THE QPC PROGRAM AND THE PRACTICAL APPLICATION OF STATISTICAL PROCESS CONTROL

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Abstract: SPECTRUM is the Graphic Communications Association's (GCA) annual conference devoted to improved communication of color and better coordination among the many segments involved in printing and publishing production. Attendees at recent Spectrum programs directed GCA's Print Properties Committee to study how the industry might evaluate, independently and in their own operations, pressroom materials such as ink, fountain solution, plates, blankets, and others, and the interaction of these materials. Such evaluations are expected to allow improved color reproduction consistency and decreased waste. After investigating possible approaches for accomplishing these objectives, the committee, led by Larry Wilson of S.D. Warren/Division Scott Paper, and including representatives from many segments of the print production community, decided that the most effective approach would couple the management philosophy of Dr. W. Edwards Deming with statistical tools. Adherence to Deming's philosophy while using statistics, such as control charts, permits good insight into the capabilities of the entire print production process as well as the means for measuring and controlling this process. Recent application work by the committee at the Rochester Institute of Technology and in individual operations has reaffirmed the power of statistical tools as a means for understanding the printing process and predicting its performance. Statistical and visual analysis of RIT data indicated that once a press reaches equilibrium, it operates with less variability when left alone than it does when adjusted by press operators. Future committee plans include establishment of a cooperative, industry-wide Quality Process Commitment (QPC)™ program to introduce and explain Deming principles and statistical tools to printing, publishing, and associated industries.

Introduction

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reproduction. It was at this conference that members of the GCA Print Properties Committee, a group of industry representatives from many segments of the print production community, presented data from 28 presses showing that mid-tone dot gain ranged between 20 and 40 percent.

We subsequently reported at SPECTRUM on our efforts to identify causes of dot gain. These reports led attendees to direct the Print Properties Committee to study how industry might evaluate, independently and in their own operations, pressroom materials such as ink, fountain solution, plates, blankets to anticipate key interactions among these materials affecting dot gain and other print attributes. Knowledge gained from these evaluations would be expected to allow improved color reproduction consistency and decreased waste.

After investigating possible approaches, we discovered that there are two related, but distinct, requirements for understanding the interaction of materials and improving the quality of a printed product. First, in order to understand the effect that any change to a process might have on that process's output, one must know both whether that process is stable and, if it is, what variation exists within it. To determine process stability and variation, one must use statistical process control tools. Second, the top management of an organization must adopt the philosophy that will give them the courage the lead the company in implementing statistical process control techniques and support the needed changes in the process that must occur to improve the capability of the process. The management philosophy of Dr. W. Edwards Deming addresses this second need.

Some Background on SPC and Deming

While both statistical tools and Deming's philosophy are equally important in achieving increased quality at reduced cost and in understanding materials interactions, it has been proven by U.S. industries that these goals can not be realized by using statistical process control (SPC) alone. SPC is an old science, and it has been available to and used by American industries for a long time. But use of this tool alone did not produce the quality or cost advantage until the Japanese coupled SPC with a commitment to a management philosophy given to them by Dr. W. Edwards Deming. They have shown that when SPC is combined with an enlightened management philosophy, high quality at reduced cost is attainable using a process that has, through proper management, reached an ideal state.

Who is Dr. W. Edwards Deming? David Halberstam wrote in the July 8, 1984, issue of Parade Magazine that "Dr. W. Edwards Deming, 83 years old and crusty, little time to waste on politeness, and hard of hearing, is the man who, more than anyone else, taught the Japanese about quality." Halberstam continues to say that Deming is a crusader, prophet, and architect of the new economic order in which American goods must compete with those from countries where manufacturing is held in higher esteem.

William Conway, the former head of the Nashua Corporation, a company Deming helped save, refers to him as the Father of the Third Wave of the Industrial Revolution. According to Conway, the First Wave was the coming of the factory-based machinery. The Second was mass production, and the Third is the revolution created by Dr. Deming that uses statistical process controls to improve quality.

Donald E. Petersen, Ford Motor Company's Chairman of the Board, writes: "I can't speak for our competitors, but let me assure you that Dr. Deming's influence continues to be strongly felt at Ford Motor Company." Petersen continues to say that Ford is moving toward building a quality culture and that the many changes that have been taking place have their roots directly in Dr. Deming's teachings. The result, as you undoubtedly have read, is that consultants and market researchers who have made comparisons say that Ford has probably taken greater strides in improving quality than any other U.S. auto manufacturer.

Deming's Philosophy Guides Top Management

Why are Deming's philosophy and statistical process control so closely aligned with the ideal state of a process? Numerous texts, such as the excellent book by Wheeler and Chambers, provide detailed information on the tools used for statistical process control. Statistics are, however, a means to achieving a goal, and Dr. Deming outlines the philosophy and principles that are necessary in order to achieve the improved quality and decreased costs possible using statistical process control.

Deming emphasizes that top management, not equipment operators or middle managers, has the responsibility for undertaking improvement of a final product's quality and the process that created that product. He has put forth fourteen principles that distill what is necessary to achieve the desired goal of higher and more consistent quality at reduced cost. Principle Number 8, for example, deals with driving out fear. Management must take the responsibility for any faults in the production process, and workers need to feel secure enough to make suggestions as to how that process might be improved and to provide accurate information about any problems with that system. Dr. Deming cites a case where management made it clear to everyone that if the 15% waste continued the company would go out of business. Because things did not improve, an outside consultant was called in. Records showed that from the time management made it clear that 15% waste was unacceptable, the inspectors' records showed waste to be 14% and 14.5% - but never 15% or over. The inspectors were afraid to report anything over 15% for fear of losing their jobs.

Principle Number 7 says that we must improve supervision. Supervisors should help people, machines, and gadgets do a better job. They must become coaches and facilitators. Note, too, that supervisors belong to the system and need time to help people. They should not just be focusing on figures that describe the level of production or the level of mistakes in the past.

Some Thoughts on the Term "Process"

The concept of a process can be difficult to grasp. A "process" is any collection of people, machines, environmental factors and materials that, when combined, produce a result or a product. No two products are alike, nor are the results from any given process exactly the same. These differences may be large, or they may be unmeasurably small, but they are always present.

One result of knowing and using Deming's fourteen principles is understanding that every process should move toward the ideal state. Any process can be classified into one of four states:

State Number 1 is called the Ideal State. The process is in control and is producing 100% acceptable product. This is the desirable state.

State Number 2 is known as the Threshold State. The process is in control but is capable of producing some nonconforming product because the variation within the process is greater than the stated specifications. Either the specifications must be changed to be greater than the process' variation or the variation must be reduced to fall within the limits of the specifications.

State Number 3 is referred to as the Brink of Chaos. The process is out of control, but at any given time it will produce acceptable product. There is, however, no guarantee that the system will continue to produce acceptable product. To move this state toward the ideal state, one must first track the process in order to detect and eliminate the cause or causes of the problem.

State Number 4 is known as Chaos. The process is out of control and is producing some unacceptable product. When a process is out of control, it means that you cannot predict what will happen. No matter what you try in order to bring the system into control, no solution works for long. The process is always changing, and one begins to speak in terms of "magic", - "art", and "craft". To move this state toward the ideal, one must track the process in order to eliminate special causes, and if necessary, reduce the variations within the system.

This is where statistical process control becomes necessary. SPC measures the quality of the process rather than the product or end result. SPC permits one to track the process and identify those variables that are inherent in the system as opposed to those that are caused by special reasons, such as materials, people, or customers.

Statistical Process Control: More Than Control Charts

Note that SPC is not only the use of statistics. It is a way of thinking about controlling a process and the discipline needed to establish these controls. As described earlier, every production process consists of people, machines, and materials together which, with their combined variations, produce a product that has variation in it. The traditional detection system in America has been inspection: the product is inspected after it is produced for conformance to some specification. Some product is good and is accepted, while some is not good and is rejected.

This type of quality control system has several disadvantages including:

- No inspection system is perfect.
- The costs of manufacturing are high, and it is always more expensive to sort out good product from bad after it has already been produced.

