PRODUCTION COLOR CONTROL - THE DIRECT APPROACH

by Robert P. Mason

Abstract

Control of color during printing production involves two stages: (a) producing the image colors achievable by making optimum settings of press controls and (b) maintaining constant image colors throughout the run.

Acquiring and maintaining specified ink densities for color bars outside the image area to achieve these conditions is usually not sufficient. Almost invariably, the operator must exercise visual color comparison skills and make additional adjustments accordingly throughout the production process to assure satisfactory output product color. This stage in the process is subjective and often exhibits a wide range of variation.

We at HunterLab have developed and reported previously a manually positioned system using direct measurement of color within selected areas of the image to provide:

- objectivity and consistency in the actions taken, and
- a useful record for analysis and characterization of the process performance regarding color.

This paper describes the PICCS 4000 system which now employs a solid state full range spectrophotometer with preprogrammed computer controlled positioning of up to 32 readings over the sheet, in addition to features previously reported. These combine to provide an immediate indication of color errors detected and the objective ink adjustments needed to maintain target

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color. Indicated ink feed adjustments can be statistically based for maintaining color periodically sampled during an extended run, or individual readings can be used in achieving target color during makeready.

Reports of process performance derived from statistical analysis (SPC) are prepared directly from the data collected.

The Need

In the booklet of Specifications for Web Offset Publications[SWOP, 1988] (SWOP) there are several statements which express the need for those involved in Graphic Arts reproduction of color to use the appearance measurement principles so widely adopted in other industries.

An excerpt among them: "Quality should be measurable and verified at each step in the chain of reproduction." Where is this more important than at the final step where the customer will focus his critical gaze?

Another: "The publisher should ... set up systems with the printer to monitor the quality of reproduction throughout the process." What better can give confidence to a printer's customer that color has been held true throughout the run than a numerical record of regular sampling of image appearance.

And another: "It is the printer's primary responsibility to match the supplied proof as accurately as possible." By what means other than with appearance-related measurement can an accurate match be determined or evaluated?

Previous Work

In 1985[Mason, 1985] we reported at TAGA the development of PICCS, a printed image color control system aimed at aiding the color judgments and estimates in making color corrections which confront the pressman during any critical color run. This instrument features tristimulus color measurements using a spectrophotometer with positioning guides and interpretive software to yield without need for knowledge of color scales, guidance about which process ink and how much increase or decrease is needed to correct detected color errors in colored image areas.*(Figure 1)* An agreed upon standard for image color is used to determine the target values for control of the run.

In a follow-up paper at TAGA in 1987[Mason, 1987], results from extended use of the system were reported. Added features were described which included the ability to statistically analyze the reported ink variations throughout the run, thus generating profiles of statistical performance at measured image segments downward through the stack. These capabilities were demonstrated to fulfill the needs to numerically characterize the color generating process and display color errors in terms of the press inking variables both directly for near-real time monitoring and for later statistical analysis. The added benefit of having data in a form suitable for use in product quality certification to the customer was recognized.

The Visual Color Perception Model

As previously described, the unique and primary feature of the PICCS instrument is the use of the tristimulus model[CIE, 1971] for visual color response in measurements taken on selected segments of the image itself. In this way, the printer's process of color synthesis is monitored directly at the point of interaction with his customer. The system design is such that when the measured image segment visually matches the agreed upon standard, there is no error reported. Departures or errors in color are formulated as corrections needed in the coverage of inks present on the substrate in use.

Image areas are selected by the operator as ones important for customer acceptance and for distribution over the sheet, front-to-back as well as side to side. During a setup procedure, the location and color of each image segment to be monitored is determined. Proper color and position is best taken from an OK sheet, though often a sample from a previous run or a proof which truly represents the color that will be achieved is used. The process inks and base stock used in the images are identified. Also, inks used in single ink or spot colors are identified and linked to associated image areas. A maximum of 32 positions on a sheet can be selected in any one setup. The setup is then stored by job name. Some of the principles underlying this method of sampling for product quality evaluation are discussed in Appendix 2.

When sheets from that job are measured, the operator need only locate the sheet with quick positioning guides and press a single key to initiate a reading cycle. The instrument then compares tristimulus color values of standard and sample. It then computes and displays coverage errors for each ink in a simple bar graph that reveals direction and amount of correction needed and recent trends for each location. A discussion of the relative merits of densitometry and tristimulus colorimetry is presented in Appendix 3.

Moving Control Chart

During the final run for color at makeready, it is necessary to measure frequently and adjust rapidly to minimize waste of time and materials. Here adjustments are properly based on quick single readings. Guidance provided by the instrument together with the pressman's skills combine to reduce time and waste when running for color.

During a press run, however, where equilibrium is reached and maintained, normal random variations of the process should be ignored and only trends owing to drift should be corrected. The press operator is frequently faced with the choice of whether to make a correction to the ink keys in response to a reading showing a color error. The bar graph display in the PICCS program can be selected to show corrections needed based on individual readings or on sample averages over several readings. The latter, then, becomes a moving control chart on the basis of which decisions on whether to take corrective action can be made. Effective use of this feature requires that the random variations of the process be established so that meaningful control limits can be derived. This permits application of the principles of statistical process control (SPC) to aid in maintaining the run within limits acceptable to the customer.

