Red-on-Red Warnings?

by

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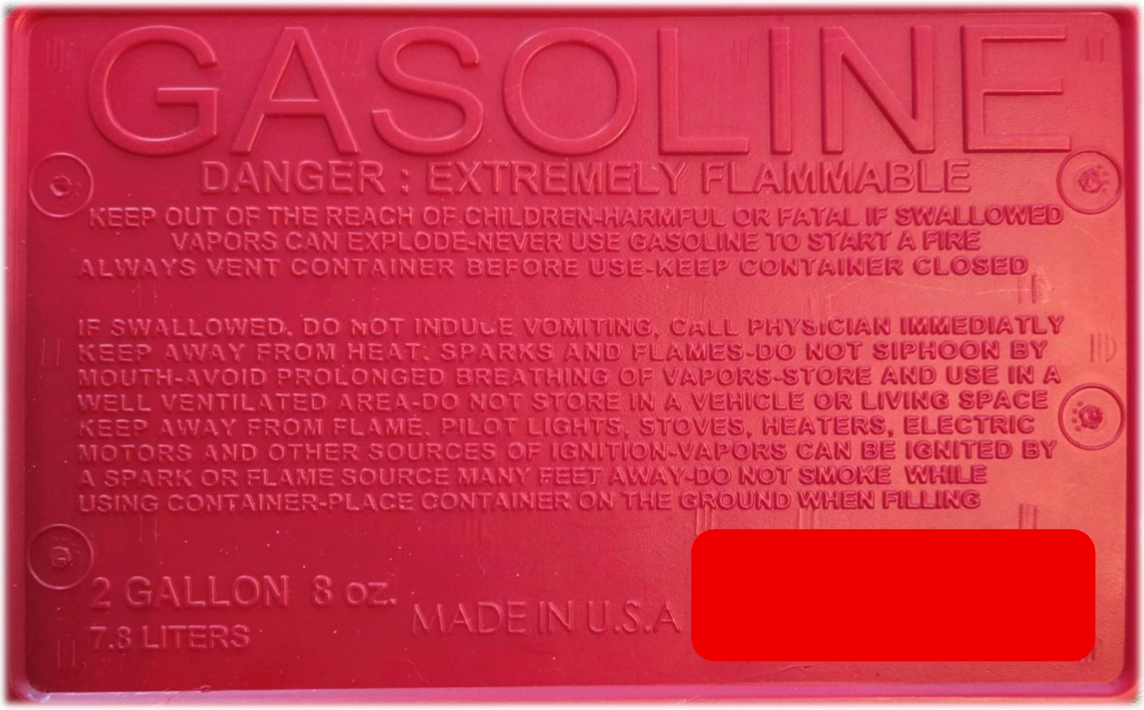
Abstract: *The warnings on Portable Plastic Gasoline Containers ("PPGC") are embossed on each side resulting in red lettering on a red background as shown below. Testing presented in this paper support the conclusions in the literature, Codes and Standards that warnings are most readable if there is a significant contrast in color between the lettering and background.* ***In addition to being difficult to read, the warnings fail to describe the explosion hazard, the consequences of the hazard, and describe how the hazard can be avoided."*** *Despite the claims of the Portable Gasoline Container Manufacturers Association, the potential for a gasoline can explosion and/or jetting from the nozzle events have been known for decades.*



The warning on the side of an exemplar PPGC.

This paper addresses the warnings on the containers and presents test data supporting the use of contrasting lettering and background colors.

Introduction

The ASTM designation F852[1] specifies the use ofdesignation F839,[2] which specifies the following warning information appear on all portable gasoline containers:

DANGER
GASOLINE
EXTREMELY FLAMMABLE
VAPORS CAN EXPLODE
HARMFUL OR FATAL IF SWALLOWED

If swallowed, do not induce vomiting, call physician immediately
Keep out of reach of children
Avoid prolonged breathing of vapors
Do not siphon by mouth
Do not store in vehicle or living space
Store and use in well-ventilated area
Vapors can be ignited by a spark or flame source many feet away
Keep away from flame, pilot lights, stoves, heaters, electric motors, and other sources of ignition
Keep container closed

The ASTM standard, however, does not: (i) specify the color of the letters contrast with the color of the background, (ii) require the points given above be provided in a list, (iii) describe that a flame can enter the container, (iv) state that the container can explode, and (v) explain why the container should be kept closed. Each of these issues will be addressed in turn below.

