SAE INTERNATIONAL

AEROSPACE RECOMMENDED PRACTICE

ARP5607™ REV. B

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Superseding ARP5607A

(R) Legibility of Print on Aerospace Wires and Cables

RATIONALE

The marking of electrical wires and cables and fiber optic cables with their unique identification codes is a critical manufacturing function to enable production and maintenance personnel to easily identify each wire and cable. The ability of personnel to read the codes is highly dependant upon the legibility of the markings. This is especially important on smaller single core wires where the wire diameter limits the dimensions of the characters making up the code. This ARP has been established to make recommendations on the ergonomic factors that equipment manufacturers should follow when designing wire marking equipment for use in wire harness production to help maximise the legibility of the codes.

1. SCOPE

The purpose of this SAE Aerospace Recommended Practice (ARP) is to provide recommendations for marking wire and cable insulations to meet legibility requirements. This information is generic and applies to any type of wire marking system, such as an ultraviolet (UV) laser marking system or an inkjet or other ink based wire marking system. This ARP is limited to the legibility of human-readable characters and does not address bar code or other machine-readable symbols. In this ARP, the term wire refers to jacketed cables and fiber optic cables in addition to individual wires.

This ARP defines the factors that affect the legibility of markings on wiring. Two generic types of variables affect legibility: stimulus variables and environmental variables. Stimulus variables are those factors involving the mark itself. This ARP establishes a set of guidelines for key stimulus variables that contribute to legibility and which should be taken into consideration in the course of specifying and using wire marking equipment. Environmental variables affect the reading of the marking, for example lighting, observer-stimulus distance, orientation of observer to stimulus, clutter, visual acuity of observer, state of mind, and visual exposure duration.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific examption has been obtained.

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2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AS4373 Test Methods for Insulated Electric Wire

"Naval White Wire Legibility Threshold Study - A Statistical Approach," presented at SAE Aerospace Electrical Interconnection Systems Conference, Williamsburg, Virginia, 29 October 1997.

2.1.2 Other Publications

Erdmann, R.L., and Neal, A.S., "Word Legibility as a Function of Letter Legibility with Word Size, Word Familiarity and Resolution as Parameters," J. Applied Psychology, Vol. 52, pp. 403-409.

Soar, R.S., "Height-Width Proportion and Stroke Width in Numeral Visibility," J. Applied Psychology, Vol. 39, p. 45.

Van Nes, F.L., and Jocobs, J.C., "The Effect of Contrast on Letter and Word Recognition," IPO Annual Progress Report, 1981, Vol. 16, pp. 72-80.

ASD-STAN prEN 3745-705 P3, "Aerospace Series Cables, Electrical, Aircraft Use Test Methods: Contrast Measurement," ASD-STAN, Rue Montoyer 10/5, 1000 Brussels, Belgium; Edition P3, 26 June 2020.

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AIR5558 Ultraviolet (UV) Laser Marking Performance of Aerospace Wire Constructions

AS5649 Wire and Cable Marking Process, UV Laser

2.3 Definitions

CONTRAST: A measurement relating to the difference in luminance of the mark and its associated background according to a precise formula. The accepted formula used for contrast of wire and cable marking (dark marks on light backgrounds) is in accordance with AS4373 Method 1001.

FONT: The defining shape and style of a character set for printing or marking.

LEGIBILITY: The quality of being legible, i.e., clear enough to be deciphered and to be read accurately.

LUMINANCE: For the purposes of contrast measurement, luminance is the integrated spectral radiance weighted by the response of the "standard" human eye (the visible flux density per solid angle).

MARK: A character, bar code, or other symbol placed on a wire or cable for identification purposes. This ARP is limited to the legibility of marks that are human-readable characters and does not address bar code or other machine-readable symbols.

WIRE ID: A wire or circuit identification code which is printed on the wire.

3. LEGIBILITY

Legibility is the property of written information that allows it to be deciphered; i.e., to be read accurately and understood.