As outlined in any plan for instigating SPC(Juran, 1988) a significant effort is necessary to establish the process characteristics. There is no substitute or short cut to securing this information. Extended runs under a variety of conditions covering what is judged to be within a normal range must be made without operator intervention. The PICCS instrument can be used to collect the information and aid in analysis of the data.

Once the normal process variation is known, the criteria for acceptability must be established jointly with the customer. These must be selected to be achievable within the variation and control characteristics of the printing process. Continued monitoring and analysis permits improvements to be identified and evaluated.

PICCS 4000

The previously reported PICCS 3000 instrument requires operator attention throughout the measurement of each sheet. Each selected image area on the sheet needs to be positioned relative to the reference guides on the instrument before measurements can be made. This occupies the operator for a few minutes during the several measurements on each sheet. Because of this, abbreviation of the measurement process can result and lead to the reduction of quality and quantity of the data collected.

To reduce labor needed and avoid compromise of the value of data that is collected routinely in typical production situations, the PICCS 4000 instrument has been developed. It consists of a 5 by 6-1/2 ft. vacuum top table with a spectrophotometer having 45/0 geometry and a two-dimensional movable mount under computer control.*(Figure 2)*

It is useful to note here that an optical filter colorimeter could be used to measure the tristimulus values of the images. As such, it could be somewhat faster in operating speed than the PICCS 4000. However, interpretation of measured color values into press operating functions is essential in this application. Spectral values are used to provide this capability.

Color formulation principles are employed to determine the ink coverage corrections needed to maintain target color. Formulation employs spectral values of the inks and the base stock used on the printing job. Therefore, a spectrophotometer is a necessary element in the instrument system.

The measuring sensor is a solid state spectrophotometer having a focused holographic grating and a 32-element detector array which allows a direct readout of reflectance values at 10 nanometer intervals across the visible spectral range. The optical system includes interchangeable components under remote control which allows selection of large (20mm diameter), or small (5mm diameter), areas of measurement. The illumination of the measured area is by optically filtered tungsten with an approximation of daylight at 5,000 Kelvins. The light is carried to the sample area through a flexible glass fiber bundle and the support ring is held in contact with the measured surface during the reading. Fiber ends are arrayed in a conical form so that the sample area is illuminated at 45° from the normal over the full 360° range of azimuth.

The instrument is maintained in calibration by frequent standardization on black and white reference plaques built into the table surface. Periodic reference to a pair of calibrated reflectance standards, also provided with the system, allows the operator to maintain longterm repeatability.

Preparation of a Job Setup

The PICCS 4000 is set up for monitoring a job by providing the computer program with a number of essential pieces of information. First, the spectral profiles of the inks and base stock used are recorded in files where they can be accessed as appropriate. Overprinted tints of these inks on the base stock form the colors generated in the process printed images. Then a white level representing the uninked base stock of the particular batch is measured and recorded. The setup also requires the operator to select among options for reading one or averaging a number of sheets to achieve suitable data.

On the Setup Screen *(Figure 3)* after entry of the job fixed data, a window opens for each standard selected and prompts the operator for information specific to it. Locations on the sheet are then selected for representative measurement throughout the run. The operator moves the sensor to the selected location by means of a joystick. The image segment, or standard, is recorded for position and measured for color at that position.

The inks used are then identified. Often a spot color is important and only one ink is present. The instrument computer must be given the identity and number of inks present in the measured area. Where four process inks are present, the ink having the least influence is also identified and, if present, an estimate of percent coverage is entered. Finally, an agreed upon specified color variation limit in ΔE is entered for reference.

Once a suitable number of standards are selected and identified for position, color and composition, the setup is saved by job name and the job is ready to run.

Positioning is an important step in this process. A pair of position reference guides are provided, hinged from the front edge of the table. They are used to establish the position of the image in reference to the table surface. Any pair of sharply defined features of the image can be used. Registration marks are especially useful for this purpose. Positioning to about 1/4mm is routinely accomplished by this system and provides excellent repeatability of readings. Quantitative examples of positioning sensitivity are given in Appendix 1.

Running the Job

Once the setup has been saved, the job may be run with very little time and effort.

The job name is entered by keyboard the first time and then selected from a short list of active jobs thereafter. The sheet is placed on the table in position as established with the positioning guides during the setup. With a single keystroke the run command is entered and the instrument proceeds without further operator intervention. Color errors for each standard position are displayed immediately after each reading is taken on the Results Screen.*(Figure 4)* They can be reviewed individually or all at once on command in a composite display. Inking errors are shown as bars extended to the left when low and to the right when high. Numerical values can be printed quickly for reference in making adjustments to the press.

The data records of the previous sheet are saved after the command to read the new sheet is given. In this way, reading errors can be deleted before they become part of the file record. The most recent reading is displayed as the lowest bar in the graph. Older bars are scrolled up, giving an indication of trends for each standard.

