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Space systems — Study of electrical wire derating

Systèmes spatiaux — Étude du déclassement des fils électriques

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Contents

Page

Foreword

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This document was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

During the design of electrical wires or wire bundles, an understanding of their allowable current is necessary. Nowadays, space system designers refer to aerospace standards to determine the allowable current to avoid exceeding wire temperature limits due to resistive heat dissipation.

Generally, in these wire standards for space systems, some margin is added to the allowable current value when the wire is used in the Earth's atmosphere. There are several standards for wire derating for space systems depending on government agencies and commercial organizations; and the allowable currents differ.

For engineers designing space vehicle systems for the first time, the differences in allowable wire current values in these standards can cause confusion. Although the differences stem from differences in the assumed thermal environment, several evaluations of the correlation between the current allowances of each standard and the thermal environment have been conducted; and understanding this background can assist the system design engineer in wire selection.

This document contributes to risk mitigation in space vehicle system design by providing general technical information on the allowable wire current, its limit in space application and information on mounting conditions and associated thermal environment considerations.

Space systems — Study of electrical wire derating

1 Scope

This document provides information on how electrical designers determine the allowable limit of electric wire in space condition. This document provides the basis of the allowable wire current and its derated value in published technical standards. This document also provides the results of comparing the derated wire current values depending on the number of bundled wires, wire type and temperature environments, which can help the system designer to handle the difference when determining the limit of wire ampacity.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
derating
reduction of electrical and thermal stresses applied to a part during normal operation to decrease the degradation rate and prolong its expected life

3.2
derating factor
multiplier applied to the upper limits of voltage, current, temperature, etc. for *derating* (3.1) on electronic components, the values of which vary depending on the operating environmental conditions and materials

3.3
American wire gauge
AWG
standard way of describing wire sizes in North America

3.4
ethylene tetrafluoroethylene
fluorine-based plastic that has high corrosion resistance and strength over a wide temperature range

3.5
single-layer insulation
sheet material that provides passive heat shielding through radiative insulation

3.6
multiple-layered insulator
insulation system consisting of multiple radiation shields separated by low thermal conductive spacers which works to limit the amount of radiative heat transfer

4 General description

4.1 Electric wire design approach for space vehicle

4.1.1 General

Current rating is only one factor to consider when choosing a cable. The choice of wire for a spacecraft is generally made with the following points taken into consideration:

— understanding the environmental requirements;

— determination of allowable current;

— wire selection;

— wire placement;

— testing and verification.

Once environmental requirements are determined, space vehicle system engineers further evaluate the thermal, radiation and vibration resistance.

For example, polytetrafluoroethylene (PTFE), a commonly used insulating material, has excellent resistance to high-temperature environments, but ethylene tetrafluoroethylene (ETFE) is superior to PTFE in radiation degradation.

4.1.2 Understanding the environmental requirements

A correct understanding of the environmental requirements for the spacecraft can enhance the design capabilities of spacecraft systems engineers. In general, space vehicle system engineers evaluate factors such as temperature, radiation, vibration, air pressure, radioactive particles and static electricity.

4.1.3 Determination of allowable current

A correct understanding of environmental conditions can support space vehicle system engineers to determine the allowable current of the wire. Factors such as wire sizing, wire material, cross-sectional area, ambient temperature and ambient radiation levels are considered in this document.

4.1.4 Wire selection

Correct understanding of relationship between the allowable current and the environmental requirements can support space vehicle system engineer to select wire. This process includes comparing materials, checking approved industry standards, and evaluating manufacturers.

4.1.5 Wire placement

Placing wires in the appropriate locations can be one approach to achieving optimal spacecraft design. This includes selecting wiring routes, adding protection and installing cooling systems if necessary.

4.1.6 Testing and verification

To check that the selected wire meets the environmental requirements, it is effective to conduct tests such as current capacity, thermal characteristics, vibration characteristics and radiation resistance. In addition, thermal analysis is an effective method for verifying the suitability of cables, especially their jackets, to thermal environments.

