

# Thermal Printing Developments for Harsh Industrial Environments

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## Abstract

Thermal transfer printing has exhibited explosive growth in the industrial marking world since the early 80's. However, as the market has matured, the applications have become increasingly more difficult. However, these difficult applications continue to be successfully addressed, giving rise to continued growth in this specialty niche market, even in the face of the so-called "maturation" of thermal printing. This paper discusses some of the actual successes in this arena, with a proven methodology to define and resolve the applications requirements. Specific issues are discussed regarding the interactions between ribbon, receiver sheet, and end use environment. The author displays and discusses specific laboratory and field results in the electronics, electrical, and metals industries to demonstrate these points. The need for new materials is reviewed, and the implications for joint development requirements between printer, ribbon, and receiver face-sheet companies discussed. The demand for higher print resolution, higher speed, and "hybrid" printing technologies is also reviewed, and examples exhibited.

## Introduction

As the applications for thermal transfer printed labels have become more demanding, the technical requirements for print receiver sheets signaled a switch from the "technology push" of thermal transfer printers "pushing" new applications along, to that of materials "pulling" printers into new applications, as new ribbons and materials became available. This "paradigm shift" places the burden of successful implementation, on the label material qualification process. Functional definition of the printed label requirements, and exhaustive applications testing provide the basis for success.

### Functional definition of the label required.

The model used for so-called "durable" label printing relies on the functional definition of a customer's requirement, to lead to the proper materials. The question "What must the label DO?" must be answered.

The label MUST: stay on (surface) when applied at (temperature) for (time period). During this time period the label will be exposed to (solvents, dust, other environmental contaminants) for (time for each exposure). Operating temperatures will be (from what to what) for (how long). The maximum/minimum temperature will be (what, what) for (how long)."

This then leads to the selection of acceptable ribbon/receptor combinations, in concert with adhesive and other label or tag requirements. Remember, **the label material is the platform for delivery** of the bar code information. If the platform fails, the information will not be available for use. The ribbon/receptor selection dictates the energy requirements of the thermal printer. Only then should the printing equipment requirement be selected.

The manufacturing process for printed circuit boards serves as a model to examine this critical relationship between printers, ribbons, and media/label materials. As a PCB is manufactured, it is exposed to several harsh chemicals, while undergoing thermal environmental changes up to 250° C, all within a few minutes. This manufacturing process will expose the weakest element in the printing system (printer/ribbon/receptor).

Let's construct a hypothetical situation whereby we are examining a ribbon/label stock combination and using each of three different printers to print the labels. The printer operator would be instructed to use the identical label/ribbon combinations across all three printers, and adjust the printer heat and speed settings until "good quality" prints are achieved. The labels are then verified; interestingly, each print would give a different ANSI grade, between A-C. We then would instruct the operator to take each of these labels, affix them to a circuit board, and soak them in a variety of 10 or 15 different chemicals that one might use in the PCB manufacturing operation. Surprisingly, we would find different results between each of the printed label sets; that is, in some instances a Printed image from one printer, may not survive a given chemical as compared to those labels printed on an alternative printer. Remember, the ribbon and substrate combination is identical in each case. The conclusions we have drawn are twofold:

- #1. An acceptable print does not necessarily mean the label/ribbon combinations will work "in use".
- #2. A better ANSI grade does not necessarily mean a better label "in use".

We then would ask the operator to take the spent ribbon (from which the bar code image has been printed, or "the negative" of the printed image) and examine the printed area under an optical comparator. In all cases, from printer A, B, or C, the bar width of the x dimension (e.g., 5 mils for example, in the case of a 200 dpi printer) is in fact 5 mils. But in the case of printer B, the printed x dimension image may in fact be 4 mils, and in the case of Printer C, the printed x dimension may in fact be 6 mils. Without trying to quantitatively answer the question "why", we can clearly state that **thermal management really matters.**

For a given family of label materials, even when using the same ribbon and printer, one will observe that each material will have a different characteristic "operating band" in which acceptable prints are achieved. If one goes through a variety of print speed and heat setting experiments, by taking printed labels from different speed/heat settings, for a given printer, and soaking them in a series of chemicals, one startling conclusion is reached. In our laboratory observations, increased speed at a given "heat" setting resulted in decreased bar width; moreover, beyond a certain speed at a constant heat setting, chemical resistance deteriorates.

