International Standards on Stability of Digital Prints

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Abstract. The International Standards Organization (ISO) is a worldwide recognized standardizing body which has responsibility for standards on permanence of digital prints. This paper is an update on the progress made to date by ISO in writing test methods in this area. Three technologies are involved, namely ink jet, dye diffusion thermal transfer (dye-sublimation) and electrophotography.

Two types of test methods are possible, namely comparative tests and predictive tests. To date a comparative test on water fastness has been published and final balloting is underway on a comparative test on humidity fastness. Predictive tests are being finalized on thermal stability and pollution susceptibility. The test method on thermal stability is intended to predict the print life during normal aging. One of the testing concerns is that some prints do not show significant image change in practical testing times. The test method on pollution susceptibility only deals with ozone and assumes that the reciprocity law applies. This law assumes that a long time under a low pollutant concentration is equivalent to a short time under the high concentration used in the test procedure.

Longer term studies include a predictive test for light stability and the preparation of a material specification. The latter requires a decision about the proper colour target to be used and what constitutes an unacceptable colour change. Moreover, a specification which gives a predictive life is very dependent upon the conditions the print encounters and will only apply to specific levels of temperature, ozone and light.

1. Introduction
Digital photography has become the dominant technology today for the capture of images. Consequently, colour hardcopies are being printed digitally, and digital imaging includes many more technologies than the chromogenic dyes used in traditional photography. A primary concern in the use of digitally printed materials is their long term stability. The permanence of the image itself is being addressed by the International Organization for Standardization (ISO) while the physical stability is being investigated by organizations such as the Image Permanence Institute. This paper is an update of the current activities of ISO. Although this topic was discussed at the 2003 meeting of the Institute of Physics, there has been considerable progress over the past seven years.

2. International Standards Organization
Before reviewing the ISO work, a brief discussion of this organization is appropriate. ISO is a worldwide recognized standardizing body which publishes standards on testing procedures and specifications. Its scope covers all fields except electrical and electronic standards. Headquartered in
Geneva Switzerland, membership is by country, not by organization or by individual. Each country is represented by its respective standardizing body, Great Britain by the British Standards Institution, United States by the American National Standards Institute, Germany by Deutsches Institut für Normung, etc. The standardizing deliberations are conducted by various technical committees, the work on image permanence being the responsibility of Technical Committee 42. This includes the permanence of photographic film, magnetic tape, optical discs and digital prints. TC42 has a membership of twelve countries and voting is by country, each country having a single vote.

The discussions and deliberations are done in various working groups and task groups. Following general agreement, a proposed standard goes through a series of ballots. This ensures that there is thorough review of the document and all points of view are considered. While this is a time consuming process, it does give confidence that the document represents the best technical information at the time.

3. Standardization of Digital Prints

Standardization of traditional photographic images is relatively uncomplicated compared to digital prints. The former consist of a silver image or a chromogenic dye embedded into a gelatine matrix. While there are differences between manufacturers, these are secondary and the basic technology is similar for all. However, this is not the case with digital prints where at least three different imaging technologies are involved – ink jet, electrophotography and dye sublimation.

- Ink jet printers use pigments or dyes which are propelled onto the substrate – including plain, swellable and porous papers.
- Electrophotographic technology uses toners composed of colorants embedded in polymer beads which are transferred to the substrate – typically plain paper – by an electrical charge, then fixed to the paper by heat or pressure.
- Dye-sublimation always uses dyes which are contained in a donor ribbon and transferred to a specialized substrate.

The stability of a digital print not only depends on the applicable technology, but also the type of colorant used to form the image and the substrate the image is printed on. There is consequently a tremendous number of possible combinations of technologies, colorants and papers. Furthermore, the situation is still more complicated since the life expectancy can be very dependent upon the printer and printer setting that is used. Results obtained using an ISO standard apply only to a very specific digital image, paper and printer.

The primary goal of the ISO standardizing committee is to establish test methods for the different environmental stresses that digital prints may experience. This includes the effects of water, humidity, heat, light, pollutants and abrasion resistance. Two types of test methods are possible, comparative tests between materials and predictive tests. Progress on the test procedures is discussed.

3.1. Comparative Tests

Comparative tests are the simpler and less expensive of the two. They establish testing uniformity between different laboratories and organizations and allow a comparison to be made between materials. However, they give no information about the expected life of the image. Water fastness and humidity fastness are comparative tests.

