Homeland Defense & Security Information Analysis Center

HDIAC TECHNICAL INQUIRY (TI) RESPONSE REPORT

Deactivation of Thermal Papers and Labels

Report Number:

HDIAC-BCO-2024-527

Completed February 2024

HDIAC is a U.S. Department of Defense Information Analysis Center

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)* 21-02-2024	**2. REPORT TYPE** Technical Research Report	**3. DATES COVERED** *(From – To)*
4. TITLE AND SUBTITLE Deactivation of Thermal Papers and Labels		**5a. CONTRACT NUMBER** FA8075-21-D-0001 **5b. GRANT NUMBER** **5c. PROGRAM ELEMENT NUMBER**
6. AUTHOR(S) Kolton Booty		**5d. PROJECT NUMBER** **5e. TASK NUMBER** **5f. WORK UNIT NUMBER**
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Homeland Defense & Security Information Analysis Center (HDIAC) SURVICE Engineering Company 4695 Millennium Drive Belcamp, MD 21017-1505		**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Defense Technical Information Center (DTIC) 8725 John J. Kingman Road Fort Belvoir, VA 22060-6218		**10. SPONSOR/MONITOR'S ACRONYM(S)** **11. SPONSOR/MONITOR'S REPORT NUMBER(S)**

12. DISTRIBUTION/AVAILABILITY STATEMENT

DISTRIBUTION A. Approved for public release: distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The Homeland Defense and Security Information Analysis Center (HDIAC) received a technical inquiry regarding deactivation of thermal papers and labels that does not destroy the paper, induce a color change, or leave the paper appearing tampered with. HDIAC subject matter experts were tasked to conduct a literature search and present findings from some of the most recent articles on this subject.

15. SUBJECT TERMS (PROVIDED BY AUTHOR)

thermal paper, thermal label, deactivation, leuco dye

16. SECURITY CLASSIFICATION OF: U			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON** Ted Welsh, HDIAC Director
a. REPORT U	**b. ABSTRACT** U	**c. THIS PAGE** U		11	**19b. TELEPHONE NUMBER** *(include area code)* 443-360-4600

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

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Abstract

The Homeland Defense and Security Information Analysis Center (HDIAC) received a technical inquiry regarding deactivation of thermal papers and labels that does not destroy the paper, induce a color change, or leave the paper appearing tampered with. HDIAC subject matter experts were tasked to conduct a literature search and present findings from some of the most recent articles on this subject.

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1.0 TI Request

1.1 Inquiry

Can thermal paper and labels be deactivated?

1.2 Description

The inquirer is searching for a method of deactivating thermal papers by inhibiting color change when the thermal paper or label is exposed to high temperatures. Thermal paper is comprised of base stock paper, a precoat layer, and a thermal layer [1]. The thermal layer consists of microencapsulated leuco dye, sensitizer (weak acid), and a stabilizer. Some thermal papers and labels will also have a topcoat and bottom coat applied to increase stability and protection. Topcoats will typically consist of polyvinyl alcohol (PVA). When the thermal paper is exposed to high temperatures at 100–120 °C, the leuco dye and sensitizer melt together and create a permanent color reaction.

The inquirer is interested in preventing the color change of the thermal paper when exposed to high temperatures, rendering the thermal paper deactivated.

2.0 TI Response

Subject matter experts at Texas Research Institute Austin reviewed and summarized relevant literature on the topic of vulnerabilities of thermal paper that could inhibit a color change when exposed to high temperatures.

2.1 Factors Affecting Thermal Paper Performance

Thermal paper performance and stability are best when handled and stored properly, as many external and environmental factors can impact the thermal paper [2]. Manufacturers generally recommend avoiding the following factors to maximize stability of thermal paper before and after color development has occurred:

- Elevated temperature exposure
- Ultraviolet (UV) light exposure
- High-humidity exposure
- Plasticizer exposure
- Solvent exposure

2.1.1 Elevated Temperature Exposure

Exposing thermal paper to elevated temperatures will not deactivate thermal paper, as it is designed to activate when heated. If thermal paper is left in temperatures that are hot enough, an activation will occur and cause the paper to change color. If the activation temperature is not reached, the paper will remain unchanged.

2.1.2 UV Light Exposure

Exposure of thermal paper to longwave and shortwave UV light will cause yellowing over time (days and weeks) [2]. The performance of the thermal paper to produce a color change after intense UV light exposure will be lighter than for unexposed paper. A topcoat on the thermal paper will help prevent damage from UV light exposure. UV light exposure will not deactivate the thermal paper but will cause noticeable color change.

2.1.3 High-Humidity Exposure

Exposing thermal paper to high-humidity conditions will fade the paper over an extended period. A topcoat on the thermal paper will help prevent damage from these conditions. Hot-steam exposure will cause the thermal paper to activate if the temperature of the steam is hot enough. High-humidity exposure will not deactivate thermal paper.

2.1.4 Plasticizer Exposure

Exposing thermal paper to high concentrations of plasticizers will induce significant fading of activated thermal paper [2]. Plasticizers will reduce the color activation property of thermal papers, and their exposure can occur from materials with light concentrations of plastic wraps, adhesive tapes, and fragrances. Concentrated plasticizers will degrade and deactivate thermal paper.

2.1.5 Solvent Exposure

Exposing thermal paper to various solvents will inhibit color change. Various solvents can penetrate the thermal layer and dissolve the microencapsulated leuco dye [3, 4], thus effectively removing the dye from the paper. If the dye is removed from the thermal paper, a color change will not occur at high temperatures. Specific solvents will deactivate thermal paper; these are discussed in the next section.

2.2 Solvent Exposure Trials

Multiple solvents were tested on three different kinds of thermal papers—acetone, methyl ethyl ketone (MEK), and xylenes (mixed isomers) [5]. Note that the exact materials used in these papers are unconfirmed, they may have had a RVA topcoat.

Samples of each thermal paper were soaked in a beaker of each tested solvent. The beaker was mixed for less than 30 s by hand to ensure good saturation in the paper. The paper was then removed from the solution and allowed to air dry. Once dried, the samples were exposed to a heat gun for a few seconds. The heat gun used is rated for over 600 °C, greatly above the activation temperature for thermal papers.

When the thermal paper was soaked in each of these solvents, the paper became slightly lighter in color and would “erase” any areas of the thermal paper that had previously been activated (printed numbers and letters on the receipts). After drying the samples and being exposed to the heat gun for a few seconds, the samples remained white and showed no activation. Some charring was seen on the edges of the paper due to the extreme heat applied. Controls of each sample of thermal paper that were not treated with any solvent turned completely black when exposed to the heat gun.

The solvent that did not deactivate the thermal label was 95% ethanol. After ethanol treatment, the thermal paper would turn black when exposed to the heat gun.

3.0 Conclusion

In summary, our test results indicate that acetone, MEK, and xylenes may be used to effectively deactivate thermal paper. However, it is important to note that thermal papers are made from a wide range of leuco dyes, microencapsulations, topcoats, and bottom coats. Some topcoats are formulated specifically to increase stability against the various factors described above. As such, a solvent that successfully deactivates the trial thermal papers may not always deactivate others. It may be necessary to utilize different solvents on different thermal papers obtained from different sources for effective deactivation.

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Biography

Kolton Booty is a chemist in the ARTEC Division of Texas Research Institute Austin, Inc., experienced in formulation chemistry, materials development, and chemical compatibility testing. His research interests include dye and pigment chemistry. Mr. Booty holds a bachelor's degree in chemistry from Texas State University.