4.2 Wire current and derating in standards

Today, it is common practice for electrical engineers in the aerospace industry to apply the derating rules of SAE AS 50881[1] and ECSS-30-11C[2] when designing wiring bundles for aircraft and space systems. The derating rules of MIL-W-5088, the origin of SAE AS 50881 was built on considerations from the 1950s onward; and this derating rule is based on natural convection cooling of free wires in air and was updated in the 1970s with the addition of a bundled wire loading condition.

Derating rules for space environments where natural convection cooling is not effective have been considered based on several tests and are reflected in MIL-STD-975M[3] and EEE-INST-002[4].

There are no cross-agency standards in the U.S. NASA that specify current and derating of wires and wire bundles; and GSFC, MSFC, JSC, and JPL have issued individual standards addressing wire ratings. This fact can cause spacecraft system engineers to worry about which documents to refer to.

Most NASA standards use the derating curves in MIL-W-50881 or SAE AS 50881 as guidance. MIL-W-50881 or SAE AS 50881 derating curves only provide wire bundle derating up to 30 480 m altitude, but additional derating curves for vacuum environments have been considered and published, for example, as JPL D-8208 (Rev. I)[5].

Another wire current standard is JERG-2-212N1[6] issued by JAXA (Japan Aerospace Exploration Agency). While the single wire current standard follows MIL-STD-975M, it is characterized by the fact that the derating curve is shown to change when the wires are bundled and under the influence of the thermal environment. There is also GJB/Z 35-93[7] published by Commission for Science, Technology and Industry for National Defence, China, which is compatible with MIL-STD-975M.

5 Wire current derating in standards

5.1 Single wire allowable current

Single wire allowable current of Cu wire under vacuum conditions for MIL-STD-975M, EEE-INST-002, JERG-2-212N1, ECSS-Q-ST-30-11C, and GJB/Z 35-03 is given in Annex A, Table A.1. If information for other conductors is required, electric system engineers can refer ECSS-Q-ST-30-11C for aluminium wire and JPL D-8208 (Rev. I) for silver-plated alloy wire.

As shown in Table A.1, the values specified in MIL-STD-975M and EEE-INST-002 are the basis for the other standards. Understanding how environmental temperature, wiring temperature and margin concepts differ from standard to standard can assist electrical system engineers in properly designing spacecraft systems.

5.2 Bundled wire allowable current

The derating on current for bundles (I_{BW}) with the number of wires (N) is calculated as $I_{BW} = I_{SW} \times K$, where I_{SW} is the derated current for single wire and derating factor K. Derated current and drating factor (K) for EEE-INST-002, MIL-STD-975M, JPL D-8208 (Rev. I), ECSS-Q-ST-30-11C and JERG-2-212N1 are shown in Annex B, Table B.1 through Table B.5, respectively.

EEE-INST-002 does not provide a derating factor with the number of bundled cables as a parameter as shown in Table B.1. On the other hand, MIL-STD-975M 3.16 indicates that the derating factor varies depending on whether there are fewer or more than 15 bundled wires as shown in Table B.2. These two standards specify that the derating factor is varied depending on the temperature rating of the wire. Since the derating factor is a factor that considers the heat generated by the wire when energized, the lower the temperature rating of the wire, the smaller the derating factor becomes, and the lower the allowable current value of the wire.

JPL D-8208 (Rev. I), shown in Table B.3, uses a slightly different specification than the other standards, but the derating values are under 101,325 kPa (which corresponds to atmospheric pressure at mean sea level), conditions are taken from the SAE AS 50881 standard, and the derating values in vacuum are presumably based on the SAE AS 50881 standard values, which are set based on test results under the vacuum environment of wires. The derating values in vacuum are assumed to be based on the SAE AS 50881 standard and are set based on the test results of the wire in a vacuum environment. The calculated derating factor is not significantly different from that of MIL-STD-975M, but the number of bundled wires is notably different from MIL-STD-975M in that it specifies 33 or more wires. The validity of the specified values in JPL D-8208 (Rev. I) has recently been re-evaluated and disclosed by NASA/TM-2018-220114/NESC-RP-17-01264,[8] which states that the standard is a little margin for single wires and a limited margin for bundled wires.

Since duty of the signal line is less than 100 %, the derating factor is changed when bundling power and signal line (JERG-2-212N1 and ECSS-Q-ST-30-11C note about this. ECSS-Q-ST-30-11C also defines “Additional factor for partially loaded bundles”.)