Records and Reports

The data records can be reviewed in selected graphic or numerical report formats. A report of raw data shows the ink variations for each image segment measured down through the stack. The data are grouped by standard and show process variations with time at each position over the sheet.*(Figure 5)*

In *Figure 5* two images on the same sheets are profiled. A periodic variation is evident in most of the ink profiles. In the first standard (left), the variations are too small to cause significant color changes. The image color has stayed within a specified color range of 2.0 ΔE units from standard. Note that equivalent percent ink coverages (EPIC) are quite low: M = 15, C = 16, Y = 25. In the second standard the yellow EPIC is 85. Yellow has been running high throughout the job and in several cases the specified color range limits are exceeded. While the first standard shows that yellow is running high, it does not have sufficient influence to demand attention. In the second standard (a yellow tennis ball) yellow is dominant and requires attention if the agreed color variation limits are going to be maintained.

Reports in the form of statistical control charts and histograms can also be prepared. Sample size can be selected in the report function to permit comparison and analysis of sampling profiles. *(Figure 6)*

Figure 6 shows examples of statistical analysis of the data shown for standard two in *Figure 5*. The histograms plainly reveal that all inks are running high with respect to the standard and that yellow is bimodal. The distribution of the black (key) ink appears to be quite normal. The control charts are plotted with a sample size of 2. Points in the chart of averages which fall beyond control limits show where adjustments would have been advised. It is interesting to note that points rarely fall outside the chart of ranges control limits.

Summary

The PICCS 4000 provides the capability to routinely sample and review the color of selected locations on sheets. It further provides objective numerical guidance to color correction actions if needed.

- The operator positions the sheet on the table top and presses a single key to commence a reading cycle.

- In less than 2-1/2 minutes up to 32 locations on the sheet have been compared with an acceptable standard for color error and corrective action indicated, if needed.

- Records are retained and reports for statistical analysis or certification are available.

- An objective basis for managerial control and/or customer acceptance of job run color is established.

Appendix 1.

Precision: Effects of Positioning

For determining color within the image where measurement fields are non-uniform, positioning of the instrument with respect to the image is critical. A good test of ability to position accurately is to use the same sheet and measure -- after repositioning. No errors from color variation will be present. The PICCS 4000 has easily passed stringent customer-conducted tests of this kind. Multiple image locations selected by the customer were measured repeatedly on the same sheet, repositioned by their operator thirty times, using the transparent ruled scales provided for position reference. The specifications were for repeatability to ± 1.5 equivalent percent ink coverage (EPIC) units under these conditions. The performance was +1.0, minus nothing in a series of such tests.

For a quantitative indication of the positioning effects, the results of two series of measurements on real products are shown here. Food cartons are typical examples. Areas to be measured are chosen for importance to the customer and for uniformity where possible. In these cases the main product has large, relatively uniform areas for measurement. The peas and corn on the plate pictured on the food carton are typical of irregular fields to be measured. With the 3/4 inch diameter measurement area, measured values on a broken field such as this change only slightly with small position changes. The required positioning accuracy to be achieved by the operation is that the sheet should fall within .01 inch (1/4 mm) or about the width of a pencil line from the predetermined position. This is not hard to achieve with narrow line reference marks and sharply defined image features. Of course, the edge of the sheet cannot be used.

Figure 1A through 1D is a plot of the change of reading versus position in .01 steps from the standard position. Note the ΔE or gross color error plot at the top of each set of graphs. It passes a minimum at the predetermined location. The EPIC changes indicated are very small. The color coordinate changes are also small. The entire range of this plot is for a ΔE value of about one unit.

A ΔE of one unit is almost imperceptible when comparing two printed images. Only in viewing large uniform areas placed adjacent without a boundary can a reliable visual assessment of only 1 ΔE unit typically be made. The profile for peas is similar to corn, but note that color values are in different quadrants.

In summary, positioning to .01 inch with respect to printed reference marks, together with suitable selection of areas to be measured, provides excellent performance.

Appendix 2

In offset printing, whether sheet or web fed, the keys associated with ink fountains provide the most accessible and effective form of adjustment of the press performance during operation.

Some systems are in use which involve targets and measurement devices to provide inking level information for each key channel on the press.

The PICCS 4000 system is not intended to provide control information in that degree of detail. Rather, the PICCS system is directed at providing objective evaluation of color in selected areas of critical importance to the overall success of the job.

Certain conditions must be met before the information provided by the PICCS instruments are of the greatest value. These include:

- The separations and plates are properly made.

- The materials (inks and paper) are those for which the separations were prepared.

- The press and materials have stabilized into an operating equilibrium.

The PICCS instruments serve to guide and confirm decisions the operator must make continuously while controlling color performance during a run. They have the added capability to record the trends in color variations and to provide a color performance record over the entire run of the job. The instruments monitor the color performance from all causes of variation in the process, whether from mechanical play in the gears, surface chemistry of the plate or blanket, ink contamination or changes in base stock.

Correction of these factors depends heavily on the pressman's skills in recognizing the causes of the color errors. The PICCS instruments provide objective indications that all is OK or that a color problem exists which demands attention. This reduces the burden of uncertainty that the pressman often carries and allows him to act quickly even when a problem may arise slowly without sudden visually obvious changes.

Appendix 3

Densitometry Versus Tristimulus Colorimetry

This subject (Popson, 1989) is of underlying significance and relevance to the purpose of the instrument described here. Several differences between the two types of color measurement are reviewed for reference.

