WHITE PAPER

GUIDE TO THERMAL PAPER

SELECTION, USAGE & ARCHIVING

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WHAT IS THERMAL PAPER?

Thermal paper contains a transparent dye that changes to a color, usually black, when heated. The paper consists of two or three layers:

- A *substrate,* the media, which can be paper or a synthetic substance, such as polypropylene
- A *coating,* which contains the transparent dye mixed with a developer
- An optional *top coating* that protects the printed thermal paper from environmental conditions that degrade the image

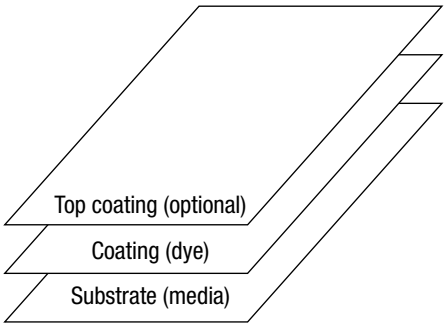

Figure 1. Thermal paper layers

When a thermal printer applies heat to thermal paper, molecules in the dye bond with molecules in the developer, producing the printed image; this is also called "developing the image." Most thermal papers produce black images. Thermal papers that produce images in other colors, such as red or green, are also available.

The thermal printing process requires good contact between print head and paper to heat the dye; thermal paper is very smooth to maximize the contact. Standard bond paper for laser and inkjet printers is not as smooth because the print technologies are different. A laser printer uses heat to bond plastic toner to the surface of the paper. An inkjet printer sprays ink on the paper, which absorbs the ink.

Thermal paper must be placed in a thermal printer so the side of the paper with the coating or top coating contacts the print head. The side of the thermal paper with the coating or top coating is smoother than the uncoated side of the media.

TIP! If you can't tell which side of thermal paper is coated, rub your fingernail against the paper in an inconspicuous place. The rubbing generates heat, which produces a mark on the coated side of the paper. No mark appears when you rub your fingernail on the uncoated side.

BENEFITS OF THERMAL PAPER

Thermal paper makes thermal printing technology possible. Thermal printers are small, quiet, and less susceptible to vibration. They can be installed and used in any orientation. Thermal printing works whether the printer is right-side-up, upside down, or sideways.

Thermal printing also is more reliable than other printing technologies because there are fewer moving parts. Maintenance costs are lower. The paper path is shorter, reducing the chance of a paper jam or misfeed.

The dye is on the paper. No ribbons or cartridges are required. There is no toner or ink to spill.

The total cost of ownership is low.

When used with thermal paper that requires higher heat to image, thermal printers can produce images that withstand temperatures up to 270°F (132°C).

For all these reasons, thermal printing is an excellent technology both for mobile use and for use in extreme environmental conditions.

THERMAL PAPER APPLICATIONS

Thermal paper is produced in many different qualities and formulations to meet the needs of different applications in different industries. The quality and formulation that work best for one application may not be the best quality and formulation for another application.

A similar situation exists with other printing technologies. For example, different papers are used to print resumes and accounting reports on a laser printer. Different papers are used to print photographs and homework on an inkjet printer.

Thermal paper has three basic applications, each with its own set of needs:

- Point-of-sale receipts
- Faxes
- Transaction documents

Point-of-Sale (POS) Receipts

Thermal printing is often used to produce receipts at points of sale such as gas stations and grocery stores. The thermal paper must be economical; typically it has a low-cost dye coating that fades rapidly. Archiving concerns are minimal. The paper is thin, 48-50 microns thick, and feels inexpensive. Heavy-weight receipt paper, 60-80 microns thick, is more durable. Seventy percent of all thermal paper sold is receipt paper.

Faxes

Traditional fax paper shares many characteristics of thin thermal paper for point-of-sale receipts. Fax paper is inexpensive and thin. People who encounter thermal paper only for fax use often believe that all thermal paper is low quality and inferior to other papers. This is a mistaken impression. Many high-quality, economical thermal papers are available.

Transaction Documents

Transaction documents include contracts, warranties, invoices, and citations. Industries that produce transaction documents include:

- Public safety
- Field service
- Route accounting
- Insurance

Transaction documents need to be legible and durable. Many of them also need to have a professional appearance. When transaction documents are printed or delivered to the recipient in less than ideal environmental conditions, the documents should withstand adverse conditions with little degradation of the printed image. In addition, many transaction documents must meet legal requirements for archiving. For all these reasons, transaction documents should be printed on higher quality thermal paper than point-of-sale receipts and faxes.

