25.1707: EWIS System Separation Requirements Assessment

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Foreword

This whitepaper from Lectromec covers many of the considerations of Federal Aviation Regulation 25.1707. The ideas and recommendations compiled here have been gathered from Advisory Circulars (ACs), industry guidance, and Lectromec's experience with Electrical Wire Interconnection System (EWIS).

As you read through this, we ask that you consider your aircraft or active design and if there are areas that are in need of improvement. Making good, data-backed engineering decisions through the design process is the best way to ensure a reliable and safely operating wiring system

- **Lectromec Editorial Team**

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Introduction

Since 2008, the aerospace community has been working to develop methods and practical engineering guidance meeting the FAA's EWIS requirements laid out in 25.1700 series. For those focused on system separation, the 25.1707 defines several factors that must be considered during aircraft design and construction.

Established in 1984, Lectromec is an engineering firm specializing on aerospace wire system safety and sustainment.

We can help your organization ensure that your wires satisfy industry operating standards, meet regulatory safety standards, and are maintained efficiently and effectively.

This whitepaper covers each of these design considerations, what the regulations mean, possible ways to show compliance, and factors that will impact maintenance. Requirements a–j are discussed in this whitepaper along with an example of an unacceptable scenario and the means to address the scenario to be in compliance with the regulations. While these scenarios will not come from actual platforms, the hope is that they will provide sufficient insight into the critical items that should be considered.

Damage Assessment

Regulation 25.1707 starts with the following:

> *"(a) Each EWIS must be designed and installed with adequate physical separation from other EWIS and airplane systems so that a EWIS component failure will not create a hazardous condition. Unless otherwise stated, for the purposes of this section, adequate physical separation must be achieved by separation distance or by a barrier that provides protection equivalent to that separation distance."*

One of the first questions after reading this statement is what is the criteria for determining an acceptable separation distance and how is this shown?

To address the first part, let us start with the following example:

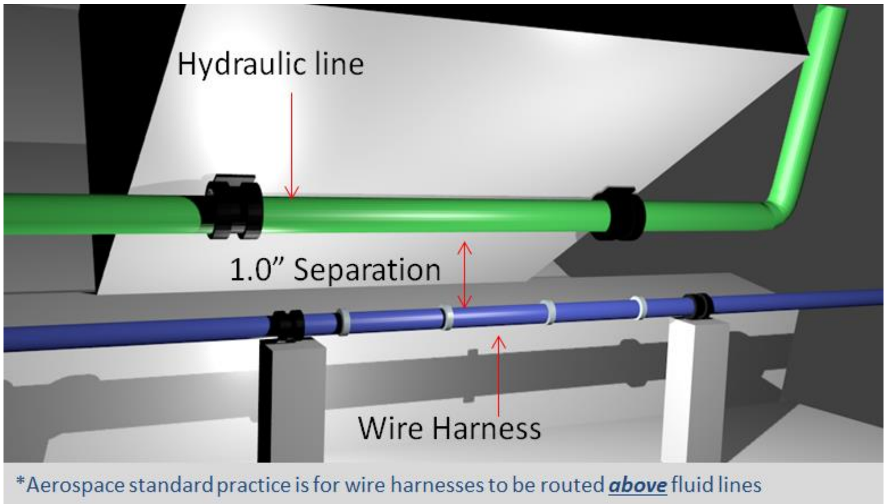

Photo: Lectromec

Here a harness is routed near a pressurized hydraulic line. The designed separation is measured in the design model to be 1.0". The wire harness here contains the following: Four powered wires of varying gauges – 2x16AWG on 15A thermal circuit breakers and 2x20AWG on 7.5A thermal circuit breakers. These wires have power from different power phases. There are two (2) of ways to determine if there is an issue:

1. Perform physical testing
2. Use a simulation

> A description of arc damage simulations and how they can help you meet certification requirements can be found here.

Option #1 – Physical Testing: With the physical test, it is necessary to match the system parameters, and define what the safety threshold should be (i.e. the maximum tube temperature). This may be a complex determination based on the operation temperature, fluid pressure maximums, and minimum tube thicknesses. A laboratory with experience with this type of test performance, such as Lectromec, can be a great resource in execution and posttest analysis.