Two generic types of variables affect legibility. These are known as stimulus variables and environmental variables. Stimulus variables are those factors involving the mark itself. Environmental variables are those factors involving the environment, including the observer.

Important stimulus variables (and corresponding section in this ARP) are:

Character size (height, height-width ratio, stroke widths) - 4.1
Contrast - 4.2
Font - 4.3
Character orientation - 4.4
Inter-character spacing - 4.5
Character formation and fidelity - 4.6

Wire color and surface reflectance are also important stimulus variables, but these parameters are only changed by altering the wire insulation and will not be addressed in this ARP.

Important environmental variables are lighting, observer-stimulus distance, orientation of observer to stimulus, clutter, visual acuity of observer, state of mind, and visual exposure duration.

To increase the probability that the wire ID will meet the legibility requirements and can be accurately read, each of the mark stimulus variables should be optimized as far as is practically possible. Recommendations are provided in Section 4 for the stimulus variables that can be controlled during the wire marking process.

3.1 Legibility Assessment

A wire ID is considered to meet the legibility requirements if it can be deciphered error free by the unaided eye (except with normal vision correction aids) under the following conditions either in its own right, or if necessary from a composite of itself and its immediately adjacent neighbors:

Wipe the wire with a soft, lint-free cloth. View the wire at 15 inches ± 2 inches in an ambient light of 30 foot candles, nominal. The wire ID information must be clear without magnification other than spectacles or contact lenses and read error-free. Record the observed wire ID and check the information against the correct wire ID information.

4. STIMULUS VARIABLES

4.1 Character Size

The size and dimensions of characters can be defined in many different ways. Figure 1 shows, as an example, the character “H” and the terminology used to describe its dimensions.