TYPES OF THERMAL PAPER

Many different types of thermal paper are available for transaction documents. The basic choices involve:

- Top coating and no top coating
- Standard and premium
- Paper and synthetic media

Top Coating and No Top Coating

Thermal dye is sensitive to handling. A top coating over the coating that contains the dye protects the dye from damage during handling. The top coating also provides protection against conditions and substances that can degrade the paper and the image.

Different top coatings can provide different benefits. For example:

- Resistance to discoloration of the thermal paper caused by exposure to sunlight
- Resistance to fading of the image caused by exposure to high temperatures
- Resistance to substances including water, oils, and grease
- Increased archival storage for up to 25 years

Thermal paper without a top coating is a good choice for uses that do not require the protective benefits of top coating.

Standard and Premium

Thermal paper for transaction documents comes in both standard and premium grades.

Standard thermal paper is similar to regular 20-lb. bond paper. Around 80-90 microns thick (thicker than both regular and heavy-weight receipt paper), standard thermal paper typically does not have a top coat and can remain readable for seven to twenty years under proper storage conditions.

Most standard thermal papers are excellent for documents requiring graphics and logos as well as for service records, repair estimates, maintenance and repair reports, work orders, product order forms, customer order history, product promotions, accident reports, price quotes, appraisals, and work estimates.

Premium thermal paper is similar to high-quality 20-lb. bond paper. Around 90-100 microns thick, it has a top coating and can remain readable for 20 to 25 years under proper storage conditions.

Premium thermal papers are excellent for a wide variety of documents including traffic citations, accident reports, warning notices, parking violations, safety inspection certificates, emergency instructions, receipts and invoices, statements of work, chemical data sheets, delivery notices, returned goods receipts, appraisals, work estimates, repair authorizations, insurance policies, contracts, and financial plans.

Paper and Synthetic Media

Thermal media may be either paper or a synthetic material such as polypropylene. While thermal media may be either standard or premium grade, thermal synthetic media is usually a premium grade.

Synthetic media provide high tear resistance and high durability as well as excellent resistance to water, degradation caused by adverse environmental conditions, and fading. Most synthetic thermal papers can remain readable for 20 years under proper storage conditions.

Synthetic thermal media is excellent for use in outdoor environments for transaction documents that include traffic citations, warning notices, parking violations, safety inspection certificates, gas inspection notices, equipment shutdown notices, and delivery notices.

HOW TO CHOOSE THERMAL MEDIA

The best thermal media for a transaction document depends on:

- The imaging capabilities of the thermal printer
- The conditions during the printing process
- The transaction environment (for example, a parking citation placed on a vehicle's windshield)
- The storage environment
- The archiving requirements
- The presentation appearance of the document

Choosing thermal paper involves trade-offs. In addition to the standard trade-off between high quality and low cost, other trade-offs include high printing speed and resistance to degradation caused by high temperatures.

Imaging Capabilities

Different thermal printers generate different amounts of heat to produce an image on thermal paper.

Some thermal printers have the ability to adjust image contrast by adjusting the optical density of the printed image. Images of higher optical density are darker. Images of lower optical density are lighter. More heat is usually required to produce images with higher optical density.

Thermal papers that image with high amounts of heat have a greater resistance to other sources of heat.

The combination of a printer that images with higher heat and a thermal paper that requires higher heat to image produces images that resist fading when exposed to high temperatures.

Print speed may affect image quality. Images printed at higher speeds may not have the image contrast of images printed at slower speeds.

When choosing thermal paper, we need to know how much thermal energy the thermal printer can produce and how much heat the paper requires to fully develop the image. Images not fully developed may fade, sometimes very quickly. This is a consideration when adjusting contrast on thermal printers. Low contrast settings may increase print speed, but may also compromise full development of the image, hence increasing susceptibility to fading and reducing the archival life of the document.

Conditions during Printing

Images produced with any print technology including thermal printing are subject to degradation from the moment the image is printed until the document is discarded.

A thermal paper's *dynamic sensitivity* is its sensitivity to heat applied over a very short period as the image is produced.