- The feedback loop is slow and inaccurate. Many times the inspection process lags the manufacturing process by several days.

Inspecting quality into the product is impossible, and the disadvantages noted above are just not acceptable. The product must be built right the first time. To effectively control quality, we must control the process. We want, in effect, to measure the quality of the production process rather than that of the end product. Our objective should be the development of a quality process so that we can produce a quality product.

Consequently, a prevention strategy using SPC is essential. Through monitoring process variability, we can recognize conditions which cause variations at the earliest possible times. Also, in accordance with Deming's directive that equipment operators have responsibility for controlling the process, SPC gives the operator information to make timely and accurate decisions. With statistical process control tools, all the early inputs to the manufacturing process permit production of the desired quality -- consistently.

SPC techniques are not arbitrarily used, but are directed toward solving specific problems. The first steps is to decide where problems are and to rank them. As in most manufacturing or service processes, there are a finite number of variables to control in order to produce a quality product. The task is to identify those variables having the greatest effect on the problem. This requires teamwork. Remember: the control chart is designed to identify problems as they develop.

For control charts to be effective they must always be used to help the operator because the operator controls the process. Control charts provide fast, accurate feedback which defines when to adjust the process and, equally important, when to leave it alone. The control chart allows the process to talk directly to the operator.

Finally, statistical process control is not something that you read a book and all of a sudden you are doing it. It is a disciplined way of thinking and controlling a process. It involves the most important part of the process -- people. It requires diligence and close attention to details. When used properly, and coupled with a philosophy that combines the resources of a company with a dedicated team of workers, SPC produces higher quality results at a significantly reduced cost.

GCA's Print Properties Committee, consisting of technical representatives from agencies, printers, and paper, ink, blanket, and other suppliers spent the last year learning about X-Bar, Range, and Run charts. At RIT's invitation, a Committee-coordinated press test took place in the fall of 1987 at RIT for the purpose of using the recently learned SPC tools. Committee members had, with RIT cooperation, previously collected samples from an August press run for comparison analyses.

The tests were run at the Technical and Education Center of the Graphic Arts at RIT on a Harris Graphics M1000B press. The objective of the effort was to provide data that could be used by the Materials Interaction Task Force to gain greater understanding about variability and control chart techniques Consequently, this was not a controlled experiment where great attention was given to all details of the many conditions that exist on press and can change during the press run. However, care was taken to insure that the primary conditions of press, paper, ink, fountain solution, plates, and inking sequence were duplicated. The same crew also worked on both press runs.

The August Run

The August run was made in conjunction with the printing of *Image World*, a full-color publication on careers in the graphic arts produced by RIT and mailed to high school students and guidance counselors. For this run, the press crew was given their normal set of instructions, namely, once the OK sheet was obtained, to do whatever they felt necessary to maintain the desired color balance. The exact actions taken and the frequency of each were not documented. However, according to members of the press crew, numerous "corrections" were needed in order to maintain proper color balance. These corrections included both changes to ink key settings as well as adjustments to the fountain solution.

The October Run

The October run was made specifically for the Task Force. A brochure detailing the principles associated with GCA's Quality Process Commitment (QPC) program was used as the test form. It was similar in design and layout to the *Image World* piece printed in August. However, in this case, the press crew was asked not to touch the press once the OK sheet had been obtained. We wanted the press to run regardless of what the operators thought should be done. They were asked to stand by for action only of an unavoidable need such as a web break or paper splice occurred. They could not, of course, believe that we would want the press to run unattended, and I am sure they thought we were crazy. Some of them wished us "good luck" in the belief that luck was the only thing that would save the job.

Sampling Procedures

The August Run

Two different procedures were followed for pulling the sample press sheets from this run. First, for the purpose of obtaining subgrouped data for the creation of Shewhart control charts, five consecutive signatures were pulled every 20 minutes to give a subgroup size of $n = 5$. Additionally, during the middle of the run, a single signature was pulled every two minutes over a 90 minute time period.

The subgroups of $n = 5$ gave limited insight into the process behavior since at the speed that the press was running each subgroup represented about one second of press time. Consequently, the variation observed was extremely small, resulting in control limits that were unrealistically tight.

The individual signatures pulled every two minutes provided the most useful insight into process variation and capability. All of the data analysis for this study made use of readings on these individual sheets.

The October Run

During the October run, in an attempt to employ a subgrouping method that would give insight into natural process variation, 100 consecutive signatures were pulled every 2000 impressions (approximately every 10 minutes). The first, fiftieth, and one hundredth signature in each set of 100 were used to create subgroups. Additionally, one signature was pulled every two minutes throughout the approximately 90 minute press run.

The subgrouping technique employed for this run again was such that the estimate of natural process variation was unrealistically small. These data were abandoned in favor of the individual samples taken every two minutes.

Response Variables

The Materials Interaction Task Force decided that the two response variables of greatest interest were solid ink density and dot gain in the 50% screen. Consequently, the forms printed for both press runs contained the GATF/SWOP Production Control bars as the test target. A color bar that was in-line with the important color components for both press sheets was selected as the target to be measured. All measurements were made with the same equipment, all of which conformed to the SWOP specifications.

Solid Ink Density

Reflecting commonly used values, the aims and specification limits for the solid ink densities for each of the colors were determined using SWOP information and were the same for both runs. These are shown in Table 1.

Dot Gain (50% Screen)

The aims and specification limits for dot gain in the 50% screen were 24% ± 4%, giving upper and lower specification limits of 20% and 28% for all colors, reflecting commonly used values stated in the SWOP Specifications.

Data Analysis and Interpretation

There are a variety of statistical techniques that could be used to evaluate the consistency of the two press runs. In fact, as stated earlier, the central purpose of the two runs was to provide the Task Force with data to which they could apply the control chart techniques they had previously been exposed to. For this paper, the data from the press sheets taken at 2 minutes intervals will be presented in the form of time charts, histograms, and descriptive statistics.

Time Charts

A time chart is a simple display of a process variable as a function of time or sequence. It reveals the fundamental process property of stability. A stable process is one where the variable studies fluctuates in a random fashion at a fixed level. Such randomness is a sign that only chance or natural factors are influencing the process behavior. However, randomness is difficult to evaluate, so we usually look for the opposite, such as runs, trends, and cycling patterns. These represent significant sources of variation and are said to be from assignable causes.

Figures 1 through 4 show the time charts for the solid ink densities of all four colors from the August run. In every case there is evidence of a lack of stability in the plots. In other words, it appears that none of these colors reached a natural level of variation.

Figures 5 through 8 contain the time charts for the solid ink densities of all four colors from the October run. Here, with the exception of the yellow ink density, there is a stable level of variation. The randomness of these plots, which can be thought of as inherent noise, indicates that the process variation is natural and common. The continuous upward trend in the yellow ink density is an indication of an assignable cause in the process. This is an unnatural pattern. Something other than natural factors is influencing the behavior of this response variable.

Figures 9 through 12 show the time charts for the dot gain of all four colors from the August run. In this case, there appears to be a lack of stability throughout the run for the black, for about the first one third of the run for the cyan, and for early on for both yellow and magenta.

Figures 13 through 16 show the time charts for the dot gain of all four colors from the October run. Here, except for a gradual, long term upward trend in the black, the plots indicate a stable, in-control process.

For all of the charts shown in Figures 1 through 16, the pattern of the data points is more important to understanding process behavior than is their level or average.

Frequency Histograms

The frequency histogram (or simple histogram) is an additional tool for graphically analyzing a set of data. It gives a snapshot of the overall pattern of variation. When continuous variables such as ink density and dot gain are measured, the overall pattern of variation should be bell-shaped if only chance causes are affecting the outcome. This symmetrical, bell-shaped pattern is termed the normal distribution. If the resulting data do not fit a bell-shaped pattern, it is taken as a signal of an assignable cause problem. As was the case with the time chart, we have a model against which we can compare process data to determine the nature of variation. On each of the histograms, the upper and lower specification limits have been included to aid in the evaluation of data.