Option #2 – Simulation: This option can go hand in hand with the testing to supplement the lab data, or can be used as a standalone assessment process. With these simulations, it can be made possible to assess the separation distance for a variety of materials (e.g. the tube failure susceptibility if made from aluminum or composite materials).

The results of lab tests and/or simulations should provide a clear indication as to the configuration safety and a good safety margin estimation. If the test results are inconclusive (the target is near a failure condition but did not actually fail), then addition testing should be performed to validate the safety, or additional design actions may need to be taken (increase separation distance or a protective barrier).

Lectromec's ADMT (arc damage modeling tool) can simulate wire failures producing arcing events and the subsequent damage to nearby harness, structure, and fuel/hydraulic lines. This tool has been used in the certification packages of aerospace organizations.

Lectromec has a full service lab capable of performing arc damage assessment tests. We can help identify the parameters and run the test to generate what you need for certification. Contact Lectromec to find out more.

Electromagnetic Interference (EMI) Compliance

The second paragraph from FAA regulation 25.1707 focuses on electrical interference and addressing this from the wire system level. The regulation states:

> *"(b) Each EWIS must be designed and installed so that any electrical interference likely to be present in the airplane will not result in hazardous effects upon the airplane or its systems."*

According to the FAA's guidance document on this regulation (25.1701-1), the following sources for EMI should be considered with regard to how they affect the EWIS:

- *Electrical noise generated from equipment connected to the bus bars*
- *Electrical coupling or cross-talk between electrical cables*
- *Electrical coupling between cables and aerial feeders*
- *Electrical equipment operating out of spec or malfunctions generating EMI*
- *Parasitic eddy currents and voltages in the EWIS and grounding systems*
- *The effects of lightning currents*
- *The effects of static discharge*
- *Dissimilar frequencies between electrical generation system and other systems*

In the following example, there are three harnesses: two of which are power carrying harnesses (blue), and a signal harness (cyan). In this design the signal harness is identified to be within two (2) inches of the closest power carrying harness. The interference from the power cables was investigated and determined to be have no effect on the shielded cables in the signal harness.

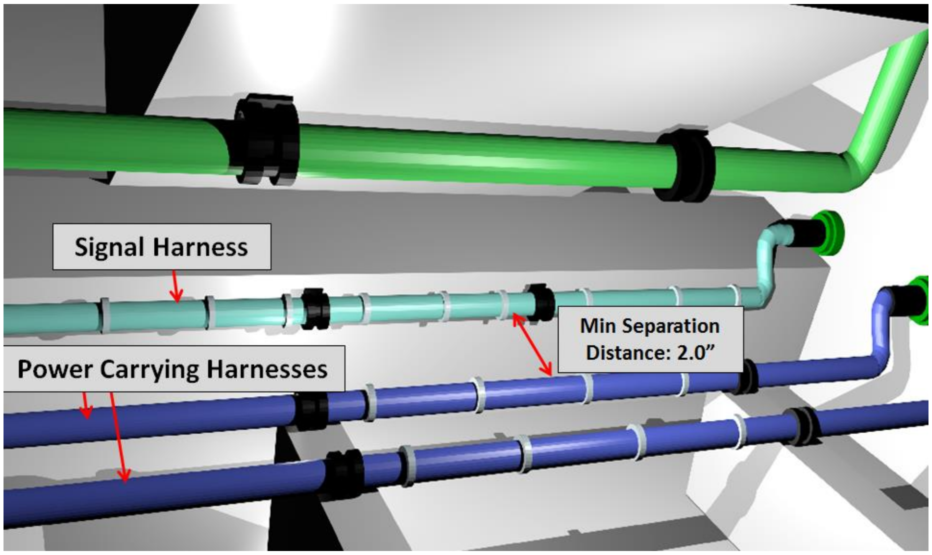

Photo: Lectromec

If, in this case, the cable shielding was not sufficient to protect the signals, then additional methods for protection would need to be considered (increase separation distance, additional harness shielding, double shielded cables, etc.).