The best choice for printing in extreme environmental conditions, such as cold temperatures and high humidity, is a high-energy thermal printer and thermal paper that images at low heat. Before the heat can be used to develop the image, the heat must first raise the temperature of the paper. If the thermal paper contains moisture, the printer must heat the paper to dry it. Papers with a top coating are less likely to absorb moisture.

Transaction Environment

Thermal media may be exposed to extreme conditions in the transaction environment: the environment between the time the thermal media is imaged and the time the document reaches the recipient. For example, a parking citation left on a windshield may be exposed to high temperatures, intense sunlight, rain, or snow for several hours or longer.

RESISTANCE TO HIGH TEMPERATURE: A thermal paper's *static sensitivity* is its sensitivity to high temperature over an extended period.

Synthetic thermal media has excellent resistance to fading and discoloration of the paper caused by an adverse environment. In addition, some top coatings are formulated to resist image degradation. See "Temperature Sensitivity Test" on page 8 for examples of image degradation on six different types of thermal paper.

RESISTANCE TO LIGHT: Ultraviolet (UV) light can discolor thermal paper and cause the printed image to fade. To minimize fading, use a high printer density or contrast setting to fully develop the image. For more information, see "Image Thermal Paper at High Printer Density Settings" on page 7. For examples of thermal paper discolored by exposure to UV light, see "Ultraviolet Light Exposure Tests" on page 9.

RESISTANCE TO MOISTURE: Moisture from rain or snow can damage thermal paper exposed to the elements. To protect a document from moisture damage, use thermal synthetic media or thermal paper with a top coating formulated to resist moisture.

REACTION TO CHEMICALS: To protect documents from degradation when exposed to a variety of chemicals, choose a synthetic thermal media or a thermal paper with a top coating formulated to resist chemicals.

RESISTANCE TO ABRASION: A top coating formulated to resist abrasion helps protect thermal paper from rough handling.

Storage Environment

Thermal media can be degraded by environmental sources during storage. Although the environmental conditions may not be as severe as in the transaction environment, the exposure occurs over a much longer period of time.

For thermal media designed to resist high temperature, light, moisture, and abrasion, see the previous topic, "Transaction Environment."

RESISTANCE TO PLASTICIZERS: A *plasticizer* is a substance added to plastic to make it flexible. Examples are plastic binders and sheet protectors. Plasticizers attack the dye, often causing serious loss of print quality. For examples, see "Plasticizer Tests" on page 11. Some thermal papers have top coatings formulated to resist plasticizers.

RESISTANCE TO CHEMICALS: Chemicals that harm thermal paper may contact the paper like colored markers or may be sprayed into the air in a storage environment. The best solution to loss of print quality from plasticizers and chemicals is to prevent them from contacting the thermal paper. For suggestions on storage, see "Store Thermal Paper Properly" on page 7. If there is no way to avoid contact, a top coating formulated to resist plasticizers and chemicals reduces the degradation.

DURABILITY is another concern when storing documents. To help keep documents from tearing when they are accessed during storage, choose a heavier weight thermal paper, a thermal paper with a top coating formulated to increase durability, or a synthetic thermal media.

Archiving Requirements

All the recommendations for the storage environment apply to document archiving. Documents stored in ideal conditions, however, may still discolor or fade over time.

The quality of the original image affects the image of the document when stored for a long period of time. The best images – images printed with an appropriate amount of thermal energy – last longer than images printed with too little thermal energy. For more information, see "Image Thermal Paper at High Printer Density Settings" on page 7.

A thermal paper top coating formulated to extend the life of the image enables documents to be archived for up to 25 years.

Presentation Appearance

An organization may have requirements that go beyond high quality printed images and resistance to image degradation. For example, they may want the paper to have an appealing appearance or they may be concerned about the cost of the thermal paper.

APPEARANCE: Thermal paper is available in different brightness levels: everything from bright white to slightly gray. The brightness of paper is measured by its reflectance. Typical brightness values range from 80% to 94%. Brighter papers provide greater contrast with the printed image. People often perceive brighter papers as more attractive. Synthetic media tends to be extremely bright.

The very smooth surface of thermal paper gives it a high gloss appearance in both paper and synthetic media.

THICKNESS: Just as 24 lb. bond paper gives the feeling of higher quality than 20 lb. bond paper, heavy-weight thermal paper gives a feeling of higher quality than light-weight thermal paper. The feeling is particularly striking when heavy-weight thermal paper is compared to a light-weight paper for point-of-sale receipts.