As shown on Figure 2, maximum chemical resistance is achieved at lower print speeds and higher heat settings on the printer. Although one may achieve equally good prints at higher speeds and lower heat settings, it is very clear, based on laboratory studies, that a minimum thermal energy is required for printed labels from a particular set of ribbon/receiver sheets, to achieve chemical resistance against a given set of test chemicals, as qualitatively depicted in Figure 2.

**Figure 2.** Relationship between chemical resistance of printed image, and printer settings

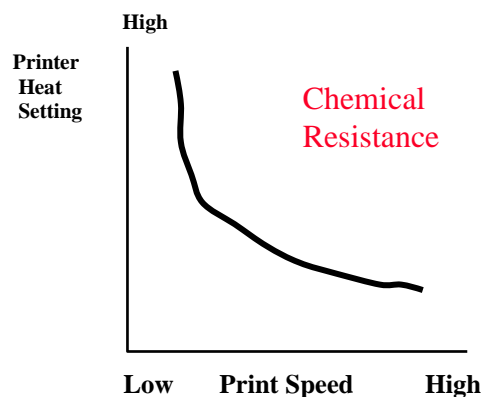
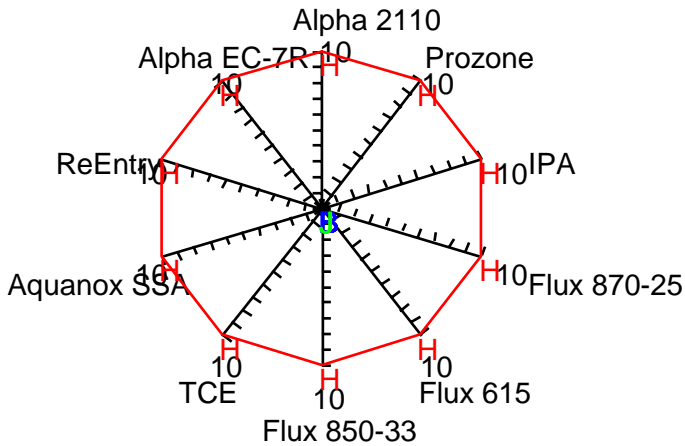


Figure 3 depicts a perfect score for the 10 solvents used to test the printed label. A score of 1 means acceptable (hence the line drawn creating a wheel around the spokes), while a failure means a zero, or no line drawn at that particular spoke. A total failure would result in a graph with no lines connecting the spokes.

Figure 3. Graphic display of 10 successful chemical resistance tests.



Let's now examine a hypothetical case with label materials A and B, and ribbons No. 1 and 2. In the case of Figure 4, substrate A/ ribbon 1 combinations look promising, except for one instance (PROZONE).

By switching ribbons (Figure 5) to label stock A and ribbon 2, the PROZONE failure has been remedied. Two of the chemicals, which previously had passed, now failed. With the wide variety of ribbons available today, this result may not be surprising, since it has been observed that some ribbons are better than others for resistance to specific chemicals.

Fig. 4. Substrate A, Ribbon 1

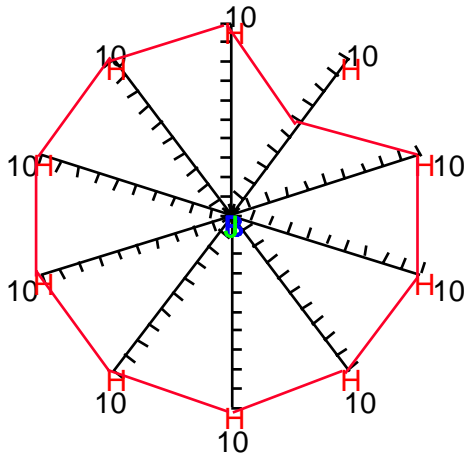
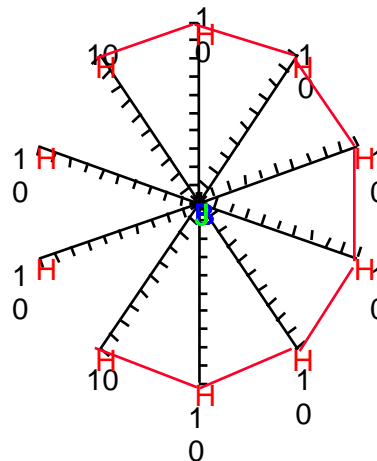


Fig. 5 Substrate A, Ribbon 2



Now, moving to Figure 6, we will change to the label material B/ribbon 1 combination.