Red-on Red Coloring

Contrast in coloring has been cited as being important in warnings since the 1930's. As noted in the 1999 text *Warnings and Risk Communication*:[3]

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[1] ASTM designation F852, Standard Specification for Portable Gasoline Containers for Consumer Use.
[2] ASTM designation F839-2006, Standard Specification for Cautionary Labeling of Portable Gasoline Containers for Consumer Use.
[3] *Warnings and Risk Communication,* edited by Michael S. Wogalter, David M. DeJoy, Kenneth R. Laughery. Published in 1999 by London: Taylor & Francis. ISBN 0-7484-0266-7. See also

> "Certain color combinations produce contrast that is nearly as good as black and white (e.g., black on a saturated yellow or white on saturated red). However, certain hue combinations (e.g., dark blue on dark purple or yellow on white) do not produce distinguishable figure-ground patterns and should not be used (Sumner, 1932)."[4]

and,

> "Black print on a white background or white print on a black background provides maximum brightness contrast, while gray print on a similar shade of gray background produces little contrast. Research shows that features with greater contrast are detected and localized faster than those of lower contrast, (e.g., Brown, 1991; Sanders and McCormick, 1993)."[5,6]

The discussion of color and contrast appear in most peer reviewed papers on the design of warnings. For example:[7]

> "Adding color to a warning can increase its ability to attract attention (Gill et al., 1987)[8] provided that the warning color is distinguishable from background and surrounding color."

This same reasoning is reflected in the ASTM American National Standard for Product Safety Signs and Labels.[9]

> **"7.6.2 When special circumstances limit the use of sign colors**
>
> When special circumstances limit the use of sign colors to two colors, the colors assigned to the signal word panel may also be

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Handbook of Color Psychology, Edited by A.J. Elliott, M.D. Fairchild and A. Franklin, Cambridge University Press, 2015, chapter 18 Use of color in warning.

4 Sumner, F. C. (1932), Influence of color on legibility of copy, Journal of Applied Psychology, 16, 201-4.

5 BROWN, T.J. (1991) Visual display highlighting and information extraction. In Proceedings of the Human Factors Society 35th Annual Meeting. Santa Monica, CA: Human Factors Society, pp. 1427–1431.

6 Sanders, M. S., & McCormick, E. J. (1993). *Human factors in engineering and design* (7th ed.). Mcgraw-Hill Book Company.

7 https://www.researchgate.net/publication/11221385_Research-Based_Guidelines_for_Warning_Design_and_Evaluation [accessed May 25 2025].

8 Gill, R.T., Barbera, C., Precht, T., 1987. A comparative evaluation of warning label designs. In: Proceedings of Human Factors Society31st Annual Meeting. Human Factors Society, Santa Monica, CA, pgs. 476–478.

9 ANSI 535.4-2007 American National Standard for Product Safety Signs and Labels.

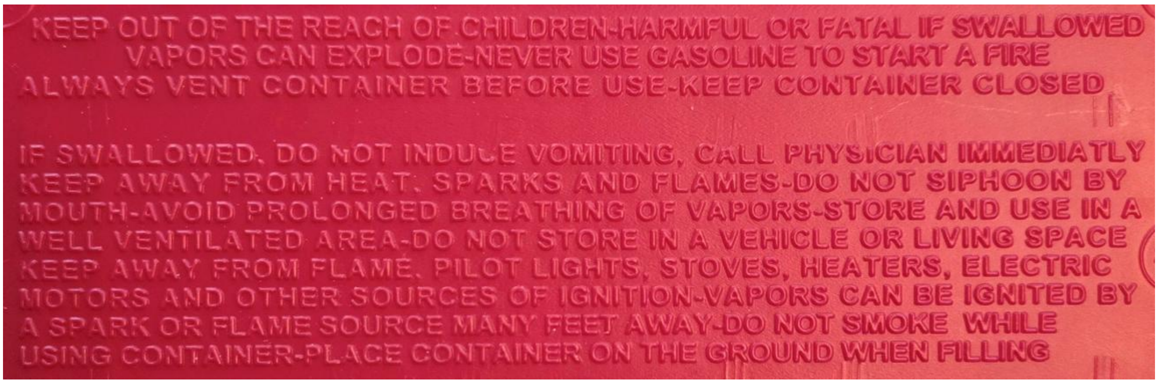
used for the message and safety symbol panels provided that the panel colors contrast with the background color of the product."

The American National Standard Safety Color Code, states:

> 4.6 To ensure optimum visibility, colors selected for safety signs should have maximum color contrast, especially lightness contrast. Likewise, contrast must be achieved between the sign and its visual environment. Thus, dark colors (red, brown, green, blue, and purple) should be used with white letters, while light colors (orange and yellow) are better seen contrasted with black.[10]

The recommendation of high color contrast between lettering and background is also reflected in general industry advice given in internet blogs.[11]

In a straightforward test, we asked 20 volunteers to allow us to measure the distance at which they could read the 2.5 mm high lettering in the gasoline can warning shown below:



Closeup of the warnings on an exemplar PPGC.