In particular, the systems that are necessary for continued safe flight, landing, and egress should be given the highest priority when assessing the EMI impact. The following are methods for protecting systems from EMI and are common practice for aerospace platforms:

- Use of EMI/EMP (Electromagnetic Pulse) filter protection connectors.
- If possible, route power and signal wires through separate connectors.
- Shielded cables should be considered for signal cables. Those flight/safety critical systems dependent on clean signal may need this type of shielding for additional noise reduction. When selecting a shielded construction, it is important to ensure that the EMI range suppressed protects the wire’s signal.
- There are harness protection schemes that offer EMI shielding. As with other shielding techniques, before considering this option, it is important to determine the shield grounding.
- Separate power wires from signal harnesses. This design choice may not be possible in some scenarios, particularly in areas where space is limited.

The reason for this requirement is that EMI can have as devastating impact on aircraft systems as electrical arcing. It is important to consider the factors when designing your EWIS, or installing new equipment in the aircraft.

Heavy Current Cables

The third paragraph from FAA regulation 25.1707 specifically identifies the need to assess the physical separation of heavy current cables from other components. The regulation states:

> *"(c) Wires and cables carrying heavy current, and their associated EWIS components, must be designed and installed to ensure adequate physical separation and electrical isolation so that damage to circuits associated with essential functions will be minimized under fault conditions."*

According to the supplemental documentation, this specifically contains the requirements that were in § 25.1353 as well as the necessary supporting EWIS components.

What is a heavy current cable?

The definition of a heavy current cable is 16AWG or larger or could cause significant damage due to an arcing failure. What is 'significant damage'? Find out here.

If testing is deemed to be necessary, there are a couple of important considerations before starting testing:

Are you looking to solve for the particular case or the general?

Solving for the particular case can be advantageous for several reasons, but the two most important are cost and compliance. The reason for this is that solving for the general case can require a broad test matrix to address many configurations (physical, electrical, and environmental). Further, with regard to compliance and aircraft design, testing for a general case may create recommendations for a boundary that are too large for a given area and are more severe than the particular case.

What is in the surrounding area?

As discussed in the first regulation (section a), the consideration of damage to nearby equipment is important. With regard to assessing the potential damage to nearby wiring components, these assessments will likely result in separation distances greater than those identified for equipment.

In this example, we will focus on the particular case shown from the previous regulation (section b). The minimum separation distance was two inches. The heavy power cables include three-4AWG wires with three difference phases. In practice, it is most likely that the breach and arcing would start at the clamps (shown in the diagram).

