Guideline for Uniform Ink Sample Preparation and Opacity Measurement

Part One of Three

By Dawn M. Hohl

As the world grows more technically advanced and quality oriented each day, the demands being placed on industry by the customer are becoming more specific and stringent in every respect. Products readily approved in the past are unacceptable in today's standards as consumers are requiring tighter tolerances and controls to be held, thereby elevating the quality, repeatability and reproducibility of that product. As if this was not enough, increased competition from other technologies and new market opportunities are also compelling companies to improve their current capability.

This type of pressure has forced many industries, including the screen printing industry to implement quality control and statistical process control programs in their processes in order to achieve and maintain the quality now being demanded.

Material sampling and testing must be an integral part of any effort to control and improve a process and its resulting product. The responsibility of testing does not fall on either manufacturers of equipment and supplies, or on companies utilizing these materials in a process alone. Both groups must undertake measures to ensure that the end result or product of their process meets the quality standards set by their customers.

For example, if a material is introduced into a process and does not meet the specifications that have been established for it to function appropriately in that process, or if no specifications have been set-up the end result is the same. The impurities, imperfections and undesirable characteristics will be magnified throughout the entire process and will adversely affect the quality of the end product. In many cases this end product becomes an input into another process and the cycle repeats itself, causing even greater difficulties. It is for this reason that both manufacturers and printers alike must be concerned and give attention to the quality of process input and control of that process.

The topics covered in this three-part research report are intended to help fulfill these goals as the important issues of ink sample preparation and opacity measurement are discussed.

It is a logical conclusion that the requirements our technically inclined world is placing on the products it will accept and purchase will not be relaxed in the future but rather will increase as the world progresses and its needs change and expand.

The Screen Printing Technical Foundation has been established to anticipate these needs and provide the screen printing industry with guidelines, techniques and insight into the screen printing process helpful to companies working to meet the requirements of the future, as well as improving their ability to meet today's standards.

The focus of this three-part project report is on ink deposit sample preparation methods and their ability to produce quality repeatable samples for testing purposes. In the first of this series a basic discussion of laboratory sampling and testing concepts will initially be covered with a detailed explanation of the purposes and critical characteristics of an ink sample, and the selection of a proper substrate for testing also being addressed later in this paper. An understanding of these topics will set the stage for presenting actual research results on the methods and techniques currently being used for ink sample preparation in the screen printing industry in Part Two of the series. Finally, in Part Three the measurement and evaluation of the opacity attribute will be defined and explained thoroughly.

The topics presented in Part One will provide the reader with important background information necessary to establish the significance of the results contained in Part Two. The reader is encouraged to complete the first report prior to reading the second in order to obtain a complete understanding of SPTF's findings.

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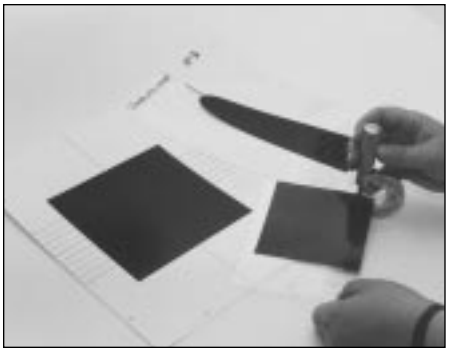

Figure 1. Ink deposit samples used to measure and evaluate characteristics of an ink.

Figure 2. Incoming quality control can assure that only quality input is accepted and purchased for use in production. This is one reason why it is desirable to sample and test ink in a laboratory situation.

Figure 3. When modifying or combining ink it is important to test the resultant mixture to ensure its characteristics are within acceptable limits before introducing it into the production process.

Laboratory Sampling and Testing Concepts

Definition of A Sample

In the screen printing process, there are several main areas where testing is focused, including the screen, the stencil, the substrate, the ink, and the end print. To perform tests in these areas a sample must be selected or created as the object to measure. Sampling is done in order that measurements be kept to a minimum while still providing accurate data by which assumptions can be based on the material being analyzed. In order to establish this confidence, the sample must be representative in every respect of the greater whole or group presented for inspection. Webster's defines a sample as "a finite part of a statistical population whose properties are studied to gain information about the whole."