JERG-2-211N1 also includes the current limit for the bundled wire which is covered with single-layer insulation (SLI) and multiple-layered insulator (MLI). In addition, JERG-2-212N1 and ECSS-Q-ST-30-11C provide derating factors for the number of bundled wires for a finer number of steps than other standards.

5.3 Study of the difference in derating factor for bundled wire

A plot of derating factor (K) for JERG-2-212N1, MIL-STD-975M, JPL D-8208 (Rev. I), and ECSS-Q-ST-30-11C Rev.2 is shown in Annex B, Figure B.1. JERG2-212N1 provides the derating factors of bundled wires for power lines only, mixed power and signal lines, power lines covered with SLI, and power lines covered with MLI. Interestingly, the derating factor of the power lines covered with SLI is in good agreement with that of ECSS-Q-ST-30-11C. This can be considered as an indication that ECSS-Q-ST-30-11C REV.2 has a very conservative derating factor.

NLR-TP-2011-469,[9] which is a study for space vehicle thermal design, states similar concerns about ECSS-Q-30-11A.[10] It concludes that the derating factor in ECSS-Q-30-11A does not take into account radiation cooling and the ‘size split’ for 20 or more wires is only meaningful when convective cooling is assumed.

American wire gauge (AWG) doubles the wire diameter for every 6 gauge down and doubles the weight for every 3 gauge down. The more conservative the derating factor, the greater the increase in wire size and weight. In particular, the higher derating factors recommended for bundled wires result in a significant increase in their mass.

Considering that U.S. standards do not specify in detail the number of bundled wires as large as 50 or more, it is one idea to split large bundles to reduce the number of wires per bundle and limit the derating factor. However, this idea is not generally effective because it has another negative aspect of increasing the mounting area and locations of bundled wires.

Ultimately, this document helps electrical system engineers understand how conservative wire standard derating factors are and perform appropriate thermal analysis and testing to make them realistic when the wire number increases in bundled wires.

Annex A
(informative)

Single wire allowable current in standards of governmental institute

A.1 Single wire allowable current in governmental standards for space vehicle

A.1.1 General

MIL-STD-975M, EEE-INST-002, JERG-2-212N1, ECSS-Q-ST-30-11C REV.2, and GJB/Z 35-93 are representatives of published wire current standards for space vehicle systems in a vacuum environment. This clause provides an overview of the values specified in these standards.

A.1.2 MIL-STD-975M

MIL-STD-975M is well known and widely used in space applications. MIL-STD-975M is a technical baseline for standardization of EEE parts and intents to provide information on the part selection on EEE parts, including the necessary criteria pertaining to use, choice, and applications, which are used in the design and construction of space flight hardware as well as mission-essential ground support equipment (GSE). In MIL-STD-975 APPENDIX A 3.16, the single wire allowable current and derating factor for bundled wire are described. The current specifications for single wires in this document are consistent with MIL-STD-975M.

A.1.3 EEE-INST-002 Addendum 1

The purpose of NASA EEE-INST-002 is to establish baseline criteria for selection, screening, qualification, and derating of EEE parts for use on NASA GSFC (Goddard Space Flight Center) space flight projects. The specifications for single wires current in EEE-INST-002 Section W1 Table 4A are consistent with MIL-STD-975M.

A.1.4 JERG-2-212N1

JERG-2-212N1 is a technical standard of JAXA (Japan Aerospace Exploration Agency). JERG-2-212N1 provides the recommended current values for Raychem SPEC 55®[1)] wire, which has a temperature rating of 150 °C with ETFE jacket and is widely used in Japanese space vehicle. The specifications for single wires current in this document are consistent with MIL-STD-975M.

A.1.5 ECSS-Q-ST-30-11C Rev.2

This is a technical specification for EEE components widely used along with MIL-STD-975M and EEE-INST-002. ECSS-Q-ST-30-11C REV.2 6.32 "Wires and cables" provides the specified values for the current value of single wires. ECSS-Q-ST-30-11C Rev.2 6.32.4 "Single wire sizing" describes detail to determine single wire current limit according to its thermal and electrical characteristics and 6.32.5 "Sizing of wires and cables in bundles" provides wire current limit for full loaded bundled wire and derating factor for partially loaded bundled wire.