Thermal paper of the same weight as bond paper does not have the same stiffness and is slightly thinner.

COST: Thermal papers that are thicker, brighter, or have a top coating usually cost more than thermal papers that are thinner or duller, with no top coating.

PRE-PRINTING: Standard, premium, and synthetic thermal media for transaction documents can be pre-printed in several different ink colors with any image that an organization wants. For example, a logo might be pre-printed on the front of the media, and contract terms might be pre-printed on the back.

BROTHER THERMAL MEDIA

Brother sells three grades of thermal media:

- Standard
- Premium
- Weatherproof (synthetic media)

They are available in individual cut sheets, continuous rolls, perforated rolls, and fanfold. They can all be pre-printed on both sides with a company logo or custom design.

THERMAL MEDIA SELECTION CHART

Always check the specifications of individual thermal media. They may vary from the general guidelines given on the selection chart.

Thermal Paper	*Public Safety*	*Field Service*	*Route Accounting*	*Insurance*
	■ Law Enforcement ■ EMS ■ Safety Inspection	■ Utilities ■ Telcom ■ Pest Control ■ HVAC ■ MRO	■ Direct Store Delivery ■ Pre-Sales	■ Auto ■ Home
Standard Typical advantages: ■ Archivability 7-15 years ■ Excellent appearance ■ Durable ■ Economical		■ Service records ■ Repair estimates ■ Maintenance and repair reports ■ Work orders	■ Product order forms ■ Customer order history ■ Product promotions	■ Accident reports ■ Price quotes ■ Appraisals ■ Work estimates
Premium Typical advantages: ■ Archivability 20-25 years ■ Excellent appearance ■ Durable ■ Resists environmental degradation	■ Traffic citations ■ Accident reports ■ Warning notices ■ Parking violations ■ Safety inspection certificates ■ Emergency instructions	■ Service records ■ Repair estimates ■ Maintenance and repair reports ■ Work orders ■ Receipts and invoices ■ Statements of work ■ Chemical data sheets	■ Product order forms ■ Customer order history ■ Product promotions ■ Customer invoices ■ Delivery notices ■ Returned goods receipts	■ Accident reports ■ Price quotes ■ Appraisals ■ Work estimates ■ Repair authorizations ■ Insurance policies ■ Contracts ■ Financial plans
Synthetic Typical advantages: ■ Archivability 20 years ■ Bright white; excellent appearance ■ High sheet strength ■ High durability ■ Resists environmental degradation ■ Moisture resistance	■ Traffic citations ■ Warning notices ■ Parking violations ■ Safety inspection certificates	■ Notices (external use such as gas inspection notices, equipment shutdown notices, etc.)	■ Delivery notices	

THERMAL PAPER BEST PRACTICES

To get high quality printed images, avoid degradation of both images and paper, and maximize the archival life of printed images, follow these best practices:

- Test new thermal paper for your specific use
- Image thermal paper at high printer density settings
- Avoid rough handling of the thermal paper
- Store thermal paper properly

Test New Thermal Paper for Your Specific Use

Thermal paper formulations change as paper manufacturers take advantage of new chemistries for their coatings.

Before you print transaction documents on a new thermal printer, test the paper in your printer to make sure it meets your specific use needs. The paper should produce dark, clear images, and it should meet your requirements for appearance, durability, and resistance to the environment.

If you purchase thermal paper that has been pre-tested and qualified for your thermal printer – for example, thermal paper sold by Brother Mobile Solutions – you do not need to test the paper.

Image Thermal Paper at High Printer Density Settings

For best archivability, always image thermal paper at high printer density settings.

Turning the print engine to low printer density settings allows the engine to print at a slightly higher speed and extends the life of the battery. However, the lower thermal energy used in low-density printing does not completely develop the dye. In time, the images fade faster because the dye was not developed completely.

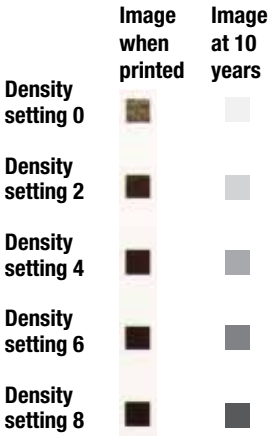

Figure 2. Printer density settings and image life

Figure 2 shows five printer density settings (0, 2, 4, 6, and 8) for the PocketJet 6 thermal printer, along with the typical image quality after ten years.