In the instance where a sample is simply selected from the whole and does not require modification for testing, a random selection process is often implemented. However, when a sample must be created, or the product being tested modified in some form before being examined, many considerations come into play. Such is the case with many of the variables present in the screen printing process.

An example of a variable that must be modified or created is an ink deposit sample which will be the focus of our analysis. Before moving on, let us define an "ink deposit sample" in specific terms to clarify what we are speaking about in the context of the report. An ink deposit sample can be described as a layer of ink of a specified thickness that has been applied by some type of method or technique to a substrate, and is measured or evaluated to quantify characteristics of that ink and/or its effect on the substrate (Figure 1).

Why Test In A Laboratory?

There are a couple of reasons why it is desirable to sample and test materials such as ink at a laboratory station. The first important need that can be satisfied is the evaluation of the quality of the materials purchased from outside vendors that will eventually become part of your process (Figure 2). Implementing incoming quality control measures on these materials serves as a checkpoint on the consistency of a vendor's product, and assures that only quality input is accepted and purchased for use in production.

Another vital area that must be monitored and controlled is any in-plant modification, mixing or altering of a process input (Figure 3). Specifications and tolerances should be established for the converted material so quality and consistency is again assured before a product enters production. After all, it is relatively inexpensive to find and correct undesirable property in a material in a small scale testing situation, than during a production run where a great deal of material, labor and press time would be lost as a result. Such quality control practices will help eliminate costly mistakes and rejects by enabling a company to "do it right the first time."

Importance of Laboratory Conditions

Sampling and testing in a laboratory situation (as opposed to a production situation) has both advantages and disadvantages, but as we have seen it is a necessary evil if quality is to be assured. Understanding the benefits and limitations of a laboratory setting is essential if accurate and beneficial results are to be obtained and properly interpreted.

There are some obvious advantages to creating and testing samples in a separate environment from the main production area. Smaller scale equipment may be utilized saving set-up and material costs and freeing up production equipment for profitable work (Figure 4).

Samples can thereby be produced quickly on a continuous basis rather than taking the time and labor to set-up and run a large piece of equipment to create several samples for testing purposes. In reality, use of production equipment for day-to-day sample generation and testing is

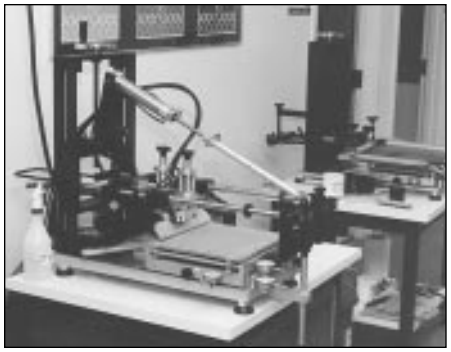

Figure 4. Smaller scale equipment can be utilized in a testing environment, saving set-up and material costs.

Figure 5. Regular preventative maintenance is an important requirement for laboratory equipment used in sample generation and measurement.

Figure 6. Instrument calibration should be checked and updated as required on test equipment.

not considered practical and is generally ruled out as a feasible option to creating samples.

The use of laboratory equipment and methods to simulate an actual product generated on production equipment presents many considerations and challenges; however, one cannot simply produce a sample with just any method and utilize it to represent what will actually be produced. As we have already covered, a true sample must typify the larger whole, or the information desired from that sample will misrepresent the population and thereby be useless as a tool for control.

Every effort must therefore be made to imitate production conditions as closely as possible, while still enabling the sample to be reproduced repeatedly. Understandably, exact replication would be difficult and costly and may be impossible in some cases. However, there are many small measures that can be easily implemented to the testing process that can greatly increase the accuracy of the results obtained.

Small, mundane details can often be overlooked causing disastrous results, as these items quite often greatly affect the sample being produced for testing. A few examples of these technicalities for ink deposit samples are ink mixing time, force drying as opposed to air drying, and time frame before measuring a dried/cured sample. All of these seem negligible, but in fact cause inconsistencies in the sample if they vary sporadically in the lab, and if they vary greatly from practices used in production.