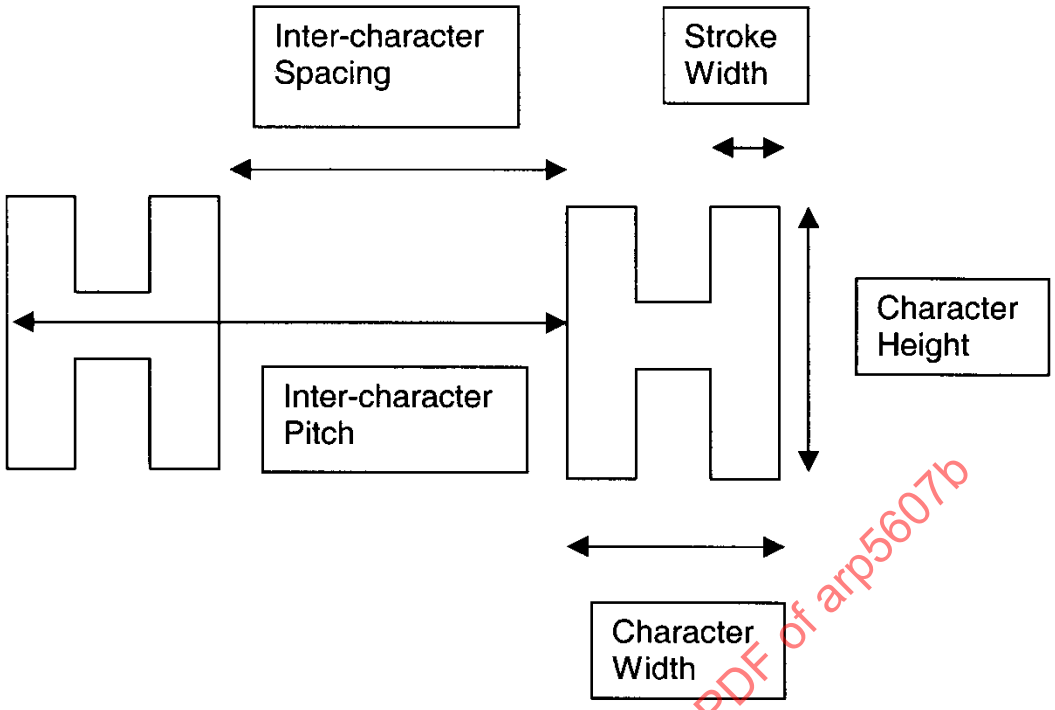

Figure 1 - Character dimensions and terminology

4.1.1 Character Height

Character size (height) is a prime factor affecting legibility. It is an unfortunate fact that aerospace wire marking constrains character size to just that area where size at the eye is a critical determinant of legibility, whereas on paper or packaging, media print size is not normally so limited. In such cases, it is normal for the majority of the text to be printed in point size 9 or 10, which equates to physical character heights of 0.09 inch and 0.10 inch, respectively (2.3 mm and 2.5 mm).

In the case of wiring, the dimensions of the wire itself impose limitations on the maximum character (print) size, in that the mark dimension across the width of the wire must be less than the wire diameter. To ensure that characters are fully formed and meet the legibility requirements in all cases it is recommended that, in general, they should not exceed 90% of the wire diameter.

The general rule for wire identification is to maximize the mark dimension across the diameter for any given wire size, taking into account the limitations of the wire marking equipment in terms of the maximum available mark size. It is particularly important to do this for wires and cables with outside diameters up to 0.12 inch (3.0 mm). Above this size, if the wire marking system can support larger size characters without trading off any other aspects that affect legibility or the performance of the equipment, it will help to make use of this additional equipment capability.

4.1.2 Character Height to Width Ratios

For optimum legibility of characters under normal, everyday conditions, ergonomic studies have determined that a ratio of character height to character width of 4:3 is preferred (refer to Erdmann and Neal, Soar, and Van Nes and Jocobs). The use of characters with this ratio is therefore also recommended for wire marking applications on 22 wire size and larger with the following proviso:

The most serious legibility issues relate to reading of wire IDs on the smallest single wires, typically 22, 24, and 26 wire size. To optimize legibility on these small wire sizes, it is recommended that wire IDs should be marked with a vertical character orientation as described in 4.4. In conjunction with vertical character orientation, it has been industry practice in some cases to enlarge the character height running along the length of the wire to further aid the reading of characters on small wires (noting that it is not possible to further increase the character width, assuming this has already been maximized in relation to the wire diameter). Increasing the character height will increase the height to width ratio. It has been established that the vertical stretching of characters in this manner does assist legibility for the smallest wires and character sizes, particularly on 24 and 26 wire size. It is therefore recommended that where possible an increased height to width ratio of up to 2:1 is used in conjunction with vertical character orientation specifically for marking on 24 and 26 wire sizes.

It is recommended, however, that this approach not be over-used, as the effect can be counter-productive, as character shape becomes distorted out of recognition and can actually reduce legibility. In general, characters with a 4:3 ratio should be used whenever possible to maximize legibility. Height to width ratios in excess of 2:1 decrease legibility and should not be used for either horizontal or vertical character orientation.

4.1.3 Character Stroke Width

Character stroke width plays an important part in legibility, particularly for the small dimension characters used for wire IDs. There are two opposing effects that result from changing stroke width. If the stroke width is too bold (too thick), the character definition suffers as the spaces formed between the character strokes become lost to the eye as it loses its power to resolve them. Characters then become difficult to decipher at best; at worst they become unintelligible blobs. At the other extreme, as stroke width becomes too narrow, the eye has difficulties in seeing the character at all due to a contrast reduction at the retina.

Ergonomic studies have indicated the use of a stroke width of at least 17% of character height for wire IDs (refer to Erdmann and Neal, Soar, and Van Nes and Jocobs). Practical results show that a stroke width in the range of 20 to 30% provides an acceptable result.

4.2 Contrast

It is known that the contrast of the mark against its associated background affects legibility and that legibility increases with contrast up to a limit (refer to “Naval White Wire Legibility Threshold Study”). Contrast is calculated according to AS4373 Method 1001 using the luminance of the mark and background. A contrast value of 100% equates to a maximum contrast mark and a value of 0% equates to a zero contrast mark, i.e., no mark visible.