As Figure 2 shows, high quality images produced with lower printer density settings do not retain their high quality over a period of years. Images printed at density setting 2 will be difficult to read after 10 years, while images produced at density setting 8 remain sharp and clear. To achieve maximum legibility of images after thermal paper has been archived for an extended period of time, make sure the paper is fully developed with the appropriate thermal energy at a high printer density setting.

Avoid Rough Handling of Thermal Paper

Scratches, scrapes, and rubbing on the coated side may discolor the paper. Care during handling keeps a high contrast between the paper and the printed image.

TIP! You can make copies of thermal paper as long as you place the paper on the copier's glass. Avoid running the paper through the automatic document feed. That may scratch and discolor the paper.

Store Thermal Paper Properly

Store printed thermal paper in paper folders, envelopes, or boxes. Do not use folders, binders, or boxes made from plastic that contains plasticizers. For example, PVC folders contain plasticizers. Plasticizers or other chemicals in the plastic may interact with thermal dye, causing it to fade.

Store paper folders in a file cabinet to protect them from exposure to light. Choose a dry, cool storage area. The relative humidity should be between 45 and 65 percent. The temperature should be below 77°F (25° C). Make sure the surrounding air does not contain vapors from alcohol, cleaners, petroleum products, or other chemicals.

Don't apply adhesive tape to thermal paper.

TIP! Unimaged thermal paper should be kept in its original packaging. The coating or top coating of one thermal paper may degrade another type of thermal paper.

TIP! To prevent fading, never allow printed thermal paper to contact plasticizers or other chemicals. Substances to avoid include vinyls, plastics, shrink wraps, adhesives, carbon papers, organic solvents (including alcohol), cleaning fluids, petroleum solvents (including gasoline), ammonia, and oils.

THERMAL PAPER TESTING

The following test results demonstrate how different thermal papers react to high temperatures, intense ultraviolet light, and contact with plasticizers.

To extend the life of your transaction documents, choose thermal papers that resist degradation from the environmental conditions common to your application.

Temperature Sensitivity Test

These test results demonstrate the sensitivity of six high-quality thermal papers (samples A through F) to high temperatures – from 165°F to 195°F (74°C to 91°C) – over a four-hour period.

Thermal printers produce images by applying heat to thermal paper. Other sources of high temperature can image the paper, resulting in dark and unreadable documents.

Figure 3 shows that none of the six samples are sensitive to a temperature of 165°F (74°C) — the typical temperature of a vehicle on a sunny day.

Sample E is a poor choice for high-temperature environments. Its images become unreadable at 175°F (79°C).

Samples A and B start to degrade at 175°F (79°C) but do not become unreadable until the temperature reaches 195°F (91°C).

Sample F maintains high image quality at 185°F (85°C) but becomes unreadable at 195°F (91°C).

The best choices for use in an extremely high temperature environment are samples C and D. They maintain excellent image quality at 195°F (91°C).