ECSS-Q-ST-30-11C Rev.2 6.32.6 "Sizing of wires and cables in bundles for specific cables or environment conditions" describes about how to analyse current limit in case that single wire sizing does not meet the limit in ECSS-Q-ST-30-11C Rev.2 6.32.4.

A.1.6 GJB/Z 35-93

GJB/Z 35-93 is a technical requirement document in China; and Section 5.13 specifies the current value of the wire. The specified value is compatible with MIL-STD-975M.

1) Raychem SPEC 55® wire is the trademark of a product supplied by TE Connectivity Ltd. family of companies. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO.

A.2 Summary of allowable current for single wire in standards

Table A.1 shows the specified values for copper wires in a vacuum among the allowable current values for single wires in the technical standards introduced in A.1.1.

Table A.1 — Single wire allowable current in standards

Wire size [AWG]	Allowable current in ampere[a]				
	MIL-STD-975M	EEE-INST-002	JERG-2-212N1	ECSS-Q-ST-30-11C REV.2	GJB/Z 35-93
28	1,8	1,8	1,8	1,9	1,8
26	2,5	2,5	2,5	2,7	2,5
24	3,3	3,3	3,3	3,4	3,3
22	4,5	4,5	4,5	5,6	4,5
20	6,5	6,5	6,5	7,7	6,5
18	9,2	9,2	9,2	10,6	9,2
16	13,0	13,0	13,0	14,0	13,0
14	19,0	19,0	19,0	18,1	17,0
12	25,0	25,0	25,0	26,7	23,0
Environment temperature	70 °C	70 °C	70 °C	70 °C	Not defined
Maximum wire surface temperature	200 °C	200 °C	150 °C	Manufacturer's maximum rating T_{max} minus 50 °C	200 °C

[a] Current value shown in this table are limits for copper wire.

Annex B
(informative)

Delated current and derating factor in governmental standards

Derated current and drating factor (*K*) for EEE-INST-002, MIL-STD-975M, JPL D-8208 Rev. I, ECSS-Q-ST-30-11C REV.2, and JERG-2-212N1 and are shown in Table B.1 through Table B.5, respectively.

For Table B.5, the derating factor *K* is determined on the following assumptions.

— ambient temperature: 40 °C;

— maximum current for a single line (AWG#20, silver-plated copper wire): 6,5 A;

— derating factor was set based on the current value when the center conductor temperature reached 120 °C in the test data.

Table B.1 — EEE-INST-002 WIRE AND CABLE DERATING REQUIREMENTS

Wire size (AWG)	Derated current (A)		Derating factor (K)
	Single wire	Bundled wire or multi-conductor cable	
30	1,3	0,7	0,54
28	1,8	1,0	0,56
26	2,5	1,4	0,56
24	3,3	2,0	0,61
22	4,5	2,5	0,56
20	6,5	3,7	0,57
18	9,2	5,0	0,54
16	13,0	6,5	0,50
14	19,0	8,5	0,45
12	25,0	11,5	0,46
10	33,0	16,5	0,50
8	44,0	23,0	0,52
6	60,0	30,0	0,50
4	81,0	40,0	0,49
2	108,0	50,0	0,46
0	147,0	75,0	0,51
00	169,0	87,5	0,52

NOTE 1 The derated current ratings are based on an ambient temperature of 70 °C or less in a hard vacuum of $1{,}33\times10^{-4}$ Pa. For derating above 70 °C ambient, the project parts engineer must be consulted.

NOTE 2 The derated current ratings are for 200 °C rated wire, such as Teflon insulated (Type PTFE) wire, in a hard vacuum of $1{,}33\times10^{-4}$ Pa.

NOTE 3 For 150 °C wire, 80 % of values shown in this table can be used.

NOTE 4 For 135 °C wire, 70 % of values shown in this table can be used.

NOTE 5 For 260 °C wire, 115 % of the value shown in this table is described in EEE-INST-002.