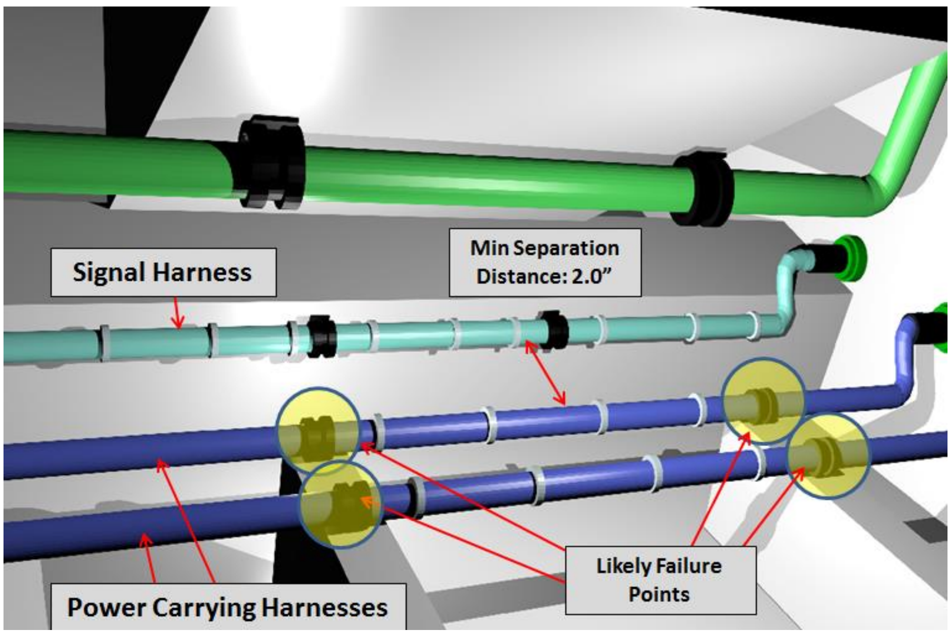

Photo: Lectromec

While a general case would examine the 4AWG under various conditions, the particular case will examine the potential damage to the jacketed, shielded, twisted pair in the signal harness. The reason that this one was selected was because based on past assessments this was deemed to be the weakest (i.e. most susceptible) to arcing damage.

The test results should determine if the arc damage impacts the EWIS airworthiness. In particular following questions must be answered:

- Is the separation sufficient?
- If the separation is sufficient, what is the margin of safety?
- If the separation is not sufficient, what is/are the necessary change(s) to make the configuration safe?

Also, if additional segregation materials are used, it is important that these be considered in the Instructions for Continued Airworthiness (ICA).

Grounding and Power Separation

The following are the requirements of 25.1707 section ‘d’:

> *“(d) Each EWIS associated with independent airplane power sources or power sources connected in combination must be designed and installed to ensure adequate physical separation and electrical isolation so that a fault in any one airplane power source EWIS will not adversely affect any other independent power sources. In addition:*
>
> *(1) Airplane independent electrical power sources must not share a common ground terminating location.*
>
> *(2) Airplane system static grounds must not share a common ground terminating location with any of the airplane's independent electrical power sources.”*

To be clear, the reference to “independent airplane power source” covers the “general source of power for the whole of the airplane” (AC 25.1701-1). This includes the engines, Auxiliary Power Unit (APU) driven generators, batteries, etc.

The first bullet point of this regulation section is fairly straight forward. According to the guidance document associated with this, the objective was to ensure that the generating system EWIS components are assessed and examined in the same way as all other EWIS components. In particular, this requires the consideration of power routing through the aircraft and the physical proximity. System components that require multiple input power sources for the purposes of redundancy require special consideration.

Handling of the isolation of separate aircraft power must be considered from a physical and functional aspect. From the physical side, this is addressed by common cause analysis and, if routed in close proximity, potential damage assessment. From the functional viewpoint, the failure of one power source should not adversely affect other power sources.

Photo: FAA Job Aid 1.0

With regard to the ground terminations, this is a straight forward concept. By maintaining separation of grounding locations for different power systems, the failure of a single grounding point will not damage or disable multiple power sources. Furthermore, by physically separating the grounds reducing/eliminating the introduction of interference into the electrical system becomes easier.

For additional information on electrical grounding and bonding requirements for aerospace systems, several important considerations are identified in aerospace standard AS50881 and in aerospace recommended practice ARP1870A (latest revision 2012). These SAE documents provide design guidance and recommendation for safe and functional grounding of electrical systems.

Component Separation Guidance

Because subparts e, f, g, and h are very similar, they will all be addressed here rather than presenting each of these regulations.

Combined revision of FAA 25.1707 subparts e, f, g, and h:

> *"Except to the extent necessary to provide electrical connection to*

The results of a USAF investigation of a Lockheed Martin F-22 aircraft crash in November 2012 point to a chaffed power feeder cable as the likely cause of failure. The F-22, attempting to return to base, crashed just short of a runway in Florida. The crash resulted in total aircraft loss at a total cost of nearly $150 million.

> *the fuel/hydraulic/oxygen/water/waste systems components, the EWIS must be designed and installed with adequate physical separation from fuel/hydraulic/oxygen/water/waste lines and other fuel/hydraulic/oxygen/water/waste system components, so that:*
>
> *(1) An EWIS component failure will not create a hazardous condition.*

(2) Any fluid leakage onto EWIS components will not create a hazardous condition."

To understand the consequences of EWIS component failure, we only have to look back at the loss of an US Air Force F-22 in November 2012.
What does this mean from a certification perspective?