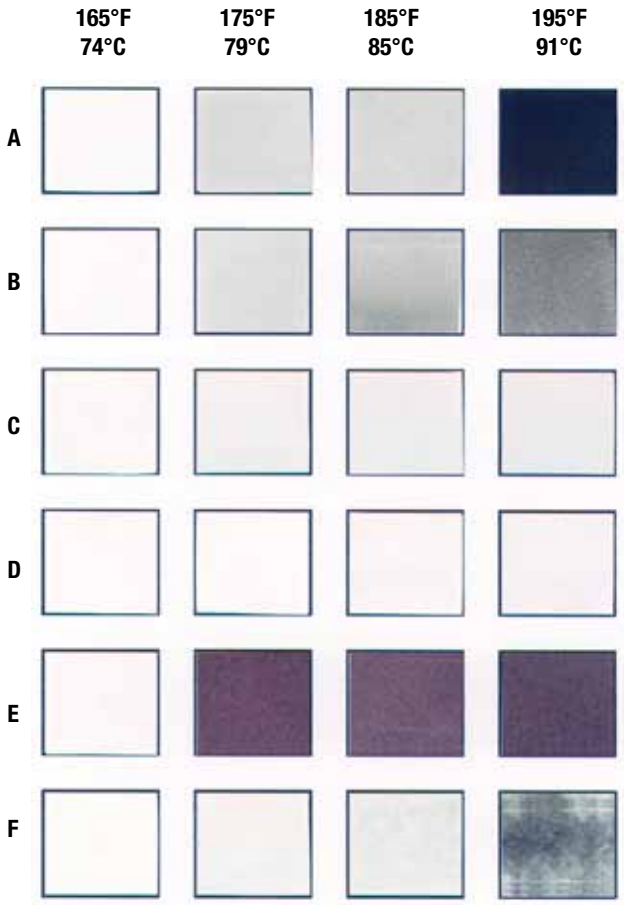

Figure 3. Temperature sensitivity test results

CONCLUSIONS: By careful selection of thermal paper for your specific use, you can print transaction documents that remain both legible and attractive in environments with extremely high temperatures.

If your thermal paper is turning dark when exposed to high temperatures during normal use, consider an alternate paper with higher static sensitivity. Thermal papers with high static sensitivity are more resistant to degradation from high temperatures. Papers with lower dynamic sensitivity require more heat from the printer.

Ultraviolet Light Exposure Tests

These test results illustrate the sensitivity of five high-quality thermal papers (samples G through K) to intense ultraviolet light exposure over the following periods:

- Twenty-four hours
- Seven days

The tests were conducted by placing 500,000 lux Class B UV lamps two inches away from the surface of the thermal paper. Exposure over twenty-four hours and exposure over seven days to Class B UV lamps are roughly equivalent to exposure over nine months and exposure over five years respectively to fluorescent office light.

TWENTY-FOUR HOUR EXPOSURE: The left side of Figure 4 shows sheet discoloration of the thermal paper samples after 24 hours. The right side of Figure 4 shows the samples at the start of the test.

Figure 4 shows that all five samples discolor slightly after 24 hours of exposure to intense UV light, but none discolor badly.

SEVEN-DAY EXPOSURE: The left side of Figure 5 shows sheet discoloration of the thermal paper samples after seven days. The right side of Figure 5 shows the samples at the start of the test.

Figure 5 demonstrates that all five samples have significant discoloration after seven days of exposure to intense UV light but remain legible. Sample J has the least discoloration and is a good choice for uses where exposure to daylight is difficult to avoid.

Figure 4. UV light exposure 24-hour test results

Figure 5. UV light exposure seven-day test results

CONCLUSIONS: Exposure to intense UV light, found in sunlight or office fluorescent lighting, over a period of a few months causes mild discoloration of documents but does not significantly reduce the legibility of a document with a clear, dark image. Documents discolor significantly when exposed to intense UV light over a period of several years. When possible, store documents in a file cabinet or other dark container in a cool, dry environment.

When the correct thermal paper is carefully selected for your specific use, your printed documents remain legible in environments with high levels of UV light over a period of several years.

Long-Term Dashboard Test

These test results demonstrate the sensitivity of five high-quality thermal papers (samples L through P) to high temperatures and intense daylight.

The tests were conducted by taping the samples to a south-facing window with no protection from intense sunlight and high temperatures for three months. The test simulates the degradation that results from leaving printed thermal paper on a vehicle's dashboard for three months.

CONCLUSIONS: Don't leave printed thermal paper on the dashboard of your vehicle for an extended period! None of the samples did well; all are nearly or completely illegible.

Some high-resistance label face stocks remain legible under these test conditions, but they tend to be more expensive and are usually special order.

Figure 6. Long-term dashboard test results

Plasticizer Tests

These test results illustrate the sensitivity of five high-quality thermal papers (samples Q through U) to shrink wrap containing plasticizers over a one-week period.

Sample Q in Figure 7 was placed in surface contact with shrink wrap but not wrapped to a drum. The amount of degradation is extremely sensitive to the surface contact with the plastic. Thus, the image has quite a bit of variation.