Figures 17 through 20 show the histograms of the solid ink densities for all four colors from the August run. In every case, the patterns fail to show a normal distribution, indicating the presence of one or more assignable causes in the system. Also, the spread of the data exceeds the total tolerance for each color.

Figures 21 through 24 contain the histograms of the solid ink densities for all colors from the October run. With the exception of the yellow, the data show a reasonable fit to the normal distribution. Additionally, the spread in the data is either equal to or less than the total process tolerance.

Figures 25 through 28 show the histograms for the dot gain for all four colors from the August run. The yellow and magenta histograms begin to look bell-shaped, but the cyan and black show some skew, indicating the likely cause of an assignable cause for these colors. Notice that in all cases the spread of the process data exceeds the total tolerance or permissible variation.

Figures 29 through 32 show the histograms of the dot gain for all four colors from the October run. The data assumes a normal distribution for every one of these colors that is equal to or less than the total tolerance.

Descriptive Statistics

The story of variation in these two press runs is best told by the graphs. However, it is possible to characterize further the differences by computing some key statistics. The statistics determined are shown in Table 2.

The mean for each data set was computer to obtain an estimate of process centering. The difference in these values is of little interest, since it is independent of the consistency of the run.

The standard deviation was computed to obtain an estimate of present in each run. Notice that in all cases, the standard deviation was was smaller for the October run than for the August run.

The variance was computed to obtain an additional estimate of variation that could be used to test significance. A series of F-tests were performed on the paired variances and in every case significance was shown at the 99% confidence level.

The process capability is defined as six standard deviations and defines the amount of natural variation to be expected in each of the systems.

The total tolerance is obtained by simply subtracting the lower specification limit from the specification.

The capability index is found by dividing the total tolerance by the process capability. It is an index that describes the ability of the process to meet the specifications that have been set. A capability index of 1.0 means that the process capability is just equal to the total tolerance. Therefore, when the index falls below 1.00, it indicates a system will unavoidably be producing non-conforming product. At no time was this index at or near 1.00 for the August run. Notice that in all cases this index is higher for the October run, and in many cases substantially higher.

Press Test Conclusions

As a result of this study, the following conclusions were reached:

1. Variation found in solid ink density and dot gain was significantly smaller in the press run during which the operators were not allowed to alter the process.

2. With few exceptions, the stability of density and dot gain was significantly better in the press run during which the operators were not allowed to alter the press.

3. The process capability of meeting specifications for all variables was significantly higher in the press run during which the operators were not allowed to alter the press.

4. Statistical process controls methods can be successfully applied to the print production process.

Implications and Recommendations for Future Work

The implications of these results and conclusions are as follows:

1. It is possible that a significant source of press variation is caused by the operators "over-controlling" the process. It appears that many press operators mistake natural press variation for real, or assignable, changes in the process and as a result take what they believe to be justifiable action to correct for this variation. Many such unneeded actions added together can increase, rather than decrease, the overall variation of a process. Although press operators want to do their best, this may not, as Dr. Deming has stated, be good enough unless they have accurate and timely knowledge about their process. Operators have been taught that press corrections are their responsibility and they are rewarded for taking such actions. Perhaps it is time to review the teachings, tools, and techniques with which we equip them.

2. A more complete understanding of the concepts of variation and the tools for measuring and controlling variation would be a major source of benefit for printers. It It is the goal to produce printed products that meet customer requirements, or specifications. True improvements in quality of the product can only be achieved through improvements to the process. This means that printing presses must not only be operated at the correct level of ink density and dot gain, but also with small enough variation to ensure that all of the output conforms to specifications. In other words, anything that we can do to reduce the process variation will translate into a higher percentage of acceptable product.

3. If these test results are not atypical, it is not surprising that many printers rely upon inspection as a major quality control tool. Even when the process is running with apparent stability, there are times when specifications such as SWOP are not met. When a production press is producing a high percentage of non-conforming product, inspection is the last ditch effort in attempting to achieve customer satisfaction.

4. If the October run reflects the most consistent press output achievable today, it indicates that specifications such as SWOP may well be unrealistically tight. Consequently, these specifications could be reviewed with an eye toward achieving a better balance between customer needs and

production capabilities. Having a set of unrealistic specifications leads to unhappiness on the part of both customer and producer.

5. Since this was by no means a definitive study, it seems that further studies of press performance with and without operator influence and other factors should be undertaken to provide greater insight into this issue.

Summary

The success of the Deming philosophy and SPC has been demonstrated over and over again by the Japanese. A key reason for this success is a strict adherence to the principles put forth by Dr. Deming. He makes it clear that these principles of management and proper use of SPC tools cannot be compromised. Consequently, GCA has made a commitment to establish a program, called the Quality Process Commitment (QPC) Program, that will guide the printing and publishing community in the proper use of Deming's philosophy and SPC tools. We have published a booklet outlining the foundation for this program and will be working cooperatively with RIT, Sinclair Community College and other institutions in the program implementation. Your inquiries are welcome.

Table 1.
SWOP Specifications on Solid Ink Density

	Yellow	Magenta	Cyan	Black
Upper Spec	1.06	1.35	1.27	1.48
Lower Spec	0.74	1.07	1.03	1.18
Aim	0.90	1.21	1.15	1.33

Table 2.
Comparison of Key Statistics

	Mean	Standard Dev.	Variance	Process Capability	Total Tolerance	Capability Index
	Aug / Oct	Aug / Oct	Aug / Oct	Aug / Oct	Aug / Oct	Aug / Oct
Dot Gain						Cp best if > 1.00
Yellow	29.16 / 22.22	1.84 / 1.01	3.38 / 1.04	11.03 / 6.11	8 / 8	0.72 / 1.31
Magenta	23.31 / 25.95	1.70 / 0.92	2.88 / 0.85	10.19 / 5.52	8 / 8	0.78 / 1.45
Cyan	22.48 / 22.00	2.40 / 1.36	5.75 / 1.87	14.38 / 8.20	8 / 8	0.56 / 0.98
Black	28.93 / 30.70	2.89 / 1.99	8.34 / 3.96	17.33 / 11.93	8 / 8	0.46 / 0.67
Solid Density						
Yellow	1.08 / 0.84	0.14 / 0.14	0.021 / 0.019	0.87 / 0.83	0.32 / 0.32	0.37 / 0.38
Magenta	1.23 / 1.33	0.11 / 0.05	0.012 / 0.002	0.66 / 0.28	0.28 / 0.28	0.42 / 1.01
Cyan	1.00 / 1.26	0.18 / 0.03	0.034 / 0.001	1.11 / 0.20	0.24 / 0.24	0.22 / 1.22
Black	1.39 / 1.74	0.20 / 0.04	0.041 / 0.002	1.21 / 0.24	0.30 / 0.30	0.25 / 1.26