To eliminate these types of problems, very specific lab procedures should be established that represent production as closely as possible. In a case where a particular variable cannot be controlled, testing should be conducted to determine the effect of that variable on the sample as the variable changes. The variable should then be monitored when a sample is created so that the data obtained from the sample can be properly interpreted using the predetermined information on the response of that variable.

Another area that is extremely critical is the condition of the laboratory equipment used in sample generation and measurement. Lack of attention to this area will greatly decrease the accuracy, repeatability and dependability of the samples produced or measurements taken with such devices.

Regular preventative maintenance is a must in this situation (Figure 5), and where appropriate, instrument calibration should be checked and updated as required (Figure 6). In addition to these straightforward precautions, the process capability and instrument accuracy should be thoroughly evaluated and established before any testing is performed with a piece of equipment. The resulting operating range should then be monitored routinely for deviation and drift from the standard. Without such controls in place, resulting data will be inconsistent over time and will be misleading.

A final area that must be mentioned is the importance of good standards and the necessity of adhering to those standards. A standard can be a procedure or technique, a material, a piece of equipment or a measurement, and in many cases is a combination of all four of these elements. A poor "standard" will be detrimental to achieving the aforementioned goal of testing, making it essential to put effort into ensuring that the standards utilized in sampling and testing are accurate, reliable and repeatable. Failure in this area will once again render data virtually useless and potentially cause many problems.

In short, the methods, techniques and equipment used to create and measure a sample are directly responsible for the quality and repeatability of that sample, and therefore strict attention should be given to ensure these factors are analyzed, adhered to, and improved upon in the laboratory. Their importance cannot be overly stressed.

The method, techniques and equipment for creating ink deposit

samples will be the primary focus of this report for the reasons we have outlined.

It is worthy to note that many of these sample principles can, and should, be implemented in the production process as well. The things we have covered in this section are basic concepts of control and repeatability and will produce beneficial results in virtually any process they are applied to.

Significance of Laboratory Results

Determining the significance of the analyzed data obtained in a lab is necessary if the information is to become useful and beneficial to the process. Generally speaking, there are several factors that need to be taken into account when interpreting test data. The first consideration is the actual application of the information. Is the area of critical importance and does it carry a lot of significance in the process, or is it something that can be compromised? Are the tolerances very narrow or do they have wide latitudes? Are there customer specifications or established production standards that must be met? Questions like these will provide a clue to the relevance of the test information being evaluated, and help to focus in on the proper goal and purpose of performing the testing in the first place.

The experimental conditions, discussed in the previous section, are a second area that must be added to the equation. Inconsistencies and problems in this area can cause the significance and validity of test data to decrease, even to the point of being useless and unprofitable.

The accuracy of measuring equipment must also be factored in so test data is not used as an "absolute," but rather put in the proper perspective with the window of accuracy of the instrument used to produce it.

Ignoring these considerations will, in all likelihood, misguide the interpretation of laboratory results. For instance, if the data is relied on excessively and over emphasized beyond the valid information it is capable of providing, reality will not be represented, and the information will be misleading and destructive to maintaining process control. The same result will occur if the opposite extreme takes place, where the data is not used or stressed to its proper position and is mistakenly thought of as worthless.

Laboratory testing can be an extremely effective tool when the proper time and attention is devoted to the various stages we have been discussing, but it is important to note that even the best of testing programs will not eliminate the need for monitoring the actual production situation. Testing of this nature is not a "quick fix" by any means or a total replacement to working with production equipment. Keep in mind the end goal is not just to have good test results, but to have a quality end product from the production process. This will not be accomplished unless that process is consistently monitored and kept "in control."

Correlation

At this point a few comments on correlation of lab results to production results are in order. There are no shortcuts in this process which is established through documentation over time. Obviously, data from both areas must be recorded and tracked with each other, giving additional support to the point that production must be monitored no matter how much laboratory testing is performed. An effective data base required for accurate correlation analysis is not completed quickly, but if time is taken to compile the proper information, the benefits can be great.

The basic goal of correlation is to be able to accurately predict the results in the production process from laboratory information. Such forecasts must take into account the interactions of many variables and their effects on the end product, thus requiring an extensive data base. The better the base to draw on becomes, the more precise and correct the predictions will grow.

