

Ergonomics Specification for Electrical Connections

**SAE/
USCAR25-3
March 2016**



Documents

Document Sharing Hub

ISBN: 978-0-7680-8319-4

Ergonomics Specification for Electrical Connections

1.	SCOPE & REFERENCED DOCUMENTS.....	2
2.	GENERAL.....	2
3.	DESIGN GUIDELINES - HAND-PLUG CONNECTORS.....	2
3.1	MAXIMUM ASSEMBLY FORCE	2
3.2	CONTACT SURFACE CHARACTERISTICS	3
3.3	DISENGAGE FORCE.....	6
4.	DESIGN GUIDELINES – MECHANICAL ASSIST CONNECTORS	6
4.1	MAXIMUM ASSEMBLY FORCE	6
4.2	CONTACT SURFACE CHARACTERISTICS	6
4.3	LEVER LOCK CONNECTORS	8
4.4	SLIDE LOCK CONNECTORS	8
4.5	CAM INSERTION CONNECTORS	9
4.6	DISENGAGE FORCE.....	9
5.	DESIGN GUIDELINES – TWIST LOCK CONNECTORS	10
5.1	TORQUE REQUIREMENTS	10
5.2	CONTACT SURFACE CHARACTERISTICS	10
6.	TESTING – HAND-PLUG AND MECHANICAL ASSIST CONNECTORS.....	11
7.	DESIGN GUIDELINES - CPAS (CONNECTOR POSITION ASSURANCE)	11
8.	HAND CLEARANCE GUIDELINES	12
8.1	GLOVES.....	12
8.2	HAND-PLUG CONNECTORS	12
8.3	MECHANICAL ASSIST CONNECTORS.....	14
8.4	TWIST LOCK CONNECTORS.....	16
9.	REVISIONS.....	16
Appendix A:	Glossary	17
Appendix B:	Surface Area Calculations	18
Appendix C:	CPA (Connector Position Assurance) Evaluation Examples	20
Appendix D:	References	23

1. SCOPE

This document describes the design relative to assembly force, and hand clearance guidelines for conventional hand-plug, mechanical assist and twist lock electrical connectors, as well as Connector Position Assurances (CPAs). The minimum values associated with this design guide need to be evaluated against other critical characteristics that impact quality, efficiency and other traits of assembly feasibility.

All possible designs and applications could not be anticipated in creating these guidelines. Where there are questions of adherence to this document, such as use of an "off-the-shelf" design, always consult the responsible Ergonomics Department.

Referenced documents

SAE/USCAR-2 Performance Standard for Automotive Electrical Connector Systems
SAE/USCAR-12 Electrical Connector Design Criteria
See Appendix D for additional references

2. GENERAL

In all cases, ***assembly forces shall be as low as possible*** while maintaining satisfactory electrical, mechanical and environmental performance.

Part packaging, process and workstation design requirements/constraints all have the potential to negatively impact the maximum assembly forces specified in this document. Such situations include but are not limited to:

- Obstructed access
- Awkward or non-neutral postures, such as wrist deviation or extended reaches
- Forces applied laterally across the body

This has necessitated the creation of a Hand Clearance Guidelines section and may result in a lower assembly force requirement. Consult the Ergonomics Department with any questions or if clarifications are needed.

3. DESIGN GUIDELINES - HAND-PLUG CONNECTORS

A hand-plug connector is an electrical connector which requires an operator to manually assemble/mate two connector halves or a connector to a device without the use of a mechanical assist. Hand-plug connectors fall into three classes as shown in Table 3.1. Each class is defined by maximum assembly force and corresponding contact surface area requirements.

3.1 MAXIMUM ASSEMBLY FORCE

Assembly force values are defined to accommodate strength capability for the working population. Under ideal conditions described in these guidelines, the maximum assembly forces shall not exceed 75 N. When these conditions cannot be met, the maximum assembly force is reduced, see Table 3.1 for specifics.

3.2 CONTACT SURFACE CHARACTERISTICS

The contact surface is an essentially continuous plane upon which the operator can apply assembly force. Contact surface dimensions accommodate a gloved hand. The minimum contact surface area shall be met. These dimensions are provided in Table 3.1.

Measuring contact surface area shall be done by defining acceptable contact surface areas based on criteria defined in Section 4.2.4. Acceptable contact surface areas need to account for reasonable areas of the connector an operator would interface with to manually connect. Sum the acceptable contact surface areas to determine total available contact surface area. Appendix B provides specific examples on calculating surface area for different connector scenarios.

3.2.1 For Class 1 connectors, there is not a minimum contact surface area defined, under the assumption that the operator is able to use the wires to assist with the aligning and seating of the connector. This assumes the wires do not collapse or buckle during loading. If the wires do collapse or buckle during loading, there is a minimum surface area requirement of 15 mm² for a Fingertip hand posture, or 100 mm² (50 mm² opposing sides) for the Pinch grip hand posture with a minimum dimension of 3 mm for both postures.

3.2.2 For Class 2 and 3 connectors, a minimum contact surface dimension of 5 mm, not including the edge radius, is required (see Figure 1). Any surface measuring less than 5 mm in width or length cannot be considered as part of the contact surface area. Contact stress limitations necessitate this larger contact surface dimension.



Figure 1: Contact Surface Area and Edge Radius

3.2.3 Design contact surfaces to be continuous or near continuous. Surface voids, though not desired, can be acceptable if one of the dimensions (length or width) is ≤ 5 mm. Surface voids are not included in contact surface area calculations unless they measure ≤ 3 mm in width (see Appendix B).