Figure 1.
Time Plot of Solid Ink Density (Yellow) August Run

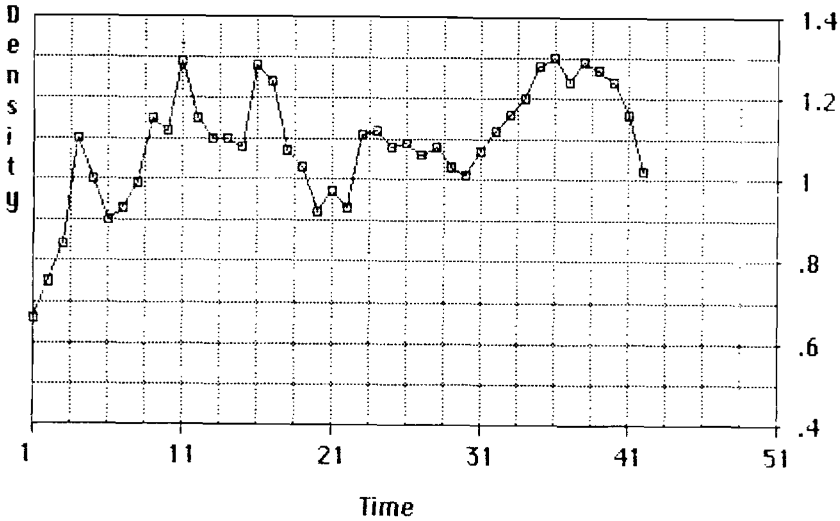

Figure 2.
Time Plot of Solid Ink Density (Magenta) August Run

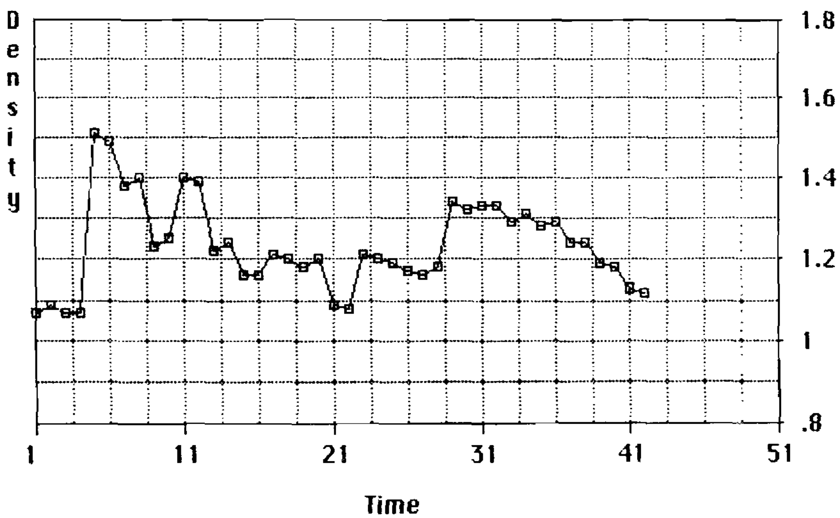

Figure 5.
Time Plot of Solid Ink Density (Yellow) October Run

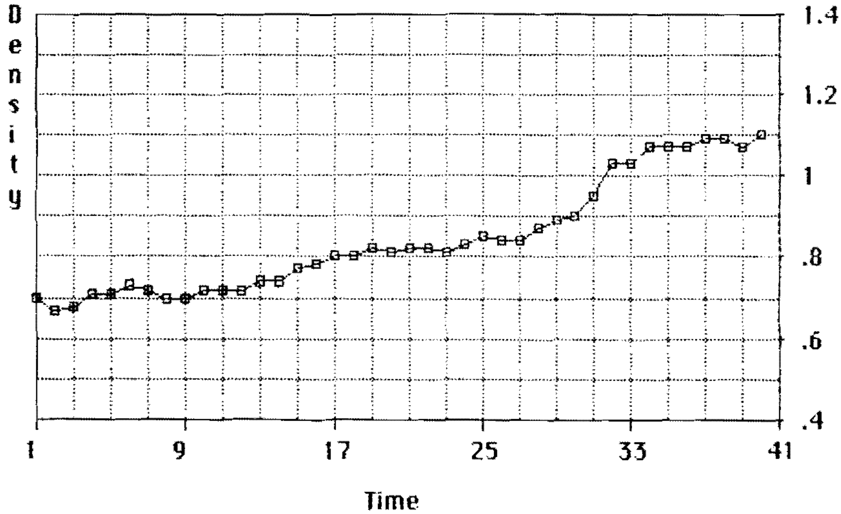

Figure 6.
Time Plot of Solid Ink Density (Magenta) October Run

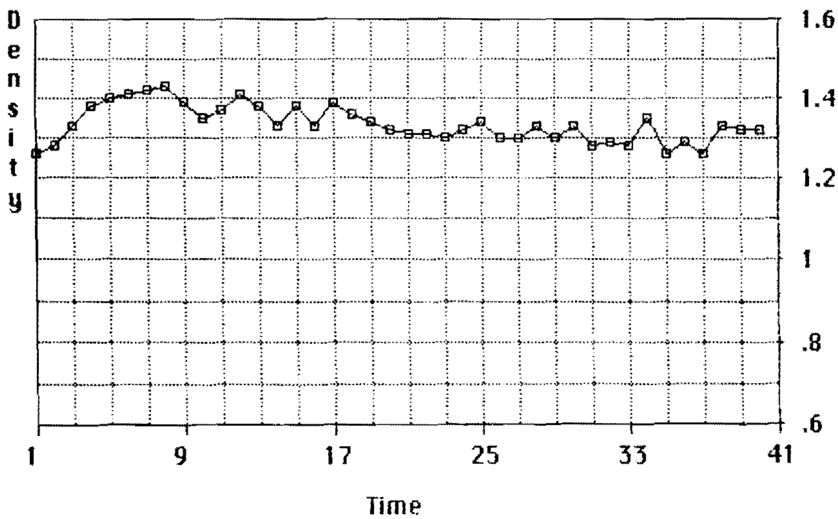

Figure 7.
Time Plot of Solid Ink Density (Cyan) October Run

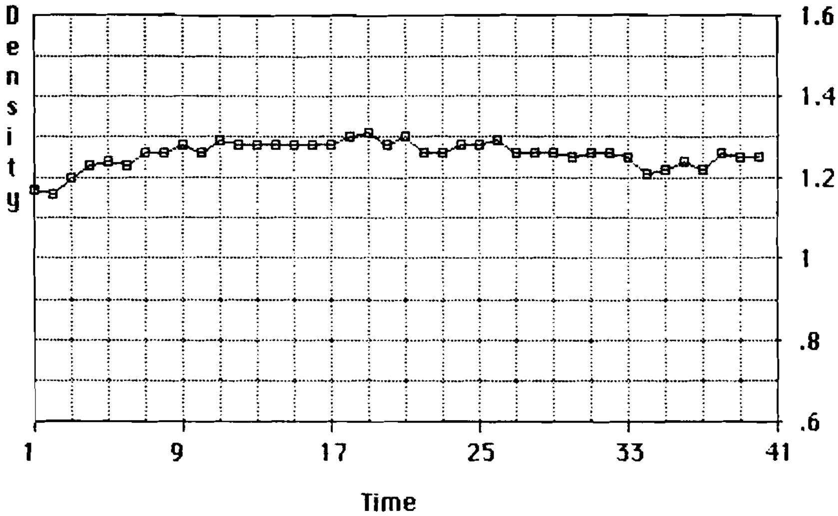

Figure 8.
Time Plot of Solid Ink Density (Black) October Run

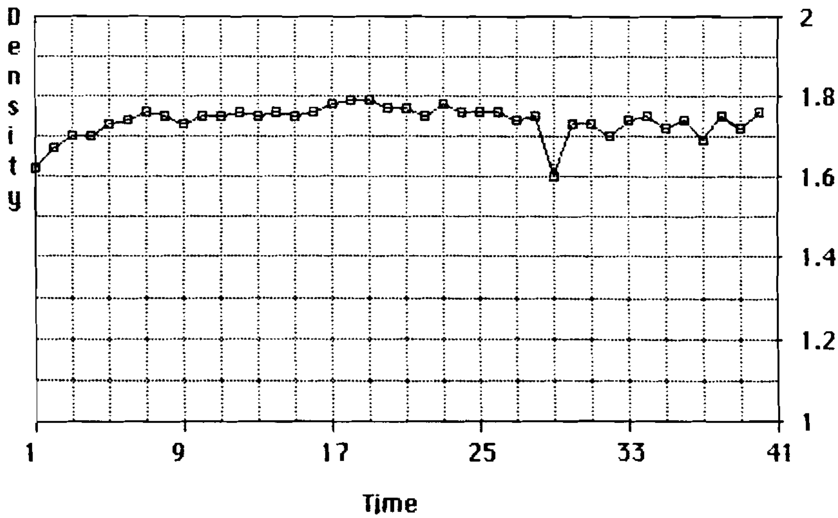

Figure 9.