The main advantages of this ability is being able to quickly determine if a given set of specifications can be met in production by simply running a laboratory test. This can be a real asset when bidding on contractual work and government jobs.

Sample Characteristics

There are two points to consider when determining the desirable characteristics for a particular sample. The first is simply the purpose of the sample or the measuring and testing application that it was created to serve. This purpose then helps identify those properties that are critical to control in the sample. A second aspect of importance is the attributes of the production processes' end product. By evaluating and quantifying the critical characteristics of the actual product that is to be represented, model attributes can be identified that may be used to pattern the sample.

Both of these areas will provide the necessary information to outline specific qualities a sample should possess in order for it to provide accurate information. These guidelines will then dictate the lab procedures needed for producing a sample with the defined characteristics.

Reasons for Sampling Ink

Ink is an indispensable and critical element in the process of screen printing. It is the very medium that makes up an image and

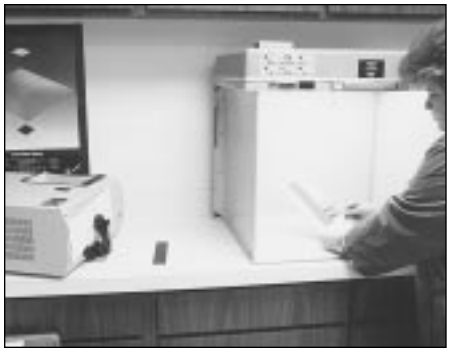

Figure 7. Color matching often necessitates the creation of an ink deposit sample.

Figure 8. Weatherability is a large ink related concern requiring ink sampling and testing.

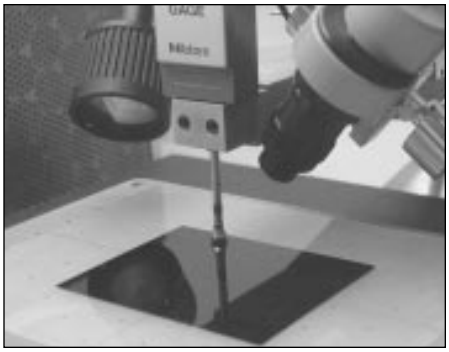

Figure 9. Determining the thickness of a wet or dry ink deposit is often a piece of information that is needed from a sample.

provides to that image certain desired characteristics.

Because the ink is so important, it is understandably subjected to a great deal of testing and measurement throughout the industry by manufacturers and printers alike.

Let us now examine some of the reasons the screen printer may have for sampling ink, and mention some common tests that are often performed to an ink sample to accomplish these purposes.

One of the biggest areas printers are involved with is color matching. A great deal of ink sampling is necessary when mixing and matching ink color, making it critical to utilize reliable methods to create accurate comparisons for testing, verification and data base generation. Color measurement is carried out through both visual examination and instrumental measurements using devices such as a spectrophotometer or a colorimeter (Figure 7).

Other appearance attributes that are often monitored are gloss, process color density, and opacity. Improper sample preparation techniques can effect the ink deposit, decreasing the revalence of the measurements that are taken with a glossmeter, densitometer, spectrophotometer or colorimeter respectively. Visual evaluation, also used for evaluating these characteristics, can be influenced as well by improper sample preparation.

Weatherability is another large ink related concern of printers and ink manufacturers that requires ink sampling and testing (Figure 8). Erratic variation in sample deposit and characteristics can cause different reactions in the various weathering exposure tests, and therefore provide false information about an ink. In a weathering experiment such things as color, gloss, chalking, ink adhesion, and cracking, just to name a few, are monitored at various stages of a weather cycle.

Determining the thickness of a wet or dry ink deposit (Figure 9) is often a piece of information that is needed from a sample and, as we will see, is an essential characteristic to monitor and control. The curing/drying response of an ink can be evaluated with samples before major production work is started in order to anticipate or correct problems with this part of the process (Figure 10). Sampling can also be an effective tool in comparing different manufacturers' inks for adhesion, weathering, curing/drying properties, color and thickness.

Testing the reaction and adhesion of an ink to a substrate can be accomplished with a sample ink deposit (Figure 11). Quality control checks of incoming ink to a plant, or outgoing ink from a manufacturer, is an additional place that ink samples can play an integral role.