Spectral Characteristics and Their Purpose

Densitometry -- Red, green and blue density functions, represented by the area under the Status T curves are spectrally isolated segments each representing a separate channel of information. These are recorded separately and recombined to synthesize the reproduced colors. The density functions are designed to provide optimum sensitivity to colorant quantities in each channel. To the extent that the necessary colorant quantities needed to produce a perceived color can be predicted, achieving target density values will produce the desired result. The difficult steps here are in achieving predictable performance and in determining target values for a perceived color. These target values are readily available only after a suitable synthesis has been achieved.

Tristimulus Colorimetry also involves three spectral functions of the standard observer roughly corresponding to red, green and blue. Their purpose is to provide a useful measure of perceived color. The X, Y and Z functions are linear reflectance values, represented by the area under the curves, from which all color scales such as CIELAB and CIELUV are derived by algebraic formula. These scales are merely convenient ways to portray the X, Y and Z values. These functions are psychophysical in nature, meaning they are derived from experiments involving human judgment. They have stood the test of time, however, and are in wide use throughout the world in nearly all industries in which product color is a factor in its use. The key point is that the observer is the common denominator, not the colorants or synthesis process.

Other Factors While many appearance factors such as surface finish are not included in the use of tristimulus values, those involving the color quality of the illumination are included. They are not in densitometry.

A spectrophotometer measures an array of wavelength dependent reflectance characteristics of the sample and, because of the fundamental nature of these data, tristimulus or RGB functions can be derived by computation. The only advantage of a spectrophotometer is its flexibility.

The term tristimulus is used here to distinguish colorimetry using the CIE standard observer functions from other color sensitive forms of measurement such as three filter densitometry.

Distinguishing Characteristics

Because of the spectral differences between the three functions of the two methods, color pairs having different spectral curves will produce different ratios of areas beneath the curves in each set. Some pairs of samples will be easily distinguishable in one system and not the other. Since the visual impact of the difference between a pair of samples as defined by the tristimulus values is of primary interest in these cases, it is fair to say that the densitometric RGB functions will be reduced in the precision with which they can numerically identify the difference.

Other differences between colorimeters and densitometers such as optical geometric configuration, inherent precision and measurement area size are cost related instrument design factors and are not fundamental properties.

The following tables summarize some practical differences in today's available instruments:

I. Problem Areas in Comparing Two Image Colors with a 3-Filter Densitometer

A. When measuring on color bars outside the image area:

- Solid bars do not show small color variations within the image.
- Tint bars must be in line with part of image being monitored.
- Front-to-back and spurious variations are not detected.

B. When measuring color fields within the image:

- Density scales are unrelated to visual response, therefore, difficult to interpret regarding appearance.
- Where small measurement area has high position sensitivity.
- Where black is present and varying within image.
- Where ink sets differ between standard and simple.
- Single inks that are not process colors.

II. Density Best for:

- Use with process inks, one at a time (as intended)
- Achieving and maintaining nominal press inking conditions for process inks.
- Analyzing press performance using test targets designed for analytical use.
- Process analysis where test target values are the result of the process.

III. Color Measurement Best for:

- Quality control of color of incoming materials.
- Achieving and maintaining a color match in the image with standard.
- Images containing non-process inks and mixtures with black.
- Process analysis where perceived image color is the result of the process.

Literature Cited

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Figure 1 PICCS 3000

Figure 2 PICCS 4000

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                              SETUP

JOB ID: HLBRO                  AVERAGE               STAT. SAMPLE SIZE:  1
INK FAMILY: HLINK
                                                     COMPOSITE SETUP
BASE STOCK ID: HLBASE
  VIEW AREA: LARGE             POSITION SPACING      CONTROL LIMIT VALUES
  a.MEASURE COLOR: L= 93.59      H.  0.000             a.CALCULATED
  b.ENTER          a= -0.09      V.  0.000             b.ENTER

STANDARD #  2.TENNIS
  STANDARD POSITION        POSITION STEPS        VIEW AREA: LARGE   L= 75.73
     H.  33.052              H.    0.000          a.MEASURE COLOR: a= -4.33
     V.   4.765              V.    0.000          b.ENTER           b= 35.13

  INKS,   .                CONTROL K. 3.0         SPEC LIMIT DELTA E =   2.0
  NON-    M.               LIMITS: M. 3.0
  FAMILY:C.                        C. 3.0
          Y.                       Y. 3.0