Time Plot of Dot Gain (Yellow) August Run

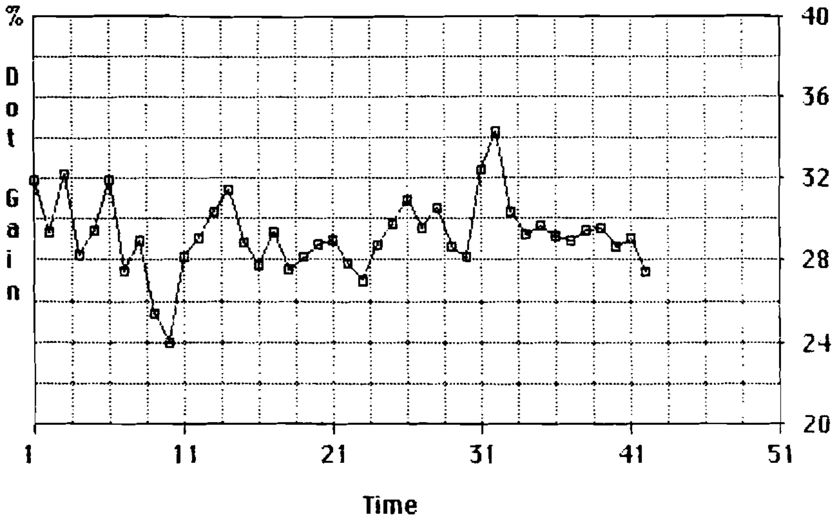

Figure 10.
Time Plot of Dot Gain (Magenta) August Run

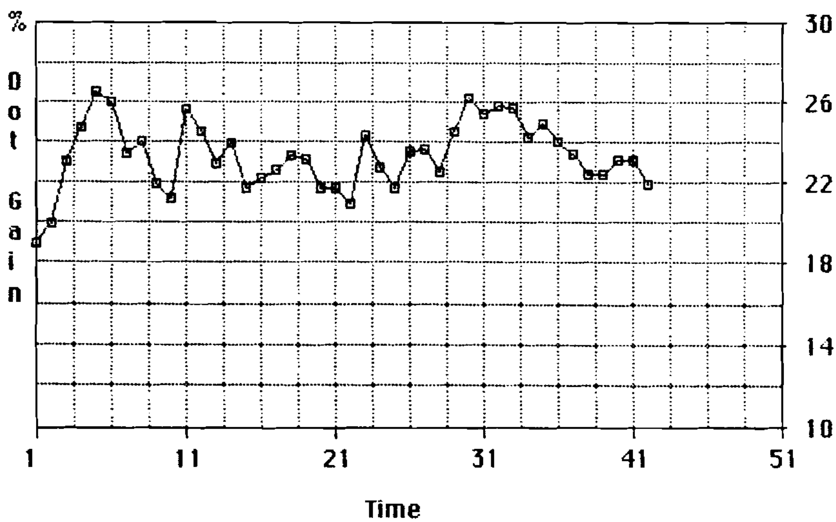

Figure 11.
Time Plot of Dot Gain (Cyan) August Run

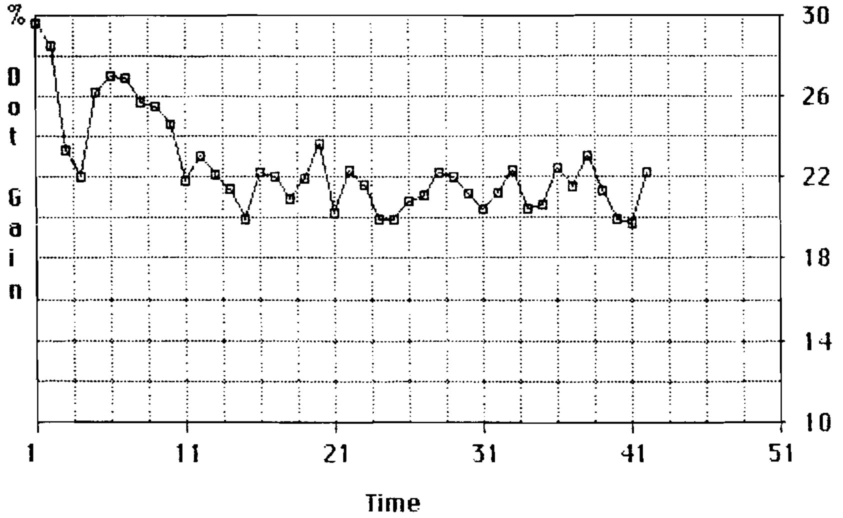

Figure 12.
Time Plot of Dot Gain (Black) August Run

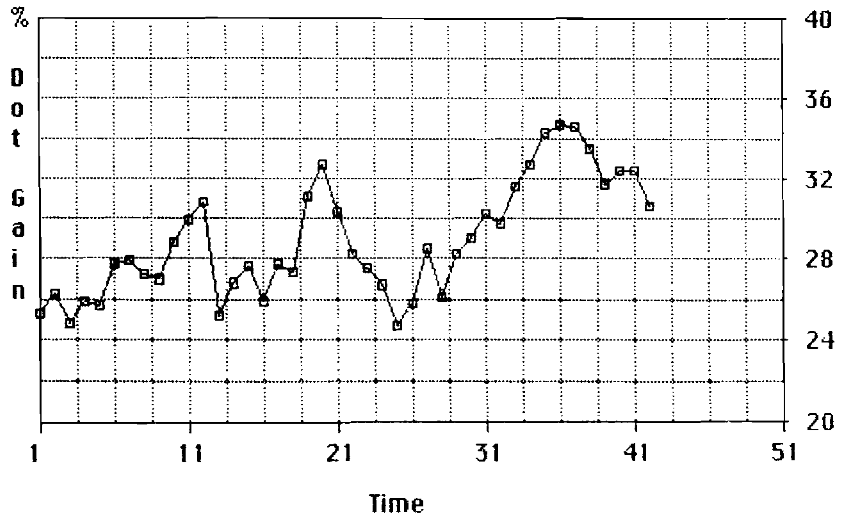

Figure 13.
Time Plot of Dot Gain (Yellow) October Run

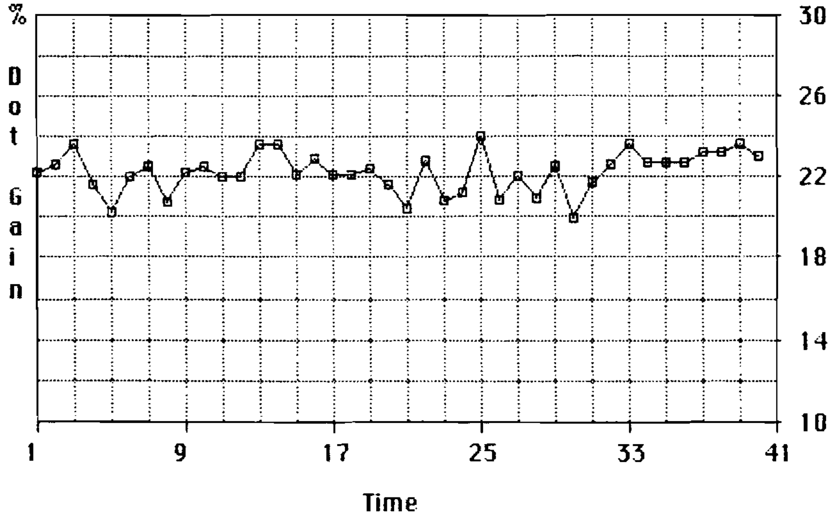

Figure 14.
Time Plot of Dot Gain (Magenta) October Run

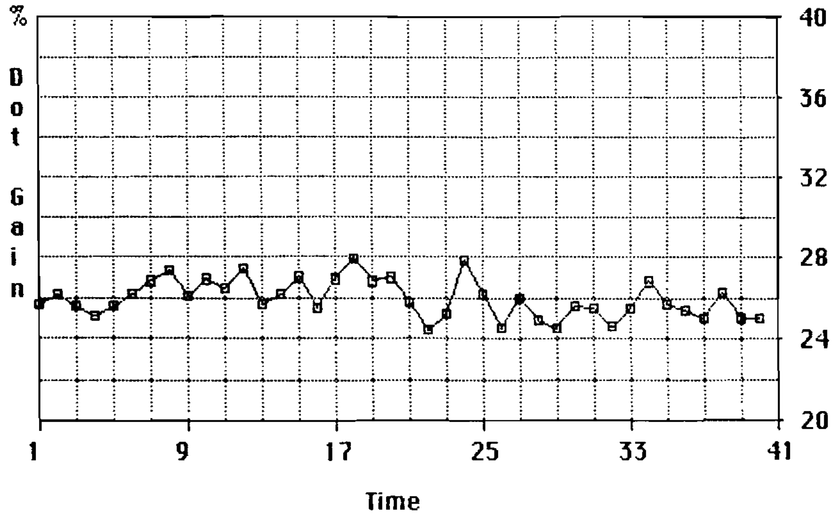

Figure 15.
Time Plot of Dot Gain (Cyan) October Run