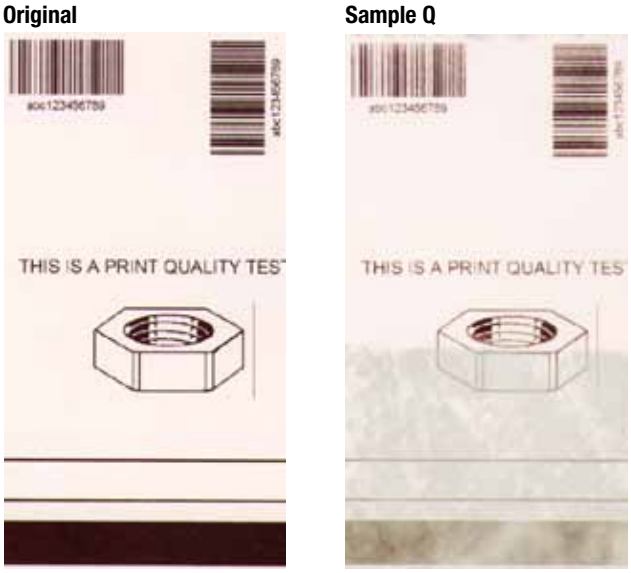

Figure 7. Plasticizer test results for shrink wrap

Samples R through U in Figure 8 were all wrapped to a drum to get better surface contact with the shrink wrap. Samples R, S, and T have top coatings. Sample U does not have a top coating.

CONCLUSIONS: Thermal papers with top coatings have better resistance to degradation from plasticizers than do thermal papers without a top coating. As in the other tests, individual papers have varying degrees of resistance.

When the correct thermal paper is carefully selected for your specific use, your printed documents can resist image degradation and discoloration of paper caused by exposure to plasticizers.

OVERALL CONCLUSIONS FROM TESTING

All the samples in these tests are high quality thermal papers formulated for transaction documents. Results from tests using lower quality thermal papers for point-of-sale receipts and faxes would not compare favorably with these results.

The samples in these tests are also well matched to the printer producing the images. Results from tests using thermal paper poorly matched to the printer would not compare favorably with these results.

High quality thermal papers for transaction documents provide different advantages based on their formulations: minimal discoloration at high temperatures or exposure to intense ultraviolet light, minimal fading of the image when the paper contacts plasticizers, etc.

High quality thermal papers that are well matched to your printer and formulated for your specific use provide the best presentation appearance for your transaction documents, the best printed image, high durability, and archiving that meets application needs and legal requirements.

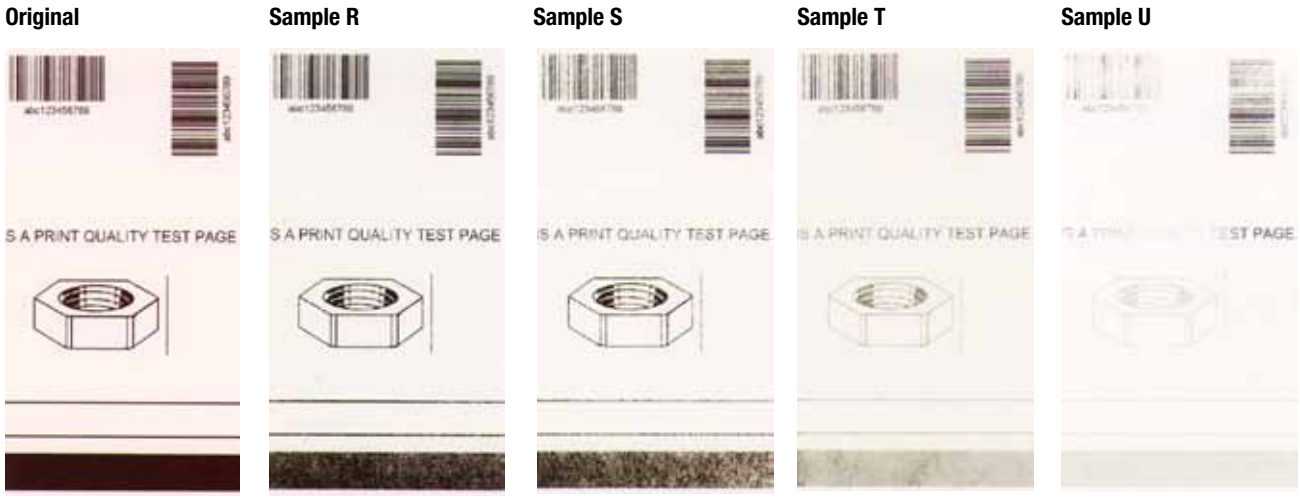

Figure 8. Plasticizer test results for shrink wrap – samples wrapped to a drum

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