Table B.2 — MIL-STD-975M 3.16 wire and cable derating criteria

<table>
<tr><th>Wire size (AWG)</th><th>Single sire current (I_{sw}) (A)</th><th>Remarks</th></tr>
<tr><td>30</td><td>1,3</td><td rowspan="17">1. Current ratings are based on wires at +70 °C in a hard vacuum, ($1{,}33\times10^{-2}$ Pa to $1{,}33\times10^{-4}$ Pa).
2. When wires are bundled, the maximum design current for each individual wire is derated according to:
FOR $1 < N \leq 15$; where:
$I_{BW} = I_{SW} \times(29-N)/28$ N = number of wires
FOR $N > 15$ I_{BW} = current, bundled wire
$I_{BW} = (0,5) \times I_{SW}$ I_{SW} = current, single wire
3. Deratings listed are for Teflon insulated wire (TYPE TFE) rated for +200 °C
a. For 150 °C wire, 80 % of values shown in this table can be used.
b. For 135 °C wire, 70 % of values shown in this table can be used.
c. For 260 °C wire, 115 % of the value shown in this table is described in EEE-INST-002.
4. Dielectric withstanding voltage rating required: at least two times the highest application voltage.
5. Derating values listed apply only to round single conductors on helically wound bundles, See project parts engineer for derating information for ribbon cable and flat conductors.</td></tr>
<tr><td>28</td><td>1,8</td></tr>
<tr><td>26</td><td>2,5</td></tr>
<tr><td>24</td><td>3,3</td></tr>
<tr><td>22</td><td>4,5</td></tr>
<tr><td>20</td><td>6,5</td></tr>
<tr><td>18</td><td>9,2</td></tr>
<tr><td>16</td><td>13,0</td></tr>
<tr><td>14</td><td>19,0</td></tr>
<tr><td>12</td><td>25,0</td></tr>
<tr><td>10</td><td>33,0</td></tr>
<tr><td>8</td><td>44,0</td></tr>
<tr><td>6</td><td>60,0</td></tr>
<tr><td>4</td><td>81,0</td></tr>
<tr><td>2</td><td>108,0</td></tr>
<tr><td>0</td><td>147,0</td></tr>
<tr><td>00</td><td>169,0</td></tr>
</table>

Table B.3 — JPL D-8208 (Rev. I) current carrying ratings

Wire type	Wire size (AWG)	Maximum allowable current rating (A)				Derating factor K (vacuum)	
		Single wire		Wire bundle (vacuum)			
		Air	Vacuum	> 5 wire	> 33 wire	> 5 wire	> 33 wire
Silver coated copper	12	66	23,0	17,7	12,0	0,770	0,522
	14	50	17,5	13,5	9,1	0,771	0,520
	16	36	13,0	10,0	6,8	0,769	0,523
	18	32	11,2	8,6	5,8	0,768	0,518
	20	23	8,0	6,2	4,2	0,775	0,525
	22	16	5,6	4,3	2,9	0,768	0,518
Silver coated Alloy	24	10	3,5	2,4	1,6	0,686	0,457
	26	7,7	2,7	2,1	1,4	0,778	0,519
	28	5,9	2,0	1,6	1,0	0,800	0,500

Table B.4 — ECSS-Q-ST-30-11C REV.2 wire and cable derating factor (K)

Counts of wires	Bundle derating factor
1	1
2	0,9
3	0,81
4	0,76
5	0,71
6	0,66
7	0,62