1) Safe separation distances must be defined for all of an aircraft's fluid carrying system components. Not all tubes are going to fail under the same conditions. Here are a couple of articles on the topic:

- Presentation on failure of pressurized hydraulic lines (here)
- Arc Damage Modeling Tool (ADMT) failure modeling (here)

2) EWIS components should be installed so that they are above the fluid/oxygen carrying components; this will help to minimize the likelihood of fluid contamination of the EWIS.

In the figure below, there are three wire harnesses routed near a fuel line. Harness #1 is routed beneath the fuel line, but is protected by a shroud; while this can be used to protect a harness from fluid exposure, it does add to weight and potentially inspection procedures for maintaining airworthiness. Harness #2 is routed above and perpendicular to the fuel line, but the supporting clamps are too far apart to prevent sagging and chaffing on the tube; additional clamping could be installed to resolve this issue. Harness #3 is routed horizontally, parallel to the line, which is of no issue, but in the presented system, the separation distance is less than the allowed distance as defined by a damage assessment; redesign, separation, or protective sleeving must be considered for harness #3 (details on this can be found http://www.lectromec.com/ewis-failure-process-electrical-arcing/).

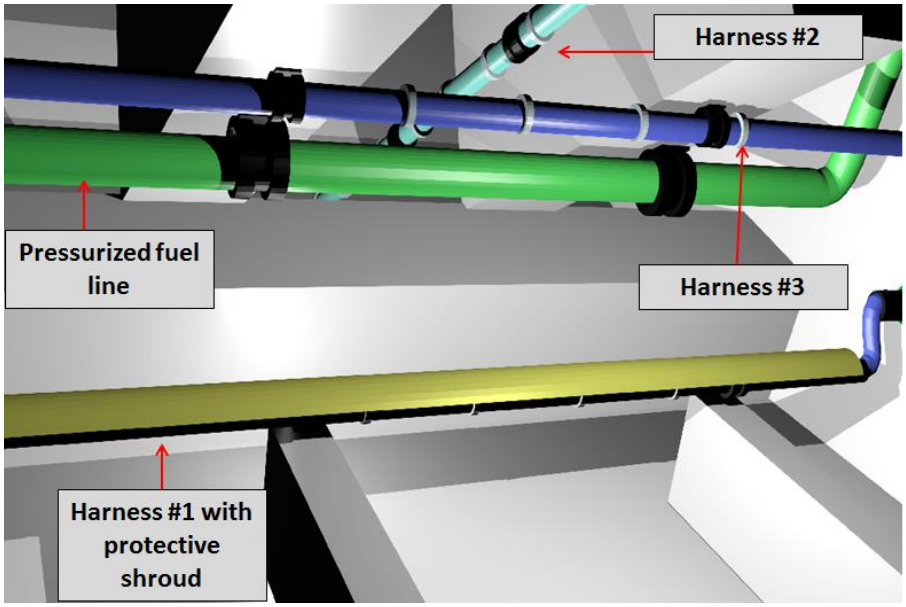

Photo: Lectromec

This part of the 25.1707 regulation should also be considered in coordination with the recommended practices of AS50881 section 3.11.11 "Gas and Fluid Carrying Lines and Tubes." Whereas the standard suggests that wiring should be routed with, "the maximum practicable separation from all fluid carrying lines," this regulation allows for wiring to be installed in close proximity as long as the failure consequences have been considered.

The support clamps for separation between the EWIS and fluid/oxygen lines, should be given additional consideration. Recommendation from AS50881 suggests that supporting clamps for EWIS should not be connected to fluid/oxygen components unless the separation is less than two inches.

If you are familiar with the recommendations of AS50881, then you are aware that the recommended standard practice is that wiring should, "… be installed to maintain positive separation [from gas and fluid carrying lines and tubes] of at least 0.500 inch." First, while this separation distance may be fine for some system configurations, it is not an acceptable blanket statement for separation. Lectromec has performed testing to show that tube failure can occur at an even greater distance from the arc plume generated during a wire failure event (article here).