  LDINK ID:C %LDINK:  0.0

Arrows move cursor  INS:Select/Deselect  Esc:Cancel          F4:Run Job
F1:Read  F2 STDS  F5:List  End:Save  DEL:Erase  Home:Main Menu  Space:Help
```

Figure 3 Setup Screen

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                         RESULTS
                                                   Sheet No.:00052
JOB ID: HLBRO

            NO. STDS: 5     STD ID:04COVER2     NEXT:05SCREEN

INK COVERAGE:      K:0      M:4       C:12       Y:14
```
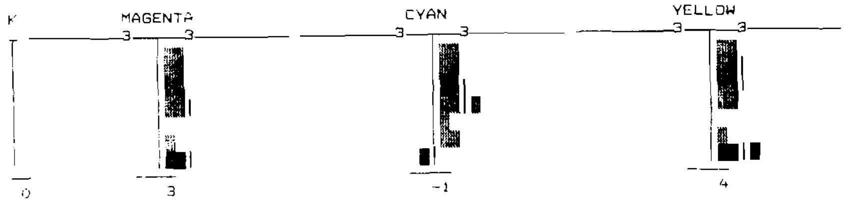
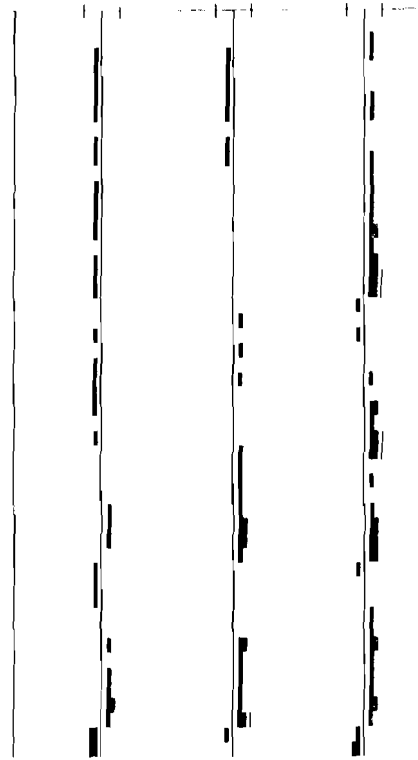




```
THE SAMPLE IS:LESS LIGHT, MORE MAGENTA, LESS CYAN, MORE YELLOW      SPEC:OUT

Prev Std.   Next Std.   V End Review   Home:Main Menu   Space Help
```

Figure 4 Results Screen

STDS IN JOB: STD. NO.: 1 STD. ID: [illegible]
NON FCM. INK:
SMPL SIZE: 1

STD. EPIC: K= 0 M 15 C 16 Y [illegible]
EPIC DEVIATION OF SAMPLE MEASUREMENT
MAGENTA CYAN YELLOW



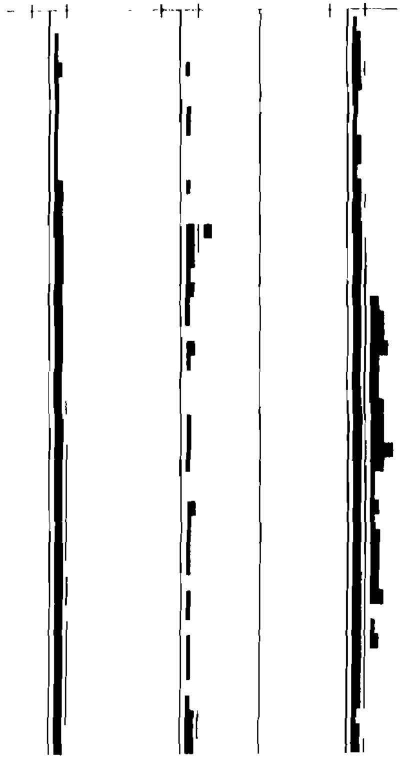
SMPL TIME	SMPL DATE	DELTA E	FLAG SYMBOL
1321	02/07/90	0.1	
1322	02/07/90	0.3	
1323	02/07/90	0.7	
1324	02/07/90	0.3	
1325	02/07/90	0.7	
1326	02/07/90	0.7	
1327	02/07/90	0.5	
1328	02/07/90	0.6	
1329	02/07/90	0.3	
1330	02/07/90	0.4	
1331	02/07/90	0.7	
1332	02/07/90	0.4	
1333	02/07/90	0.4	
1334	02/07/90	0.5	
1335	02/07/90	0.7	
1336	02/07/90	0.6	
1337	02/07/90	0.7	
1338	02/07/90	1.6	
1339	02/07/90	1.3	
1340	02/07/90	0.8	
1341	02/07/90	0.6	
1342	02/07/90	0.7	
1343	02/07/90	0.7	
1344	02/07/90	0.4	
1345	02/07/90	[illegible]	
1346	02/07/90	0.4	
1347	02/07/90	1.1	
1348	02/07/90	0.4	
1349	02/07/90	1.3	
1350	02/07/90	1.5	
1351	02/07/90	0.6	
1352	02/07/90	0.6	
1353	02/07/90	0.9	
1354	02/07/90	1.2	
1355	02/07/90	1.2	
1356	02/07/90	1.5	
1357	02/07/90	0.8	
1358	02/07/90	0.5	
1359	02/07/90	0.4	
1401	02/07/90	0.5	
1401	02/07/90	0.3	
1402	02/07/90	0.7	
1404	02/07/90	1.4	
1405	02/07/90	0.9	
1406	02/07/90	1.5	
1407	02/07/90	1.2	
1408	02/07/90	1.9	
1409	02/07/90	2.3	#
1410	02/07/90	1.4	
1411	02/07/90	1.2	

*=OUT OF CONTROL; #=OUT OF SPEC;
?=OUT OF GAMUT.

SPEC LIMIT DELTA E 2.0
SCALE: 12% EPIC MAX.