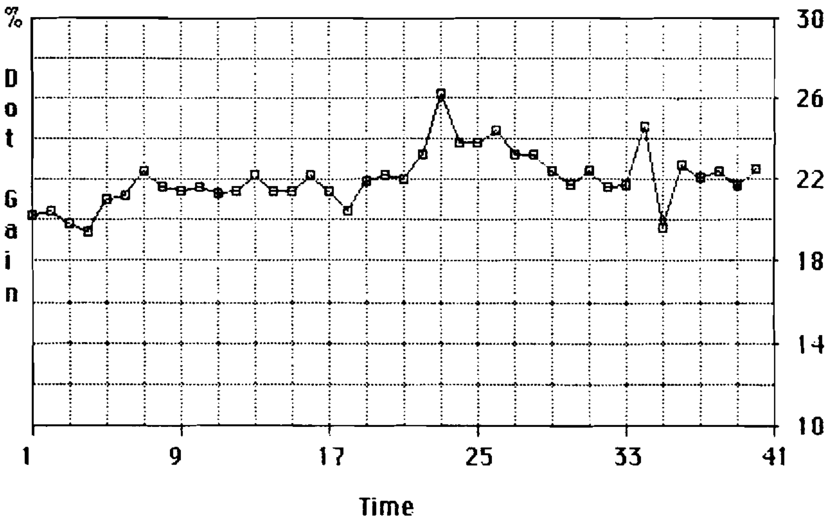

Figure 16.
Time Plot of Dot Gain (Black) October Run

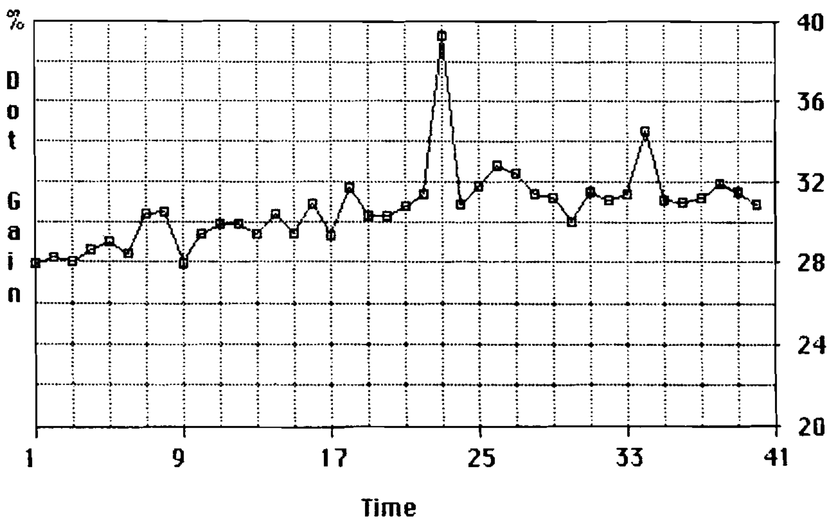

Figure 17.
Histogram of Solid Ink Density (Yellow) August Run

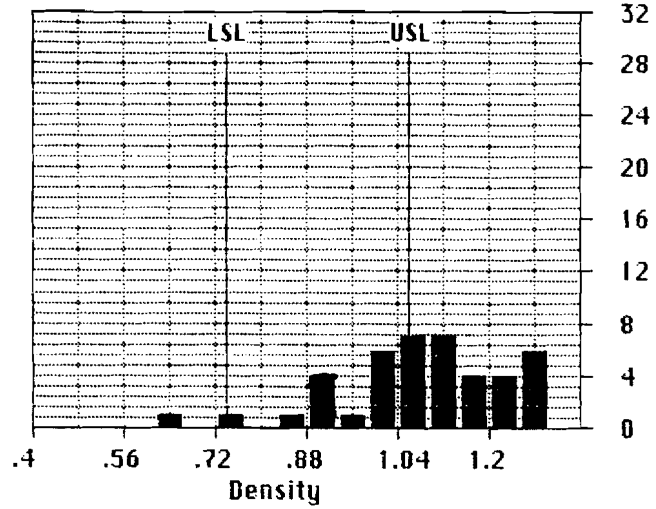

Figure 18.
Histogram of Solid Ink Density (Magenta) August Run

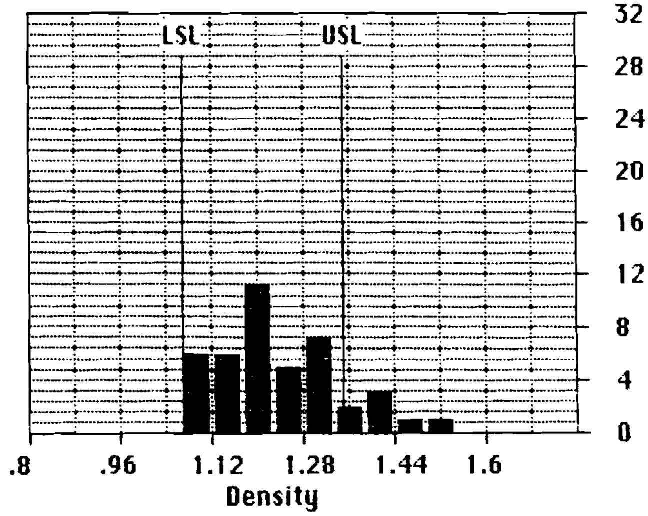

Figure 19.
Histogram of Solid Ink Density (Cyan) August Run

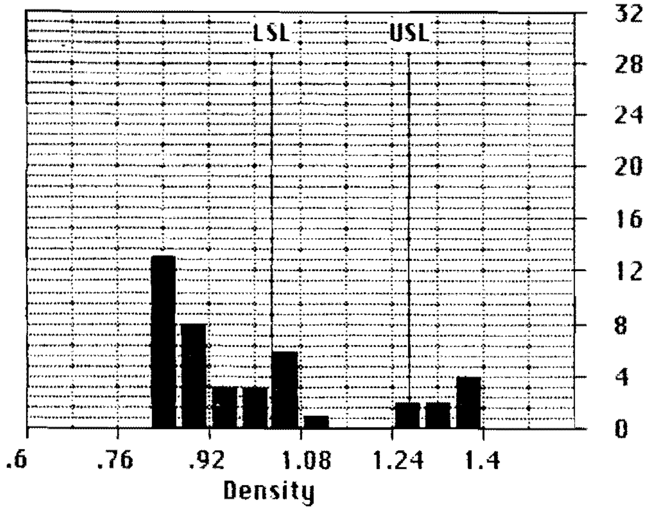

Figure 20.
Histogram of Solid Ink Density (Black) August Run

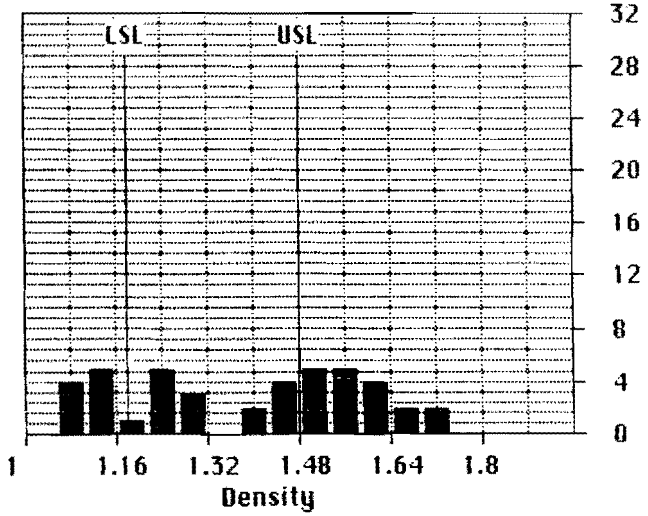

Figure 21.
Histogram of Solid Ink Density (Yellow) October Run

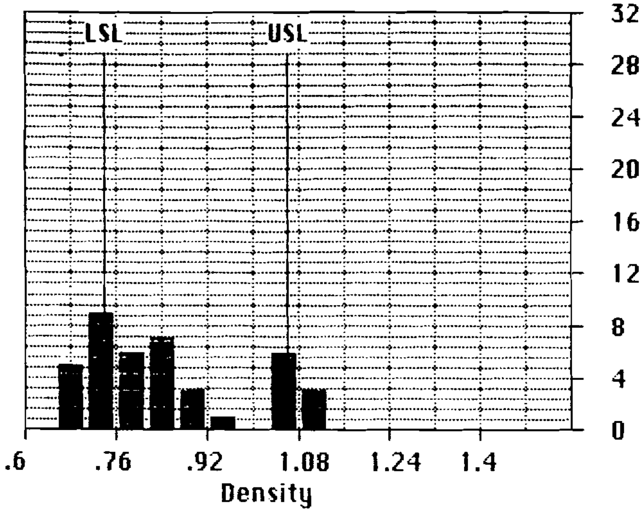