And at what distance could they read the same message printed with black lettering on a white background and with red lettering on a yellow background (same font and size) as shown below.

[10] ANSI 535.1-1998 American National Standard Safety Color Code.
[11] https://www.bluelabelpackaging.com/blog/these-color-combos-could-be-hurting-your-labels-heres-what-to-know/.

KEEP OUT OF THE REACH OF CHILDREN-HARMFUL OR FATAL IF SWALLOWED
VAPORS CAN EXPLODE-NEVER USE GASOLINE TO START A FIRE
ALWAYS VENT CONTAINER BEFORE USE-KEEP CONTAINER CLOSED

IF SWALLOWED, DO NOT INDUCE VOMITING, CALL PHYSICIAN IMMEDIATELY
KEEP AWAY FROM HEAT, SPARKS AND FLAMES-DO NOT SIPHOON BY
MOUTH-AVOID PROLONGED BREATHING OF VAPORS-STORE AND USE IN A
WELL VENTILATED AREA-DO NOT STORE IN A VEHICLE OR LIVING SPACE
KEEP AWAY FROM FLAME, PILOT LIGHTS, STOVES, HEATERS, ELECTRIC
MOTORS AND OTHER SOURCES OF IGNITION-VAPORS CAN BE IGNITED BY
A SPARK OR FLAME SOURCE MANY FEET AWAY-DO NOT SMOKE WHILE
USING CONTAINER-PLACE CONTAINER ON THE GROUND WHEN FILLING

KEEP OUT OF THE REACH OF CHILDREN-HARMFUL OR FATAL IF SWALLOWED
VAPORS CAN EXPLODE-NEVER USE GASOLINE TO START A FIRE
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WELL VENTILATED AREA-DO NOT STORE IN A VEHICLE OR LIVING SPACE
KEEP AWAY FROM FLAME, PILOT LIGHTS, STOVES, HEATERS, ELECTRIC
MOTORS AND OTHER SOURCES OF IGNITION-VAPORS CAN BE IGNITED BY
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USING CONTAINER-PLACE CONTAINER ON THE GROUND WHEN FILLING

The same warning with black lettering on a white background and red lettering on a yellow background.

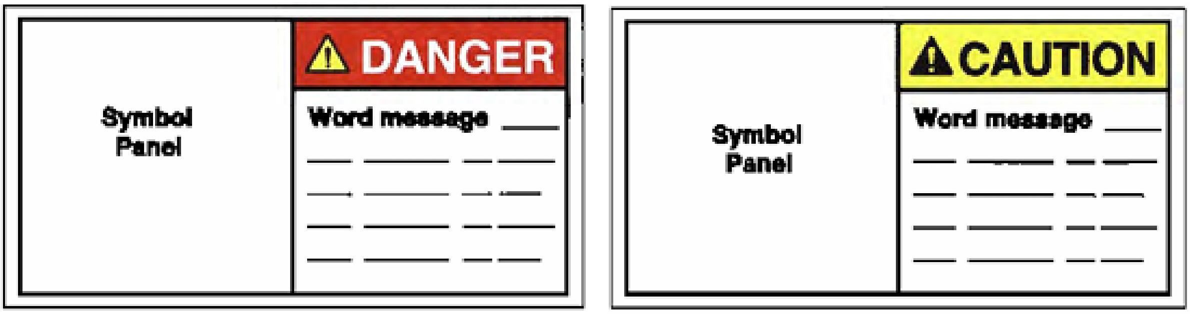
The results are shown below in Table 1.

Table 1. Distance at which a Label with 2.5mm Letters can be read with Red-on-Red, Red-on-Yellow and Black-on-White, lettering on background coloring.

2 gal PPGC		**Distance (inches)**		
Letters 2.5 mm		Red/Red	Red/Yellow	Black/White
Male		18	37	
Female		19	47	
Male		50	60	
Male		12	48	
Female		28		48
Male		19		22
Female		33		62
Female		40		45
Male		12		44
Female		48		48
Male		12		36
Female		45		61
Male		31		42
Male		35		44
Male		12		38
Female		0		45
Male		10		58

Male		44		57
Female		37		55
Male		30		50
Average		26.8	48.0	47.2
≤ 12 inches		30.0%	0.0%	0.0%

The data clearly shows that the participants could read labels with contrasting letters and background coloring at almost twice the distance as a red-on-red embossed label. Observations during the testing suggested the participants could not read the red-on-red label as fast as the high contrast versions. Additional testing would be needed to verify this observation. Further, 30% of the participants had to be within 12 inches of the red-on-red label to read it. The test data is consistent with findings in peer reviewed literature, textbooks, Codes and Standards, and industry blogs, going back as far as 1932. High lettering / background contrast coloring is significantly easier for a user to read and almost certainly more effective. As shown below, the examples in ASTM American National Standard for Product Safety Signs and Labels always contain a high contrast between the lettering and background coloring.[12]



Examples of Signal Word Panels with Various Safety Alert Symbols.