Second, conformity to the regulation takes precedence over industry guidance. Certification relies on data to verify the safety of design, and the recommendations of AS50881 do not provide sufficient data to support certification.

Control Cable Separation

The eighth section of the system separation requirements focuses on EWIS separation from control cable. Section 'I' of 25.1707 states:

> *"(i) EWIS must be designed and installed with adequate physical separation between the EWIS and flight or other mechanical control systems cables and associated system components, so that:*
>
> *(1) Chafing, jamming, or other interference are prevented.*
>
> *(2) An EWIS component failure will not create a hazardous condition.*
>
> *(3) Failure of any flight or other mechanical control systems cables or systems components will not damage the EWIS and create a hazardous condition."*

This requirement poses a separate set of challenges, than those identified in section c. Whereas section e, f, g, and h focus on EWIS proximity and protection regarding fluid/oxygen lines, this considers the proximity to mechanical cables.

Clearly moving cables can create a hazardous situation with EWIS as they can quickly abrade through the protective insulation. The obvious failure conditions here include:

- Electrical arcing damaging or destroying all wires in the cable
- Damage and loss of functionality of a flight control cable
- Damage to nearby systems due to arc plume or ejected molten materials

One of the popular terms within the EWIS community is a critical clamp marker – an example is shown in the figure below – these are markers on harnesses that indicate where a clamp should be placed on the harness. This provides a quick visual reference to a maintenance technician if there is a misalignment of a harness or a harness has slid from its designed location.

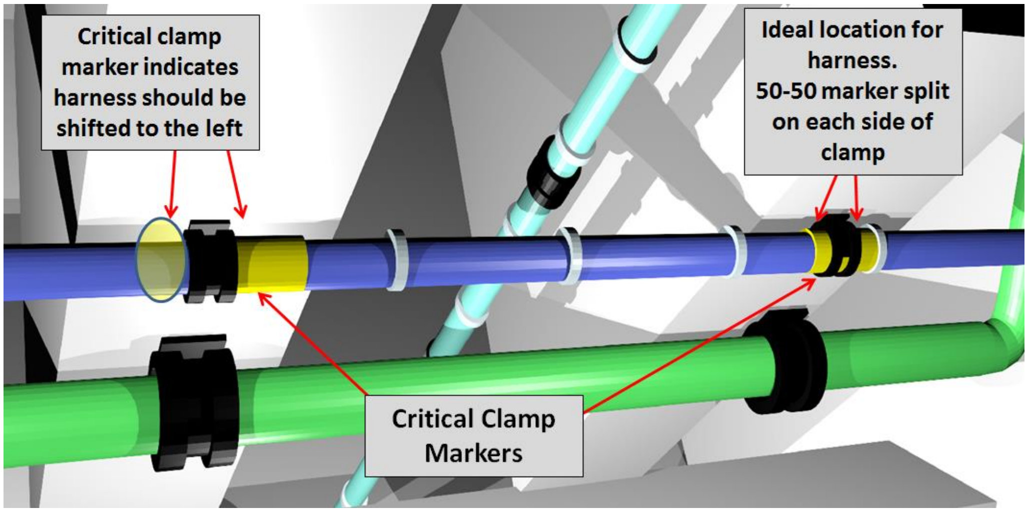

Photo: Lectromec

While not necessary, it is recommended that these be added to EWIS harnesses in areas with mechanical cables. This will ease inspections and ensure EWIS components that moved during maintenance are reinstalled with the proper clearance.

An additional consideration with the mechanical cables is the jamming of mechanical components, such as a harness jamming a pulley. As such, areas routed near cables should have sufficient clamping to prevent this from occurring. In particular, the clamping and EWIS harness support must be designed to prevent a hazardous condition from occurring with the loss of a single clamp. Inspection of these items should also be included in ICA/EZAP (Enhanced Zonal Analysis Program).

The failure of a control cable should adversely affect any EWIS component and create a hazardous condition. Mechanical cable routing and protection mechanism should be considered in these areas.

Common Cause Analysis (CCA) must be done to ensure that the loss of a mechanical cable will not damage an EWIS component that supports a secondary/redundant system.