3.1.1. Water Fastness. The only test method that has been completed to date is for water fastness [1]. The digital print is subjected to three different degrees of water exposure. These are a one-minute soak in water without subsequent air drying, a one-minute soak in water followed by blotting, and a one-hour soak in water. The behaviour of the print is rated qualitatively as water resistant, moderately water resistant or not water resistant. It is apparent that this is a highly subjective procedure. Laboratory comparisons indicated that it is not possible to give a more quantitative rating since the degree of water damage is so dependent upon the observer. Nevertheless, this procedure does provide some degree of uniformity in evaluating water fastness.
3.1.2. Humidity Fastness. The resistance of a digital print to humidity can differ from its stability in water. High humidity exposure may cause dyes to bleed or to be transferred to adjacent sheets. Consequently there is a need for a humidity fastness test. Such a test has been under development based on published research [2, 3] and is nearing completion. Tentatively it is proposed to subject prints to (a) 85% RH condition for four weeks, (b) exposure for two weeks at three humidities ranging from 60 to 95% RH depending upon the material and (c) a long time exposure at 20% RH for times up to six months. Evaluation is by colorimetry.

3.2. Predictive Tests
Predictive tests are intended to determine how long a print will last. They are required in order to achieve the goal of preparing a specification for the life expectancy of a digital print. Thermal aging, the effects of pollution and light are all predictive tests. All three involve requirements to evaluate changes in the colour targets resulting from the stress described in the test methods. These colour changes are quite complex. They include the degree of fade of individual colours as well as a neutral colour patch, the change in colour balance caused by unequal colour fading, and the colour increase in the Dmin (white) areas. Measurements are made of density. These predictive tests also require the establishment of end points which determine the degree of image acceptability. These test procedures must be completed within a reasonable time frame. Consequently, this requirement involves subjecting the digital prints to severe stress conditions and then extrapolating the result to a practical condition.

3.2.1. Thermal Aging. The thermal aging test is intended to predict the colour change with time. This prediction is made by the Arrhenius procedure [4] which involves conditioning the print to 50% RH, sealing the print in a humidity proof foil bag followed by incubation for different times at elevated temperatures. Alternatively the specimens can be free hanging in a humidity controlled oven. The incubation time required to reach an end point (such as a specified increase in Dmin or level of fade) is determined. It is then plotted as a function of temperature using the Arrhenius relationship. Figure 1 shows such a treatment which gives a linear relationship with temperature for two hypothetical materials and allows a prediction to be made at a practical use temperature. This approach is only
applicable if the Arrhenius plot is linear. However, it has been very successfully used to predict the image change of chromogenic dyes and also the life of acetate film base.

An important requirement for the application of the Arrhenius method is that the incubation time/temperature condition must result in the end point being reached. Figure 2 illustrates a test in which the end points were not reached and there is no way in which a prediction can be made. In this illustration comparing the two materials, the one more stable at 120°C is actually less stable at 20°C. The critical criterion is not the stability of the image at the high temperature but the temperature dependence of the end point. One of the test problems found with some digital images is a very high stability, even at elevated temperatures. While this is a distinct advantage, it makes predictions impossible.

A proposed ISO test procedure is now in the final stages of the balloting process.

3.2.2. Pollution Susceptibility. Early testing by the ISO group showed wide variability between laboratories and this was subsequently found to be caused by the effect of pollutants on the image stability, particularly the effect of ozone on dye images applied onto porous paper [5, 6, 7]. The presence of pollutants in the environment is a fact of life. Consequently the standardization of a predictive test to evaluate pollution susceptibility is essential and work has proceeded along this line [8, 9], specifically addressing the effect of ozone which was found to be particularly virulent.

As with the thermal procedure, a test must be completed in a reasonable time. It is essential to subject the digital print to a high stress condition and then extrapolate the results to a practical situation. This is being done by use of the reciprocity law. The assumption is made that a short time at a high ozone concentration is equivalent to a long time at a reasonable ozone concentration [10, 11].

A proposed ISO test procedure is also in the final stages of balloting. This includes standardized methods for producing ozone, measuring the ozone concentration and establishing the relative humidity, temperature and ozone concentration of the accelerated test. In addition, the life expectancy must be based on calculating the results to a standardized practical ozone concentration.

3.2.3. Light Stability. As with the pollution susceptibility test, the light stability procedure also assumes that the reciprocity law applies [12]. The test method requires standardizing the light intensity used to calculate the life expectancy under practical conditions. In addition to the light intensity, the image stability is very dependent upon the wavelength distribution of the exposing illumination. This is obvious by practical experience; sunlight will cause sunburn whereas indoor illumination will not. Currently a proposed procedure is intended to evaluate the image permanence under different lighting conditions. Indoor home lighting conditions are simulated using a xenon arc lamp, while office and public buildings are simulated using fluorescent illumination. Tungsten halogen illumination is also included.