[12] ANSI 535.4-2007 American National Standard for Product Safety Signs and Labels.

Additional Warning Deficiencies

The PPGC warnings are also deficient regarding formatting. ANSI Z535.4 provides a list of desired formatting characteristics for warnings (summarized, **emphasis added**):

- Section 6.1: Panels. Safety signs or labels consist of a signal word panel plus a message panel.
- Section 6.3: Safety Alert symbols shall precede the signal word (i.e. Danger, warning, etc.).
- Section 6.4: Distinctiveness. The warning shall be distinctive, such as a contrasting border.
- **Section 6.5.1: Multiple messages should be provided with sufficient space between them to prevent them from visually blending together.**
- Section 7.1.3: the word “CAUTION” shall be in black letters on a yellow background.

As shown above, the warnings are grouped together in two run-on paragraphs. All the words are capitalized and dashes instead of periods are used to separate the individual warnings. This is clearly inconsistent with the ANSI Z535.4 desired warning formatting characteristic of providing “sufficient space between them to prevent them from visually blending together.” It may also explain the difficulty test participants appeared to have in understanding the red-on-red warnings.

Just as important, the warnings fail to describe the most significant hazards, (i) an external flame can enter the container, (ii) a PPGC can explode or jet burning fuel out of the nozzle.[13],[14] The warnings also fail to explain why the container

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[13] Hasselbring, L.C., “Case study: Flame arresters and exploding gasoline containers”, Journal of Hazardous Materials 130 (2006) 64–68.

[14] Stevick, G.R., Rondinone, D., Sagle, A., and J. Zicherman, "Portable Plastic Gasoline Container Explosions And Their Prevention", Presented at the Society of Forensic Engineers and Scientists Winter Seminar, Yosemite, California, March 19-21, 2010. Stevick, G.R., Rondinone, D., Sagle, A.,

should be kept closed. As described by Zicherman (1992) "... effective warnings for a product need to (1) be visible to end-users, (2) describe the hazards in question to end-users *with care,* and (3) describe to the end-user the *consequences of not heeding the warning."*[15]

Conclusions

The standard warnings on PPGCs are defective for the following reasons: (i) no color contrast between the lettering and background, (ii) the individual warnings are grouped together in two run-on paragraphs instead of provided in a bulleted list, (iii) the warnings fail to describe that a flame can enter the container, (iv) the warnings fail to describe that a PPGC can explode or jet burning fuel out the nozzle, and (v) the warnings fail to explain why the container should be kept closed. Each of these design defects is inconsistent with the standard of care in engineering and warning design. Further, it should be noted that warnings are not just for the user. As warnings should be developed during the design process, they provide an opportunity for the designer to revisit, mitigate or eliminate hazards from the design.[16]

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and J. Zicherman "Fire Incidents and Explosions Involving Portable Plastic Gasoline Containers and Their Prevention", J. Failure Analysis and Prevention, Aug 2011. St. John, A.D., Loa, J.M., and B.S. Grove, U.S. Department of Justice Fire Research Laboratory Report, Reference 774040110026, Majd Al-Shara Fire, ATF Laboratories, December 29, 2010.

[15] PC-based Product-selection Systems to Enhance Fire Safety in Construction, by J.B. Zicherman and D. Frey, Fire and Materials, Vol. 16, 53-60, 1992. "For example, effective warnings for a product need to (1) be visible to end-users, (2) describe the hazards in question to end-users *with care,* and (3) describe to the end-user the *consequences of not heeding the warning."*

[16] Frantz, J.P., Rhoades, T.P. & Lehto, M.R. (1999), Practical considerations regarding the design and evaluation of product warnings. In M.S. Wogalter, D.M. DeJoy & K.R. Laughery (Eds.) *Warnings and Risk Communication* (pp. 291-311). Philadelphia, PA: Taylor & Francis. Nemire, K., Stevick, G., and D. Xu, "Forensic Evaluation of a Hazardous Household Product." *Ergonomics in Design,* 25(2) (2017) 15-24.