Heated Equipment Separation

This last section covers section ‘j’ from 25.1707. This section states:

> *“(j) EWIS must be designed and installed with adequate physical separation between the EWIS components and heated equipment, hot air ducts, and lines, so that:*
>
> *(1) An EWIS component failure will not create a hazardous condition.*
>
> *(2) Any hot air leakage or heat generated onto EWIS components will not create a hazardous condition.”*

Important aspects to be considered include:

- The heat generated by the local equipment/air ducts
- The ambient temperature of the zone
- The heat generated by the wire harness

#1: Generated heat

Nearby equipment and air ducts may radiate heat that can impact EWIS components. Although the constituent harness wires may be rated to a 150°C or more, the supporting ancillary EWIS components, such as splices, heat shrink tube, clamps, and harness sleeving my not be rated to the same temperature.

#2: Ambient zone temperature

The local radiant heat can impact the harness, but so too can the local environmental conditions. Like all other components, prolonged exposure to elevated temperatures can lead to degraded performance. While this item is fairly obvious, it is important to also consider the resistive heating of the wires, which leads into EWIS heat generation.

Lectromec has developed a harness derating tool. Click here to find out more.

#3: EWIS heat generation

As means for estimating a harness’s rated current carrying capacity (or ampacity) is included in AS50881. Along with charts 1-5 in this standard a formula is included for calculating the current carrying capability of a wire harness with a variety of wire gauges. Based on data gathered several decades ago, this is a good first order estimate on the maximum current for the harness wires to not exceed the wire rated temperature.

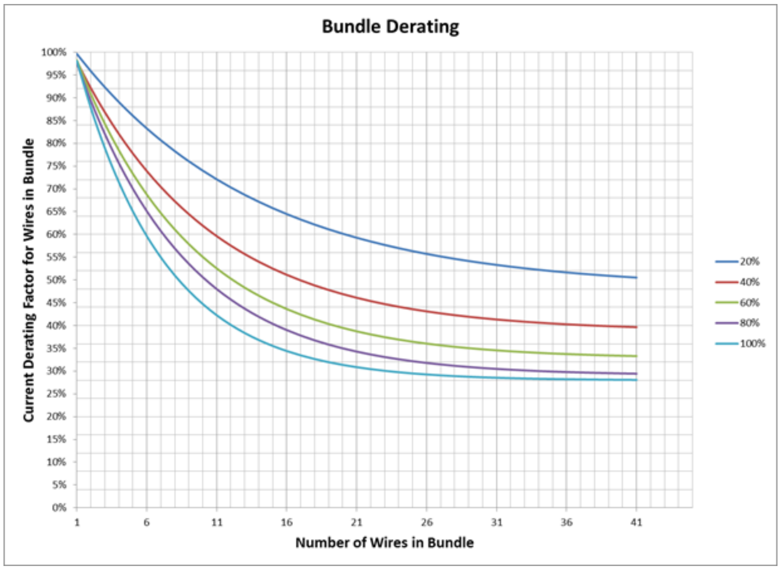

Photo: Lectromec

This formula can also be used to account for heating in nearby systems. For example, suppose we have a harness that is rated to 150ºC (based on the wire specification). The ambient temperature in the zone during flight is 50ºC, which leaves a potential for a 100ºC increase during operation. Using the formulas and charts we find that the ampacity is approximately 40A.

Furthermore, suppose this harness is routed near a hot air duct. Testing has shown that the radiant heat will increase the surface temperature of the harness by 20ºC. After recalculation, the harness ampacity drops by 10% to 36A. The results of the analysis may require use of larger gauge wires, rerouting, or the addition of a protective sleeve.

Compliance for Your Organization

EWIS safe and reliable operation is more than just the other wires in the harness, but also requires consideration of the nearby systems. Lectromec can address the needs of your certification program in identifying and addressing your physical separation needs with a defined and systematic method. This process starts with understanding the particular needs of your effort and working to define test and parameters to cover both your design and regulatory requirements.

Contact Lectromec to find out how we can help you with your project.

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