JOB ID: [illegible] STDS IN JOB: 5 STD. NO.: 2 STD. ID: [illegible]
INK ID: [illegible] NON FCM. INK:
SMPL SIZE: 1

STD. EPIC: K 10 M 5 C 0 Y 85
EPIC DEVIATION OF SAMPLE MEASUREMENT
KEY MAGENTA CYAN YELLOW

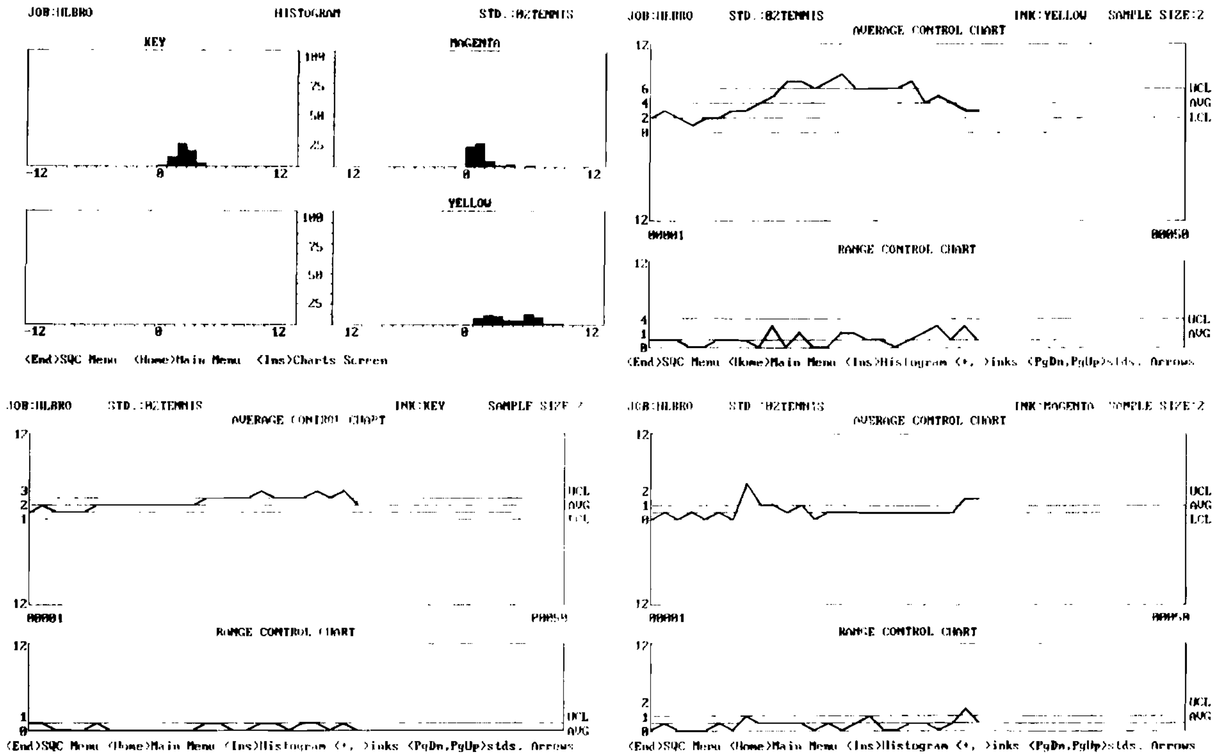


SMPL NO.	SMPL TIME	SMPL DATE	DELTA E	FLAG SYMBOL
00001	1321	02/07/90	0.3	
00002	1322	02/07/90	1.1	
00003	1323	02/07/90	1.2	
00004	1324	02/07/90	1.7	
00005	1325	02/07/90	0.6	
00006	1326	02/07/90	0.7	
00007	1327	02/07/90	1.6	
00008	1329	02/07/90	1.5	
00009	1329	02/07/90	1.2	
00010	1330	02/07/90	1.2	
00011	1331	02/07/90	1.3	
00012	1332	02/07/90	2.4	#
00013	1333	02/07/90	1.8	
00014	1334	02/07/90	1.4	
00015	1335	02/07/90	5.1	#
00016	1336	02/07/90	4.0	#
00017	1337	02/07/90	2.7	#
00018	1338	02/07/90	1.8	*
00019	1339	02/07/90	2.6	#
00020	1340	02/07/90	2.3	#
00021	1341	02/07/90	2.7	#
00022	1342	02/07/90	2.4	#
00023	1343	02/07/90	2.9	#
00024	1344	02/07/90	2.5	#
00025	1345	02/07/90	2.3	#
00026	1346	02/07/90	2.3	#
00027	1347	02/07/90	2.5	#
00028	1348	02/07/90	2.4	#
00029	1349	02/07/90	2.8	#
00030	1350	02/07/90	3.2	#
00031	1351	02/07/90	2.7	#
00032	1352	02/07/90	2.6	#
00033	1353	02/07/90	2.8	#
00034	1354	02/07/90	3.5	#
00035	1355	02/07/90	3.3	#
00036	1356	02/07/90	4.1	#
00037	1357	02/07/90	2.8	#
00038	1358	02/07/90	2.5	#
00039	1359	02/07/90	2.3	#
00040	1401	02/07/90	2.9	#
00041	1402	02/07/90	2.5	#
00042	1403	02/07/90	2.0	#
00043	1404	02/07/90	3.7	#
00044	1405	02/07/90	3.[illegible]	#
00045	1406	02/07/90	3.1	#
00046	1407	02/07/90	2.7	#
00047	1408	02/07/90	3.4	#
00048	1409	02/07/90	6.[illegible]	#
00049	1410	02/07/90	3.4	#
00050	1411	02/07/90	3.1	#

FLAGS: *=OUT OF CONTROL; #=OUT OF SPEC;
?=OUT OF GAMUT.