Figure 22.
Histogram of Solid Ink Density (Magenta) October Run

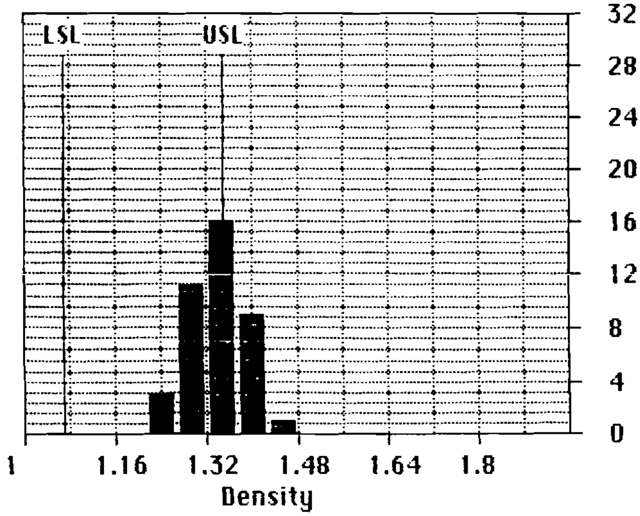

Figure 23.
Histogram of Solid Ink Density (Cyan) October Run

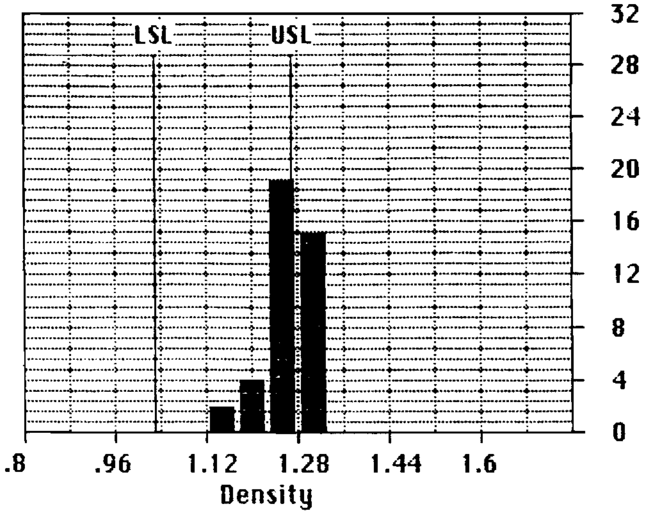

Figure 24.
Histogram of Solid Ink Density (Black) October Run

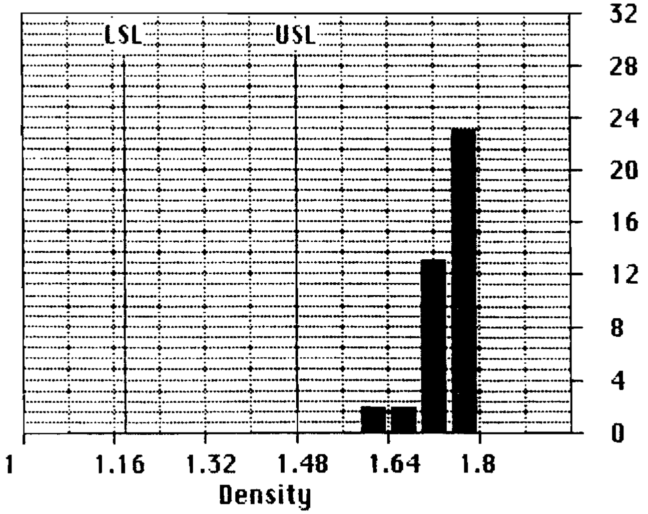

Figure 25.
Histogram of Dot Gain (Yellow) August Run

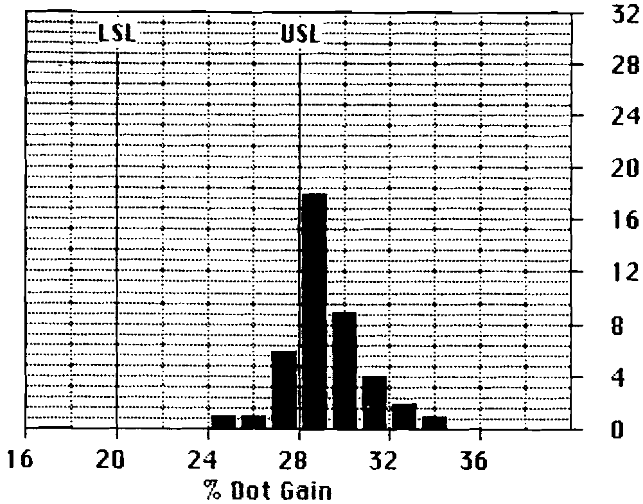

Figure 26.
Histogram of Dot Gain (Magenta) August Run

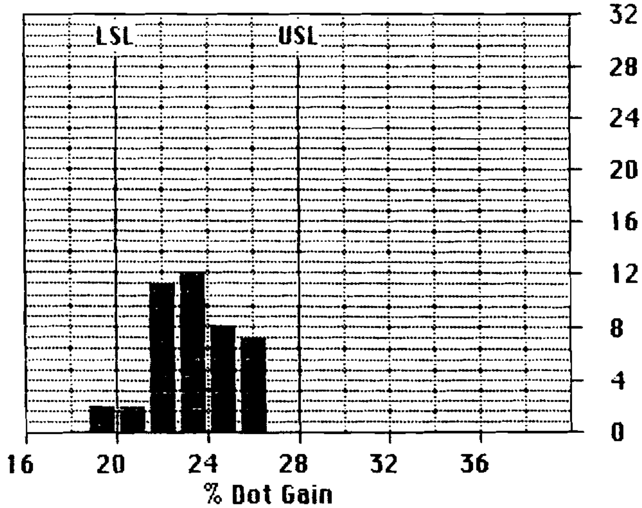

Figure 27.
Histogram of Dot Gain (Cyan) August Run

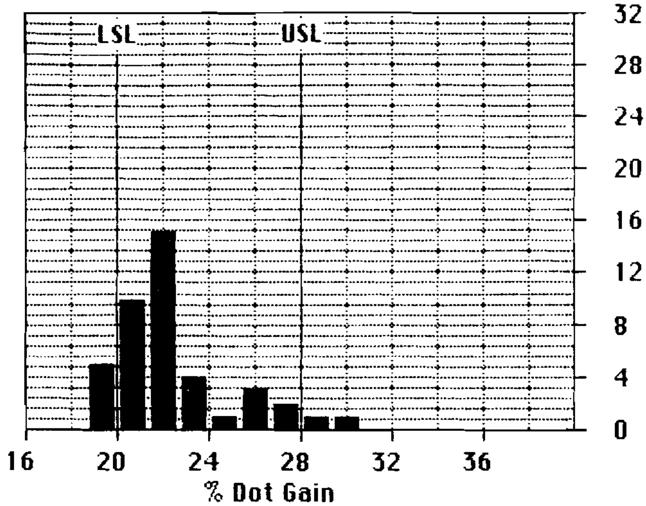

Figure 28.