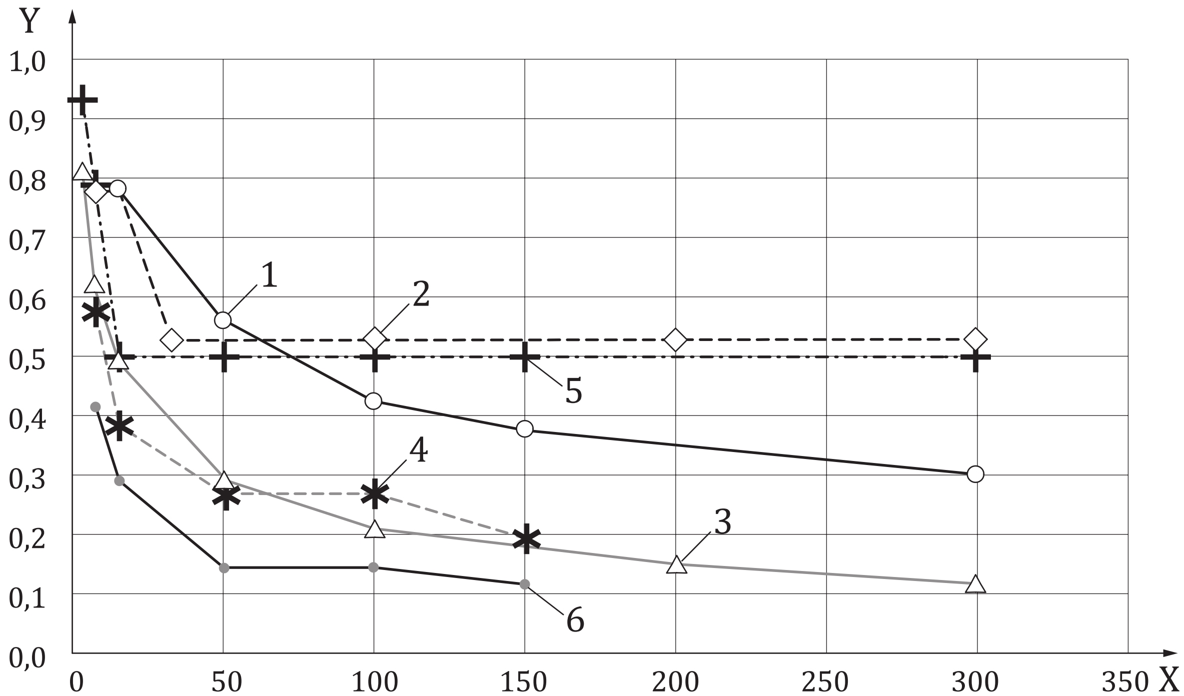
Table B.4 *(continued)*

Counts of wires	Bundle derating factor
8	0,6
9	0,59
10	0,57
15	0,49
25	0,4
50	0,29
100	0,21
200	0,15
300	0,12

Table B.5 — JERG-2-212N1 wire and cable derating factor for AWG#20

Number of wires	Maximum allowable current (A)	Derating factor *K*		
		Power line only	Power line with SLI	Power line with MLI
7	6,8	1,04	0,57	0,41
15	5,1	0,78	0,38	0,29
50	3,6	0,56	0,27	0,14
50	3,7	0,57	0,27	0,14
100	2,7	0,42	0,19	0,11
150	2,4	0,38		
300	1,9	0,30		

A plot of derating factor (K) for JERG-2-212N1, MIL-STD-975M, JPL D-8208 (Rev, I), and ECSS-Q-ST-30-11C REV.2 is shown in Figure B.1.



Key

X number of wires

Y derating factor (*K*)

1 JERG-2-212N1

2 JPL D-8208 Rev. I

3 ECSS-Q-ST-30-11C Rev.2

4 JERG-2-212 with SLI

5 MIL-STD-975M

6 JERG-2-212 with MLI

Figure B.1 — Summary of comparison of derating factor in standards

Bibliography

[1] SAE AS 50881G, *Wiring Aerospace Vehicle, August 2019*

[2] ECSS-Q-ST-30-11C Rev.,2, Space product assurance, Derating EEE components, June 2021

[3] MIL-STD-975M, *NASA Standard Electrical, Electronic and Electromechanical (EEE) Parts List, August 1994*

[4] EEE-INST-002, *Instructions for EEE Parts Selection, Screening, Qualification, and Derating, Incorporated Addendum 1, April 2008, Incorporated Addendum 1*

[5] JPL D 8208 (REV., I), Spacecraft Design and Fabrication Requirements for Electronic Packaging and Cabling, July 2002

[6] JERG-2-212 N1, Design Standard Wire Derating, September 2008

[7] GJB /Z 35 93, Derating criteria for electrical, electronic, and electromechanical part, September 1993

[8] NASA/TM–2018-220114/NESC-RP-17, *01264, Re-Architecting the NASA Wire Derating Approach for Space Flight Applications, November 2018*

[9] R. C. van Benthem, et al, NLR-TP-2011-469, Thermal analysis of wiring for weight reduction and improved safety - Requirements review and validation of wire bundle model inside enclosure, October 2011

[10] ECSS-Q-30-11A, Derating – EEE components, 24 April 2006

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