SPEC LIMIT DELTA E 2.0
SCALE: 12% EPIC MAX.

Figure 5



JOB:HLBRO
HISTOGRAM
STD.:82TENNIS
KEY
MAGENTA
YELLOW
100
75
50
25
-12
0
12
<End>SQC Menu <Home>Main Menu <Ins>Charts Screen
JOB:HLBRO STD.:82TENNIS INK:YELLOW SAMPLE SIZE:2
AVERAGE CONTROL CHART
UCL
AVG
LCL
00001
00050
RANGE CONTROL CHART
<End>SQC Menu <Home>Main Menu <Ins>Histogram <+, >inks <PgDn,PgUp>stds. Arrows
JOB:HLBRO STD.:82TENNIS INK:KEY SAMPLE SIZE:2
AVERAGE CONTROL CHART
RANGE CONTROL CHART
JOB:HLBRO STD.:82TENNIS INK:MAGENTA SAMPLE SIZE:2
AVERAGE CONTROL CHART
RANGE CONTROL CHART

Figure 6

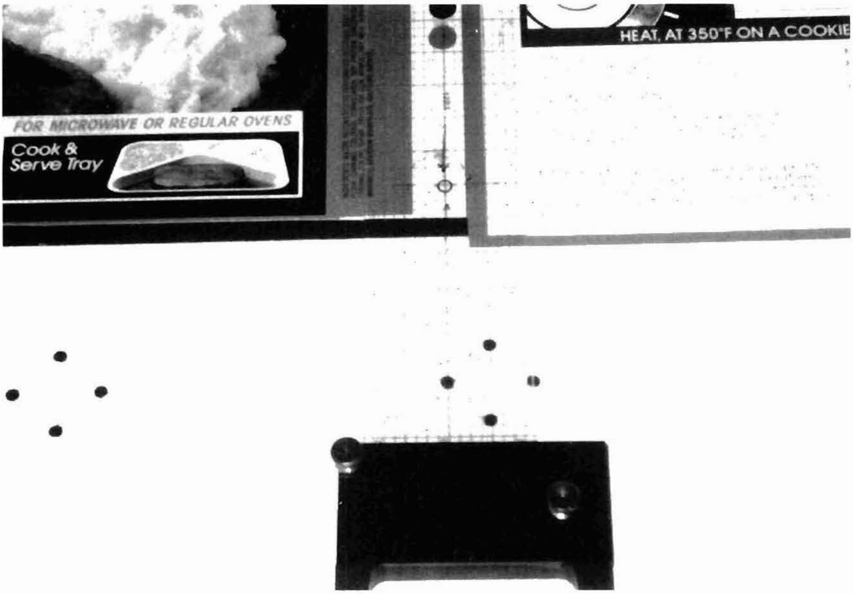
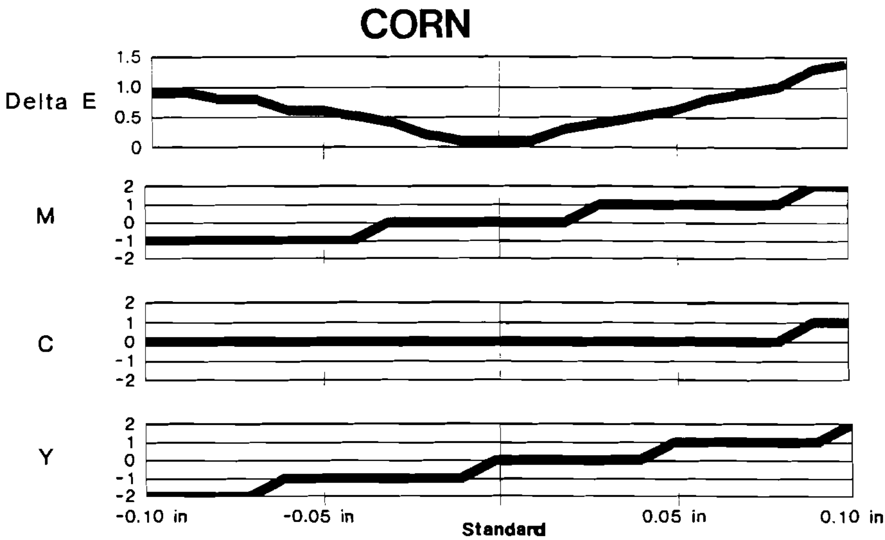


Figure 1A

Figure 1B


CORN
Delta E
1.5
1.0
0.5
0
M
C
Y
2
1
0
-1
-2
-0.10 in
-0.05 in
Standard
0.05 in
0.10 in