These items are by no means an all inclusive list of possible reasons for sampling ink, but include the most prevalent areas of interest to printers and manufacturers.

Figure 10. The curing/drying response of an ink can be evaluated with samples before major production work is started.

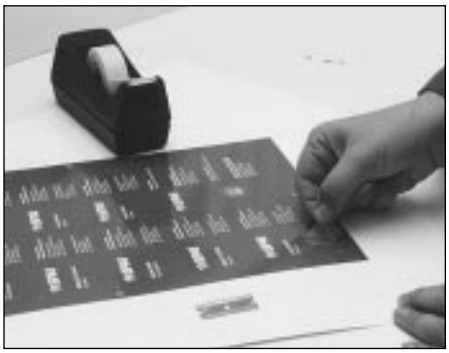

Figure 11. Testing the reaction and adhesion of an ink to a substrate can be accomplished with a sample ink deposit.

Critical Characteristics of an Ink Sample

There are some desirable characteristics that should be present in any ink deposit sample, regardless of its end purpose. One of the common traits that is of critical importance is the thickness of the ink that is deposited on the substrate.

Considerations when looking at thickness include the achievement of the target thickness, the uniformity of the target thickness throughout the sample, the repeatability of the specified thickness and uniformity from sample to sample.

Control of these four characteristics is imperative no matter what goal or test is being performed on the sample, as thickness variations affect virtually every area of an ink deposit.

It must be noted that in order to monitor these attributes an accurate ink deposit thickness measuring system must be in place. For more information on ink deposit measurement see SPTF's research reports entitled "Guideline to Wet and Dry Ink Measurement Methods, Parts One, Two and Three."

Another property that must be ensured is the homogeneous or uniform composition of the ink throughout the sample. Proper mixing and dispersion of the ink can eliminate any problems associated with this area in most cases.

A final consideration is the surface texture of the resulting deposit. Again the sample's surface characteristics should resemble the actual characteristics generated on the production line as closely as possible. Great differences between the two could result in inaccurate analysis and recommendations on color and gloss based on the unrepresentative sample ink deposit. As we will see, different sample preparation methods will produce different surface textures on a deposit which must be taken into account when selecting the method or technique used for a particular application.

Substrate

Before an evaluation of the various methods and concepts being utilized for sample preparation is presented in Part Two, a discussion is in order on the importance of the substrate and its influence on the sample deposit.

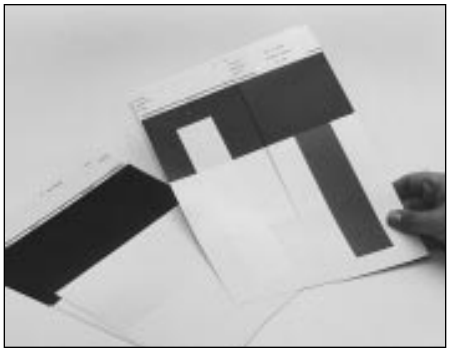

Figure 12. A "LENETA" card is used to evaluate the opacity of a coating and can be considered a specialized testing substrate.

Very often substrate selection for ink sampling is simply a matter of using the same material that is printed or in production. Generally speaking, this practice is the best and easiest when the purpose or test intended for the sample is to be related to the actual production run in some way. Some examples where this situation would occur includes color matching, appearance attribute evaluation (opacity, gloss, density, etc.), weatherability testing, curing/drying response parameters, and adhesion characteristics.

However, in the case of quality control checks of incoming inks, a substrate can be selected and standardized that is not necessarily used in any production run. A "LENETA" card, used to evaluate opacity among other things, is an example of such a substrate (Figure 12). These cards are designed exclusively for testing purposes, and should be used accordingly. "LENETA" cards and their purpose will be covered in Part Three of this report on Opacity.

Another instance where a "specialized" substrate should be selected is for a capability study on a testing device or instrument. The purpose of evaluating a testing apparatus is to determine the precision and accuracy of its results under one or more sets of conditions. With this base information in hand, future data produced on the instrument can be analyzed correctly, and interpretation can be put in perspective. The reader will recall that capability studies should be performed on testing equipment before placing it in the laboratory environment for regular use. The initial goal when undertaking this type of study is to isolate the true performance of an instrument by eliminating unpredictable and uncontrolled variation in the materials introduced in the experiment.