The failure in the first example (Figure 4, PROZONE) is now remedied by **changing label stock; note that the ribbon is the same**, as in the case of Figure 4. Yet we had always assumed that ribbon 1 would fail that one particular chemical; however, it now passes, by changing to a new label surface. Interestingly, ribbon 1, which passed Aquinox SSA in the first example (Figure 4), **now fails that same chemical**.

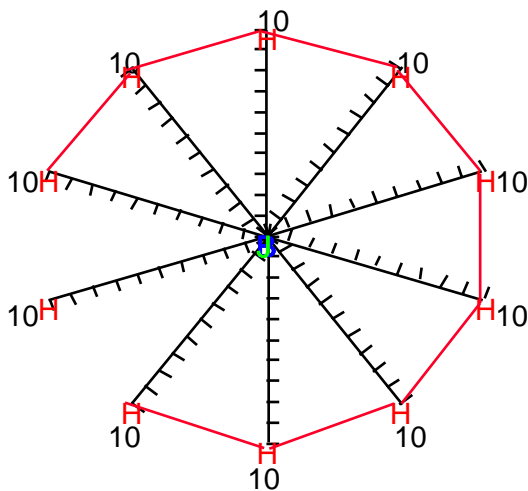


Figure 6. Substrate B, Ribbon 1

Conclusions: Thermal management of the print head is significant for label durability in harsh environment applications. The **combination** of ribbon/receiver sheet is extremely important for chemical resistance.

The thermal diffusivity of each layer in the “composite”, at the moment of printing is very important, i.e. the heat flow from the print head, through the carrier film, ink layer, and into the receiver sheet. Obviously, print head pressure, angle of stripping away the ribbon, and other mechanical features dictate print quality, but do not explain print durability, at least in the present study. Certainly the surface tension of the molten ink with respect to that of the receiver sheet, at the printing temperature, influences wetting, and hence ink receptivity. But as shown, ANSI verification or quality does not guarantee label performance in the intended use.

Label failure in the chemicals employed appears to happen by one (or more) of several mechanisms. The ink from the printed image may dissolve leaving a blank label. The ink may partially dissolve, leaving a discernible, yet gray image. The imaged characters may literally “float away” from the receiver sheet, leaving a blank label, but with discrete characters floating in the chemical bath, i.e. the “alphabet soup” effect. The coating on the receiver surface may dissolve, in which case the image cannot be expected to stay on the now, non-existent label surface. In many cases, it has been noted that if a printed label is heated, the inked image becomes increasingly resistant to chemical attack, by whatever mechanism.

A variety of thermal effects are clearly at work. One may speculate as to the contributing influence of:

1. Mechanical effects, as the ink flows into the interstices of the receiver sheet layer;
2. “Melt blending” of oligomers and low  $T_g$  copolymers;
3. The chemical composition and layered construction of the ink layer, and its final chemical resistance to the solvents employed;
4. Internal thermo-chemical reactivity of the components of the inked image;
5. Internal thermo-chemical reactivity of the receiver sheet;

6. Chemical resistance of the receiver sheet;
7. Chemical reactivity between the ink layer and the receiver sheet surface; and,
8. Combinations of the above.

Preconceptions of the relative “goodness” of ribbon archetypes must be discarded. In many cases, the “lower quality wax ribbons” clearly outperform the newest of the “super premium resin” ribbons, solely because they (the wax) work in the application at hand, in concert with the properly matched receiver sheet.

Preconceptions about the nature of the receiver sheet surface (gloss vs. matte) are equally faulty. Again, the successful combination of matched receiver and ribbon will determine the degree of success of the thermal transfer printing project.

Conclusions:

1. Thermal management and thermal profile of the printer is significant for successful implementation of harsh environment applications.
2. An acceptable ANSI image of a given printer/ribbon/receiver combination does not guarantee its success in its intended use.
3. A higher ANSI grade of a given image, as in 2. above, does not insure better print permanence “in use”.
4. The ribbon/receiver “in combination” must be evaluated for specific applications.
5. Beware of preconceptions wrought by marketing “buzz”. Stay focused on functional definition of the requirement, and the actual data from tests in the customer’s application.
6. “TEST, TEST, TEST” each combination of printer, ribbon, and receiver in its intended application prior to commissioning that combination into use.
7. For more information visit [www.polyonics.com/pr\\_ribqual.html](http://www.polyonics.com/pr_ribqual.html).

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