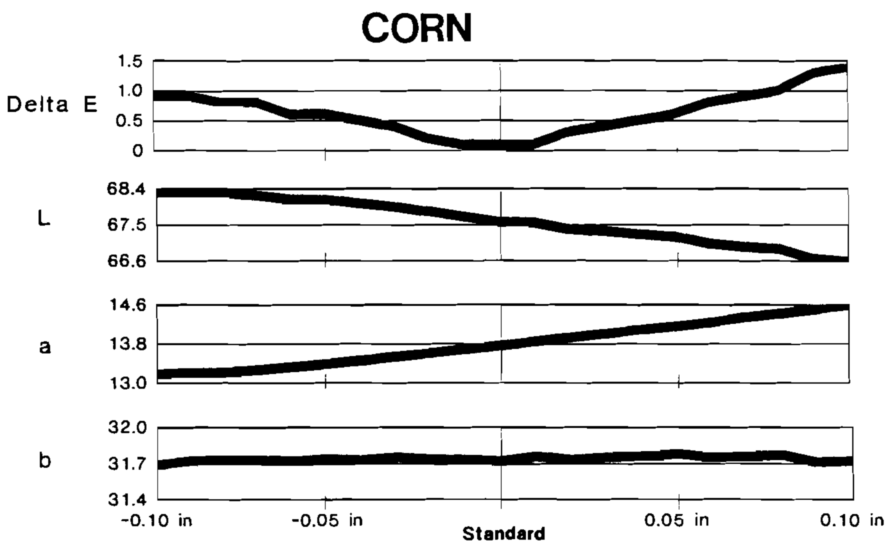
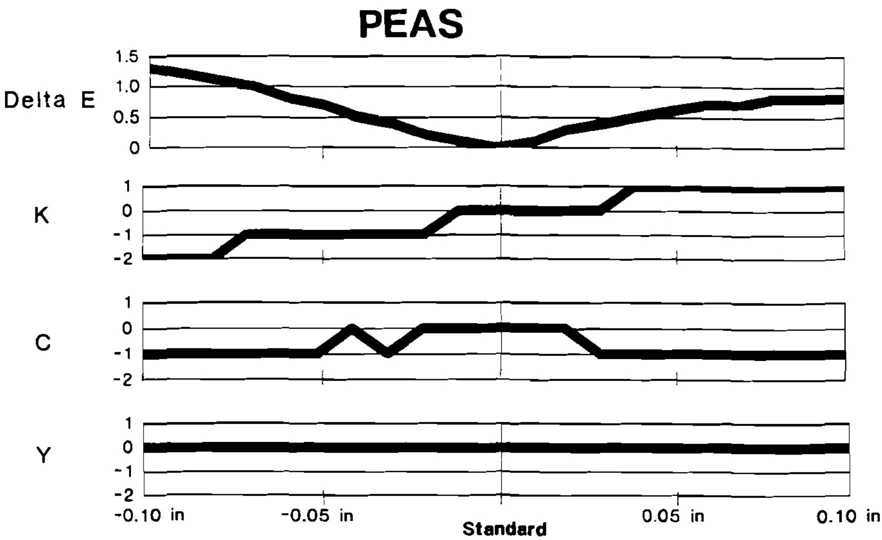

CORN
Delta E
1.5
1.0
0.5
0
L
68.4
67.5
66.6
a
14.6
13.8
13.0
b
32.0
31.7
31.4
-0.10 in
-0.05 in
Standard
0.05 in
0.10 in

Figure 1C


PEAS
Delta E
1.5
1.0
0.5
0
K
1
0
-1
-2
C
1
0
-1
-2
Y
1
0
-1
-2
-0.10 in
-0.05 in
Standard
0.05 in
0.10 in

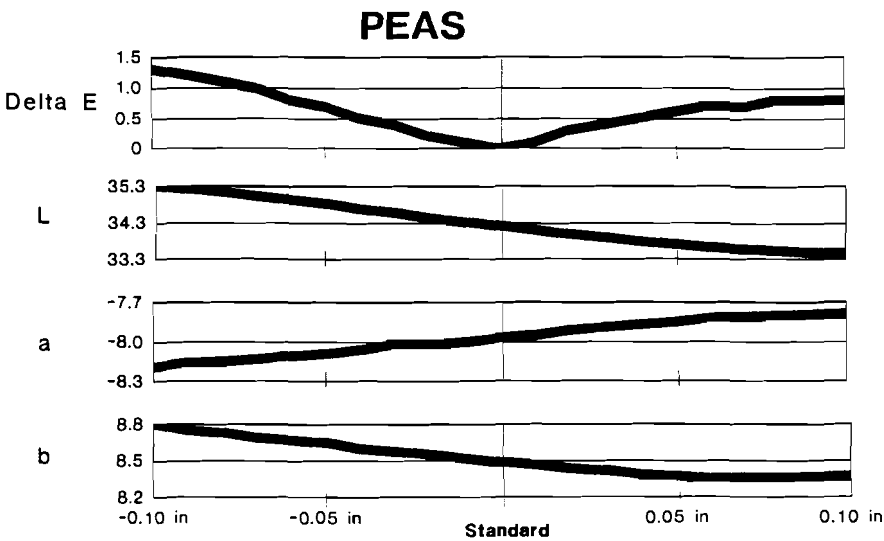

PEAS
Delta E
1.5
1.0
0.5
0
L
35.3
34.3
33.3
a
-7.7
-8.0
-8.3
b
8.8
8.5
8.2
-0.10 in
-0.05 in
Standard
0.05 in
0.10 in

Figure 1D