DO 1120 N=1,2
        IF(N.EQ.1) VAL(1)=R(L,N)
        IF(N.EQ.1.AND.I.GE.4) RC(L,1,I-3)=VAL(1)
        IF(N.LE.2) VAL(2)=R(L,N)*0.5+VAL(2)
        IF(N.EQ.2.AND.I.GE.4) RC(L,2,I-3)=VAL(2)
1120 CONTINUE
    IF(I.GE.4) GOTO 1140
    NM=390+L*10
    IF(NM.NE.NM1(K)) GOTO 1140
    WRITE(5,300) NM,(VAL(M),M=1,2)
    IF(ABS(VAL(2)-ST(K)).LT.AV(K)) GOTO 1135
    WRITE(5,210) NM1(K),(SPL(M,I),M=1,4)
    GOTO 970
1135 IF(I.EQ.1.AND.K.LT.3) K=K+1
1140 CONTINUE
2000 CONTINUE
C      I IS THE TRISTIMULUS COUNTER
C      J IS THE AVERAGES COUNTER
C      K IS THE SAMPLE NUMBER OF THE PLASTIC CHIPS COUNTER
C      L IS THE WAVELENGTH COUNTER
DO 2900 I=1,3
    TRI0(I)=0.
DO 2900 L=1,32
2900 TRI0(I)=TRI0(I)+100.*CHF(I,L)*D65(L)
    TH=1./3.
DO 3070 K=1,2
DO 3070 J=1,2
DO 3020 I=1,3
    TRI(I,J,K)=0.
DO 3000 L=1,32
    TRI(I,J,K)=TRI(I,J,K)+RC(L,J,K)*CHF(I,L)*D65(L)
3000 CONTINUE
3020 TRI(I,J,K)=TRI(I,J,K)/TRI0(I)
C      WRITE(5,450) PLAST(K),AVGNO(J),(TRI(M,J,K),M=1,3)
3070 CONTINUE
DO 3080 I=1,3
DO 3080 J=1,2
DO 3080 K=1,2
3080 TRI(I,J,K)=TRI(I,J,K)**TH
DO 3170 K=1,2
DO 3170 J=1,2
    STAR(1,J,K)=116.0*TRI(2,J,K)-16.0
    STAR(2,J,K)=500.*(TRI(1,J,K)-TRI(2,J,K))
    STAR(3,J,K)=200.*(TRI(2,J,K)-TRI(3,J,K))
3170 CONTINUE
DO 3180 J=1,2
DO 3200 I=1,3
3200 STAR(1,J,1)=(STAR(1,J,2)-STAR(1,J,1))*(STAR(1,J,2)-STAR(1,J,1))
    C0(1,J)=SQRT(STAR(1,J,1))
    C0(2,J)=SQRT(STAR(2,J,1)*STAR(2,J,1)+STAR(3,J,1)*STAR(3,J,1))

```

Appendix D (continued)

```
CD(3,J)=SQRT(CD(1,J)*CD(1,J)+CD(2,J)*CD(2,J))
WRITE(5,700) AVGH0(J), (CD(M,J),M=1,3)
3250 CONTINUE
IF(ABS(CD(3,2)-ST(6)).LT.AV(6)) GOTO 3300
NSAM=4
WRITE(5,240) (SPL(M,4),M=1,4)
GOTO 950
3300 WRITE(5,800)
4000 STOP
END
```

?