Histogram of Dot Gain (Black) August Run

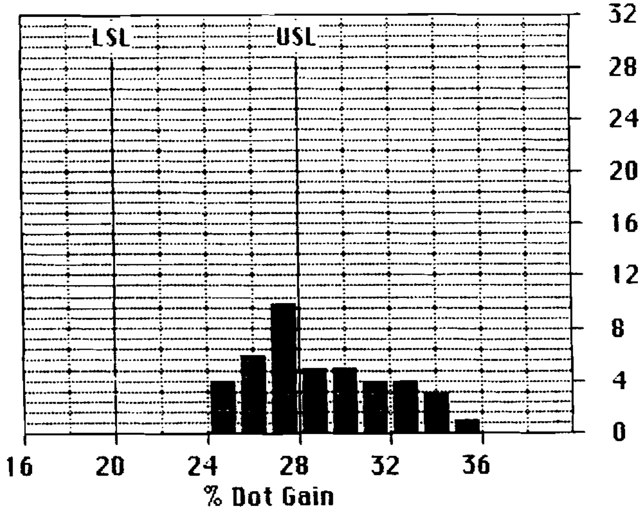

Figure 29.
Histogram of Dot Gain (Yellow) October Run

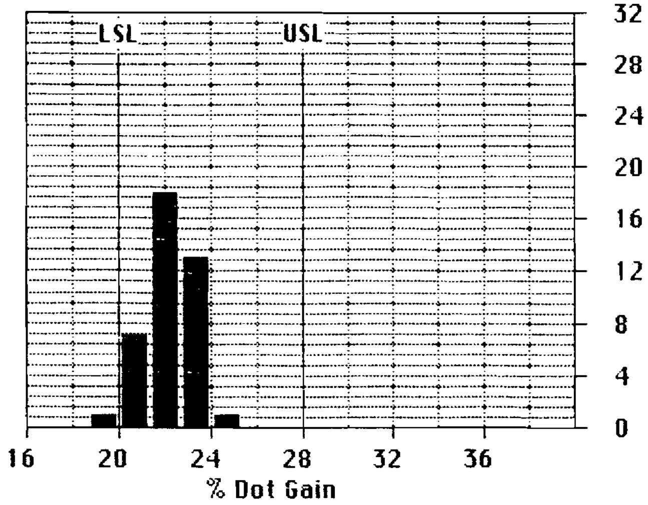

Figure 30.
Histogram of Dot Gain (Magenta) October Run

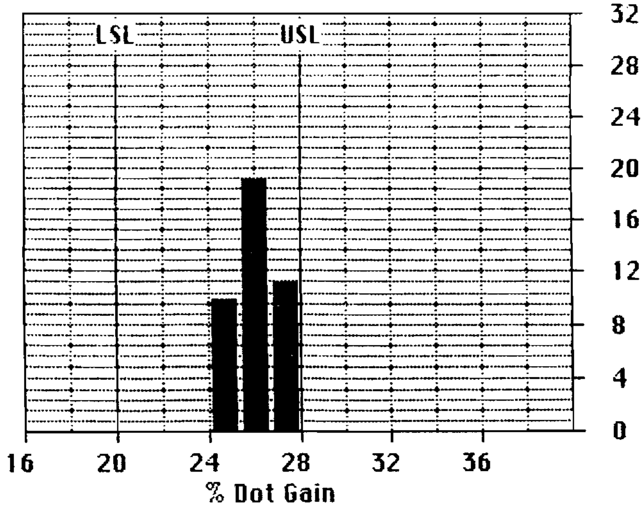

Figure 31.
Histogram of Dot Gain (Cyan) October Run

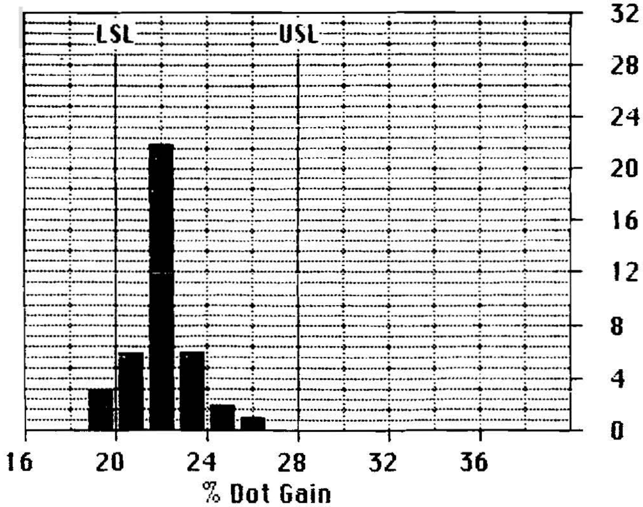

Figure 32.
Histogram of Dot Gain (Black) October Run

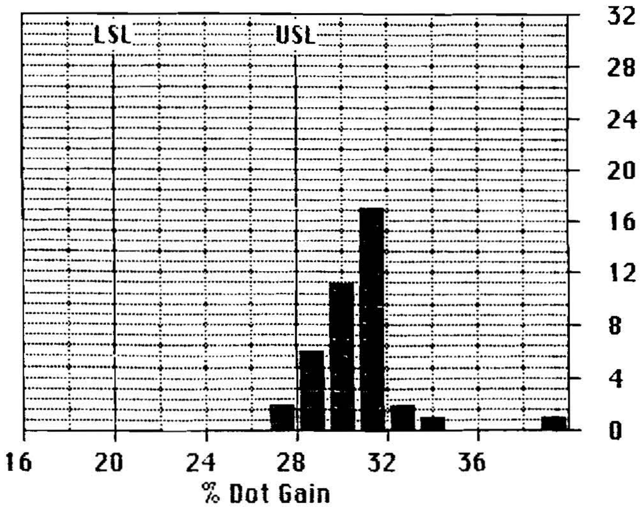

Figure 3.
Time Plot of Solid Ink Density (Cyan) August Run

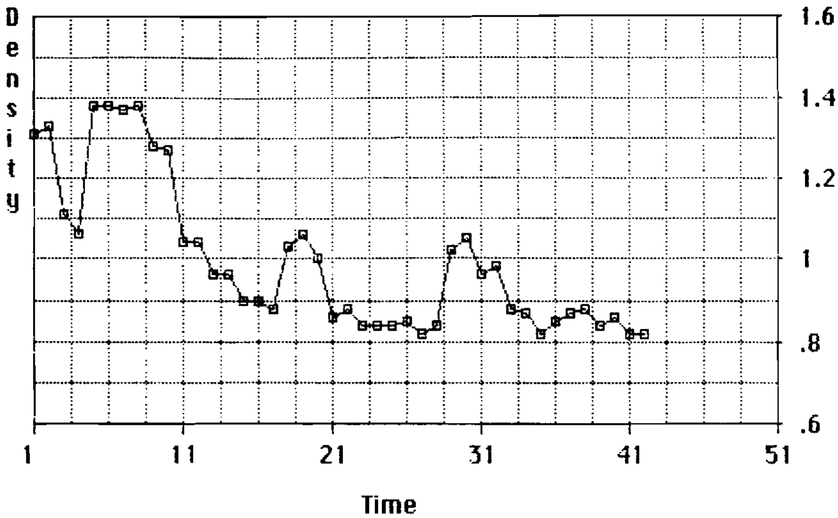

Figure 4.
Time Plot of Solid Ink Density (Black) August Run