However, there are still a number of unresolved issues. The xenon lamps produces very high heat and temperature control of the test specimen must be established. In addition there are questions about whether a UV filter should be placed in front of the light source. To resolve a number of these issues, a round robin test program is planned in which different laboratories will test identical samples. This will provide information about the reproducibility of the procedure. A proposed final draft is not as close to completion as the thermal and pollution tests and will not be ready in the near future.

3.3. Material Specification

When the predictive tests for thermal stability, pollution susceptibility and light stability have been standardized, the ISO group can then consider the preparation of a specification about the life expectancy of a digital print. The goal would be to specify the number of years that the print would last without exceeding the established end points. However, it must be recognized that it is not possible to ever obtain a single number for life expectancy since the stability of a print differs widely depending whether the pertinent stress is thermal, pollutants or light. While an image printed with a specific technology on one paper may be resistant to one type of stress, such as heat, it may be very
susceptible to another, such as pollutants. Moreover, standardizing such specifications involve a
number of serious concerns [13, 14].

There are some reservations about the test methods themselves. Each of the stresses evaluated deal
with only one stress at a time. It is obviously impossible to prepare test methods which determine all
interactions between thermal, pollution and light effects. However, such interactions occur and do
represent the real world. Another possible source of error is that both the pollution and the light
stability tests assume that the reciprocity law holds. This is a necessary assumption so that the test can
be completed in real time, but it is still an assumption.

It is recognized that image stability is very dependent upon the technology involved as well as the
nature of the colorants, whether they are dyes, pigments or toners. In addition, the permanence of the
image varies with the nature of the paper used. For example dye images on porous paper are very
susceptible to ozone attack, whereas on swellable paper they are more resistant. It has also been found
that even with the same colorants/paper materials, ink jet stability behaviour can be dependent on the
printer used. In summary, any prediction of life expectancy applies only to a very specific material.

There exists another problem which is related to the needs of the user. The end point specification
differs for different applications. Obviously the changes that are acceptable for a circus poster are
much less stringent than for a fine art photograph

In addition, the end points in the predictive test methods apply to specific levels of stress. The
average user does not know what levels of stress apply to a particular situation. While temperature
measurements are easily obtained, analysis of the effects of the temperature variation over an extended
time period is beyond the reach of most users. The effective temperature requires a calculation since it
is not the average temperature which is critical. This is because a low temperature does not undo the
harmed effects of an elevated temperature.

While many users may be able to determine the prevailing relative humidity, this may vary over
time. Again the harmful effects of a high humidity cannot be compensated by subsequent storage at a
low humidity. Consequently the effective humidity must be calculated.

Most users have no information about the ambient pollution levels and no way to determine them.
High pollution susceptibility may be extremely important for some collections and of little importance
for others. This would be critical in estimating life expectancy in any particular situation.

Another stress level to be considered is the quality of the incident light, specifically the intensity
and the wave length. This is unimportant for dark storage but quite important for images displayed at
home or in offices.

In summary, the life expectancy values are subject to the uncertainties described above, namely
concerns about the test methods, the appropriate end points and the stress levels that are pertinent.
Several different approaches have been discussed in the ISO group:

- Not to specify any life expectancy value since the result is open to error. This is technically
defensible but does not satisfy the needs of the consumer who desires to have some
information about the expected life of the print.

- Provide a life expectancy value in “years” since the consumer requires some knowledge of the
property in a unit which is understandable. This has the advantage that the consumer can relate
to the life expectancy value. However, it has the disadvantage that the value may be wrong.

- Give a number which represents a rating for life expectancy and which uses a unit other than
“years” such as “cumulative dosage” or “nominal years”. Such a rating may be useful in
comparing prints but it will not give the consumer information about how long the print will
still be useable.

This is obviously a complex question which has yet to be resolved.

4. Conclusion

Preparing standards on the life expectancy of digital prints is extremely complicated. Some of the
important variables were not realized when this activity was started and this obviously delayed
progress. However, there have been substantial contributions in recent years. To date one comparative
standard on water susceptibility has been completed, and the final balloting progress is underway for another comparative test method on humidity susceptibility. Two predictive test methods on thermal and pollution susceptibility are also in the final stages of balloting. Unresolved issues remain on a light stability test method and on a material specification.

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