When these variables are removed or minimized, the true capability of the device can be determined accurately. With this information obtained, the variables can then be introduced selectively in order to determine the true effect each one has on the output of the instrument. In this way material variability is isolated from the "process spread" (or measurement error) inherent in that instrument.

The substrate is one of these variables that must be controlled when testing an ink deposition system. The ultimate goal is to reduce the effect of the substrate as much as possible as it relates to the system's process, although it can never be completely eliminated.

Some important aspects of the substrate to consider during the selection process include thickness uniformity, surface flatness and texture, porosity and absorption, surface tension, color, heat and humidity sensitivity, and material makeup.

Although all of these will influence a process to some degree, certain characteristics become more crucial than others in different testing applications. Selection therefore must first be based on the critical properties of the substrate which are dictated by the testing situation, and second on the less sensitive traits.

To give an example of how these considerations play a part in

choosing a substrate, let us consider a particular application the Screen Printing Technical Foundation encountered when setting out to evaluate the various ink deposition devices and methods that will be presented in Part Two of this project report. The purpose in performing a study on these different sample preparation techniques was to provide the screen printing industry with an overall picture of each method's capability, advantages and disadvantages related to ink sampling. In order to compare these methods, a common base had to be established in the testing process. For this reason, a controlled process capability study was performed on each system under identical conditions (i.e., same substrate, ink, measurement instrument, etc.).

The substrate used during this testing had to be selected carefully as many of its attributes had the potential to drastically effect the ink deposit. Without effectively minimizing these influences on all the devices with the same substrate, common conditions could not be achieved, direct comparisons would not be relevant, and the results would be skewed in an unpredictable manner.

Several different substrate types were experimented with before discovering one with optimum results. A piece of cast glass was initially tested for several reasons. A glass test substrate eliminated several key variables of concern including irregularity in the surface, absorption of the ink, heat and humidity sensitivity and material consistency. However, although the surface was smooth, the glass was not uniform in thickness and did not lay flat because of its rigidity. These irregularities greatly affected the ink deposit thickness on some of the devices tested.

The next logical step was to experiment with a ground glass substrate which is created by first casting and then fine grinding one side to improve its flatness and uniformity (Figure 13). A ground glass substrate provided all the benefits of the cast glass, and also possessed an increased measure of flatness and uniformity.

This substrate proved to serve our testing relatively well until we acquired a more precise solution, namely a thin ceramic block. The block measures 11"x7"x1/2" and is ground and polished to a flatness of 3/4 of a micron across the entire surface (Figure 13). With the ceramic, virtually all variation in flatness and uniformity is eliminated while still retaining a smooth, non-porous, consistent material with a high heat and humidity tolerance. Two substrate characteristics that are of secondary importance in our application are color and surface tension. The ceramic was acceptable in these two areas as well (as were the two glass types).

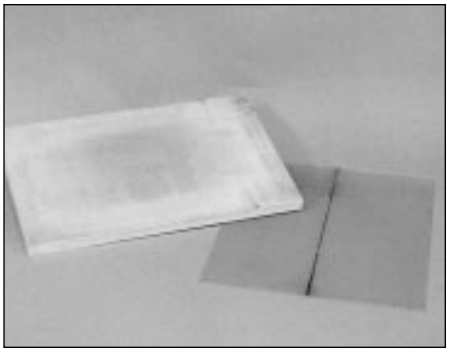

Figure 13. Ceramic (left) and ground glass (right) substrates.

We have found the ceramic substrate to be the most effective for our purpose here, and the majority of the comparisons in the following report will be based on results obtained with it. Results with the two glass types will also be presented in Part Two and the differences discussed.

Part Two of "Guideline For Uniform Ink Sample Preparation and Opacity Measurement" will cover in-depth three ink sample generation methods, including wire wound drawdown systems, fixed open gate systems, and screen printing. These sample preparation methods will be compared to each other with guide-lines and recommendations made based on SPTF's findings. The importance of standardization and communication between manufacturer and printer will also be discussed.