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# AEROSPACE RECOMMENDED PRACTICE

SAE ARP5607

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## Legibility of Print on Aerospace Wires and Cables

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1. SCOPE:

The purpose of this report is to provide recommendations for producing legible marks on wire and cable insulations. 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 report is limited to the legibility of human-readable characters and does not address bar code or other machine-readable symbols. In this report, the term wire refers to jacketed cables and fiber optic cables in addition to individual wires.

This report 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.

2. REFERENCES:

1. Contrast Formulae for Use with Contrast Measuring Devices, Spectrum Technologies PLC Report, Ref: ST0005, Revision 2, 1 December 1999 (obtainable on-line from www.spectrumtechnologies.co.uk/technology/reports.htm).

2. 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.

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

4. 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.

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

6. AS4373 - Method 711, Durability and Legibility of Wire Installer's Identification.

7. EN3475 - Part 705, Aerospace Series Cables, Electrical, Aircraft Use Test Methods: Contrast Measurement; Assoc. Europeene Constructeurs Materiel Aerospatial, 175 Rue Jean-Jacques Rousseau F-92138, Issy-Les-Moulineaux Cedex, Paris, France; 31 May, 1999.

3. RELATED PUBLICATIONS:

SAE Aerospace Information Report AIR5468, UV Laser Wire Marking

4. DEFINITIONS:

LEGIBLE: Clear enough to be deciphered; i.e., 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).

CONTRAST: A measurement relating to the difference in luminance of the mark and its associated background according to a precise formula. A variety of formulae (see Reference 1) have been devised over time for different applications. The accepted formula used for contrast of wire and cable marking (dark marks on light backgrounds) is given as follows:

$$C = \frac{(L_b - L_m)}{L_b} \times 100 \qquad \text{(Eq. 1)}$$

where:

C = % Contrast
$L_b$ = Luminance of the background
$L_m$ = Luminance of the mark
$L_b > L_m$

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

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

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

5. 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.

5. (Continued):

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

Character size (height, height-width ratio, stroke widths) - 6.1
Contrast - 6.2
Font - 6.3
Character orientation - 6.4
Inter-character spacing - 6.5
Character formation and fidelity - 6.6

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 is legible 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 6 for the stimulus variables which can be controlled during the wire marking process.

5.1 Legibility Assessment:

A wire ID is considered legible 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.

6. STIMULUS VARIABLES:

6.1 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.

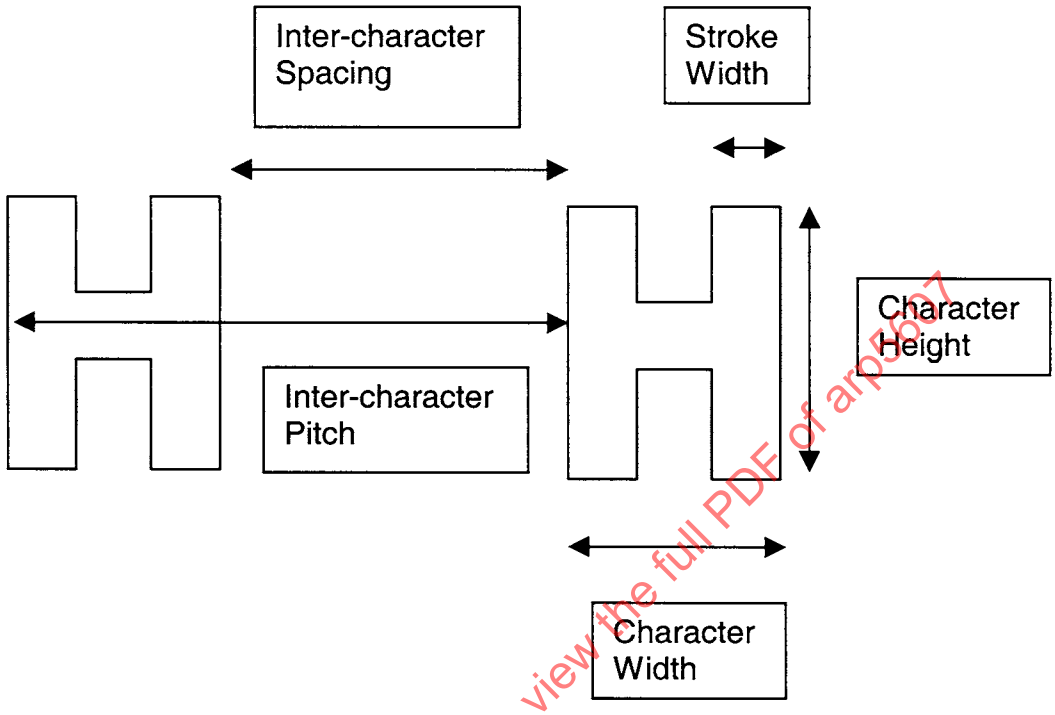


FIGURE 1 - Character Dimensions and Terminology



6.1.1 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 and 0.10 inches respectively (2.3 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 legible 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 inches (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.

6.1.2 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 (see References 2, 3, and 4). The use of characters with this ratio is, therefore, also recommended for wire marking applications 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 gauge. To optimize legibility on these small gauge wires it is recommended that wire IDs should be marked with a vertical character orientation as described in 6.4. 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. The vertical stretching of characters in this manner may assist legibility for the smallest wires and character 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.

6.1.3 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 (see References 2, 3, and 4). Practical results show that a stroke width in the range of 20 to 30% provides an acceptable result.

6.2 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 (see Reference 5). Contrast is calculated according to Equation 1 using the luminance of the mark and background. Equation 1 gives a value of 100% for a completely back mark and a value of 0% for an absent mark.

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 (see AIR5468).

Suggestions for the test method for measuring contrast and the apparatus required is as per AS4373, Method 711 (see Reference 6) and EN 3475 Part 705 (see Reference 7).



6.3 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 the font should be a sans serif font. 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 | UNDESIRABLE FONTS |
|---|---|
| ARIAL ABC123 | TIMES NEW ROMAN ABC123 |
| **UNIVERS ABC123** | COURIER NEW ABC123 |
| TAHOMA ABC123 | 𝔒𝔩𝔡 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. In particular, 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. In all such situations it is recommended that a constant stroke width is maintained.

6.3 (Continued):

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 gauge wires. 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".

6.4 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 or cable size, and hence the character size, reduces, there will come a point when the character height of a normally printed horizontal format character is reduced to the point where the legibility is critically impaired. 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.



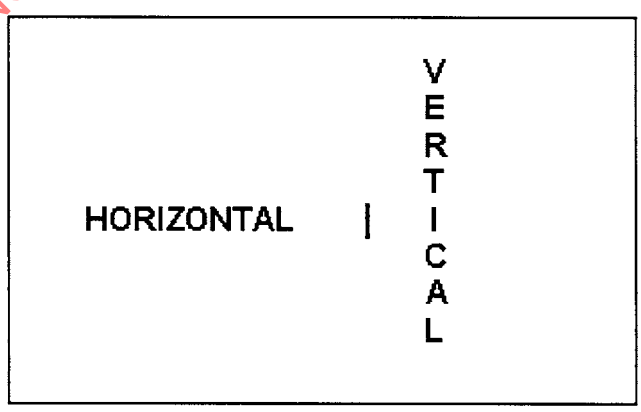


FIGURE 3 - Horizontal and Vertical Print