Current industry recommendations vary regarding specific contrast levels, but typically indicate a requirement of ≥60% contrast for a dark mark against a white background. This ARP recommends a contrast level of 60% when initially marked, with a minimum of not less than 55% unless the wire type is incapable of supporting this contrast level. However, most common wire types should meet or exceed this requirement when marked in accordance with AS5649 (refer to AIR5558).

The suggested test method for measuring contrast and the apparatus required is as per AS4373 Method 1001 and EN 3745 Part 705.

4.3 Font

The font is the definitive shape and style of an alphanumeric character set. To optimize wire ID legibility, it is recommended that a clear, simple font is used. To avoid confusion and aid correct character identification a sans serif font should be employed. Acceptable fonts should have a constant stroke width and exhibit clear, specific character shapes which are easy to decipher and familiar to a large proportion of the population. As new fonts are constantly being developed, it is impossible to provide a definitive and exhaustive list of acceptable fonts.

Examples of acceptable and undesirable fonts are shown in Figure 2.

ACCEPTABLE FONTS	UNACCEPTABLE FONTS
ARIAL ABC123	TIMES NEW ROMAN ABC123
UNIVERS ABC123	COURIER NEW ABC123
TAHOMA ABC123	𝔒𝔑 𝔈𝔑𝔊𝔏𝔦𝔖𝔥 𝔄𝔅𝔠123

Figure 2 - Example fonts for wire IDs

Having chosen a standard font meeting the above recommendations, it is likely that it will become necessary to modify the font for wire and cable identification use, particularly for mask based UV laser wire marking systems. In such cases, characters may have to be restrained to a specified maximum “cell” size, corresponding to the chosen height to width ratio. This will necessitate reducing the width of larger than average characters, such as W and M. It may also be deemed necessary to stretch the vertical dimension of vertically orientated small characters as noted previously. It is recommended that a constant stroke width is maintained in all such situations.

The font should be of a design that reduces errors associated with specific letter and number confusions such as Q, O, and 0 (queue, oh, and zero). Where possible, grouping can be used to reduce the risk of error (e.g., 123 ABC). However, this has very limited potential application for wire identification applications.

It is inadvisable to use lower case letters for wire marking, particularly when marking small wire sizes. However, where lower case and upper case characters are required, particular attention to the similarity of pairs is critical, such as “p” and “P” and “w” and “W.”

4.4 Character Orientation

Western print is normally presented to the reader in horizontal format, i.e., as presented to the reader here, and reading from left to right. This is the print format we normally expect and under normal circumstances is that which is easiest to read and understand. Ergonomics indicate that it will assist in optimizing legibility of wire IDs if they are also presented in this fashion.

There is one important exception to the above as follows:

As the wire size and thus the character size are reduced, a point will be reached where characters cannot be discernable. In such cases, although it is not the norm for everyday printed material, there is a benefit in the case of wire IDs to switching to the use of vertical format marking.

Examples of “horizontal” and “vertical” print are shown in Figure 3. Horizontal print is sometimes also referred to as landscape format. Vertical print is sometimes also referred to as portrait, hotel (after the typical vertical style signs), or chimney format.

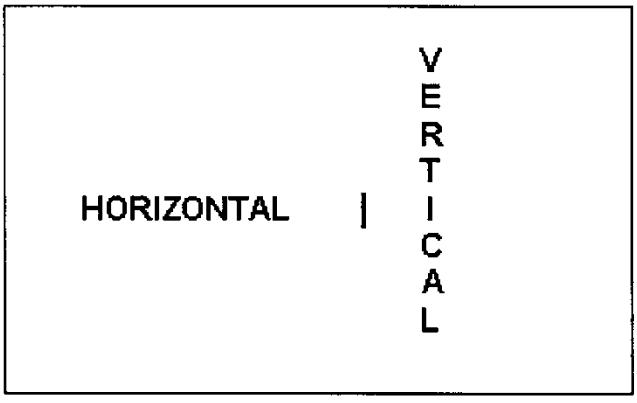

Figure 3 - Horizontal and vertical print