3.2.4 Design potential contact surfaces with no uncomfortable pressure points. In some situations, knurls or serrations can be used to improve grasp, provided they do not create uncomfortable pressure points. Serrations, knurls, and ridges greater than 0.8 mm in height are not acceptable (see Figure 6). On contact surface areas or edges likely to be contacted by the operator's hand has a recommended edge radius of 3 mm. An edge radius less than 0.8 mm is unacceptable (see Figure 1).

3.2.5 Position contact surfaces optimally angled between 30° and 90° (perpendicular) from the direction of force insertion (see Figure 2) for maximum allowable assembly force per Table 3.1.



Figure 2: Contact Surface Angle. Acceptable Contact Surface: Optimally angled between 30° and 90° from the direction of the force insertion.

- 3.2.6** Only surfaces in contact with the finger/thumb can be included in the total contact surface area (see examples in Appendix B). For force applications that require a pinch or grasp posture, contact surfaces shall be on opposing sides (i.e. top/bottom or left/right). See Figure 3, where the top picture is showing examples of contact surfaces on opposing sides vs. the bottom picture showing contact surfaces only on one side. Note: The shaded areas represent contact surfaces.

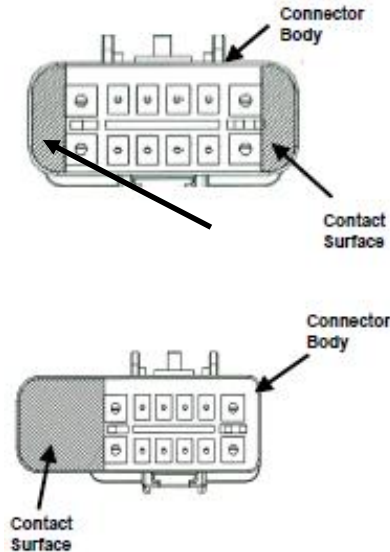


Figure 3: Contact Surface Area Examples

- 3.2.7** Where the wire harness bundle is grasped during mating of the connector, the contact surface area can include the harness ramp surface created when the wires exit the connector housing. The harness ramp surface may be included in the contact surface area as long as that ramp is greater than 30 degrees in the direction of force application and the surface area requirements are met (see Figure 4 and Example 3 in Appendix B).

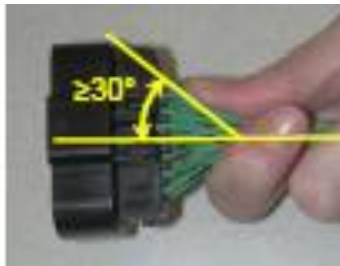
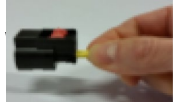
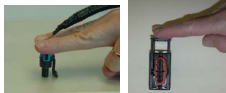


Figure 4: Wire Harness Bundle Contact Surface Area. The wire harness bundle may be considered a push surface if optimally angled $\geq 30^\circ$ from the direction of force insertion.

TABLE 3.1 HAND PLUG CONNECTOR DESIGN GUIDELINES

Class	Maximum Assembly force	Typical Hand Posture Options for Design	Minimum Contact Surface Area	Minimum Contact Surface Dimension	Grip Span
1	$\leq 25\text{N}$	Wire Harness Push 	If operator is able to use wires to assist with aligning and seating the connector, there is no specific surface area requirement for Class 1 connectors. If wires collapse or buckle during loading, surface area requirements are listed below.		
		Fingertip Push (with optimally angled push surface) 	15 mm ²	3 mm	NA
		Pinch grip (without optimally angled push surface) 	100 mm ² With a minimum of of 50 mm ² provided on each opposing grip surface.	3 mm	NA
2	$\leq 45\text{N}$	One Thumb or One Finger Push (with optimally angled push surface) 	100 mm ²	5 mm	NA
		Pinch grip with Thumb tip and fingertip push (with optimally angled push surface) 	100 mm ² With a minimum of of 50 mm ² push surface provided on two opposing sides of the wire bundle.		NA
		Hand Grasp (key grip without optimally angled push) 	100 mm ² With a minimum of of 50 mm ² provided on each opposing grip surface.		10 - 55 mm
3	$\leq 75\text{N}$	Hand Grasp (key grip with optimally angled push surface) 	150 mm ² With a minimum of 50 mm ² push surface provided on one side of the wire bundle (for the thumb)	5 mm	NA
		Hand Grasp (power grip without optimally angled push surface) 	15 mm minimum diameter wire bundle size with tapes or conduit bundle		15 mm minimum 50 mm maximum
		Pinch Grip with Thumb tip and two fingertip push (with optimally angled push surface) 	150 mm ² With a minimum of 50 mm ² push surface provided on one opposing side of the wire bundle (for the thumb)		NA
		Two Finger Push 	150 mm ² With a minimum of 75 mm ² provided for each finger		NA

- 3.2.8** The wire harness bundle, when grasped using a power grip, can be used for assembly of the connector when there is no optimally angled push surface. A power grip can only be achieved when the bundle diameter is between 15 mm and 50 mm. The bundle shall be stiff enough to ensure that it does not flex when force is applied.

3.3 DISENGAGE FORCE

Disengagement of the connector in the assembly plant may be required for testing. In these cases, values for the maximum disassembly force with the secondary lock or CPA released are the same as the maximum assembly force for each class (see Table 3.1). Disengagement forces are applicable for cyclic assembly tasks. Non-routine repair tasks do not apply to this standard.

4. DESIGN GUIDELINES – MECHANICAL ASSIST CONNECTORS

Mechanical assist connectors utilize levers, cams or slides to provide a mechanical advantage to the operator in making the connection and thus reduce assembly force. Mechanical assist connectors fall into three classes as shown in Tables 4.1 and 4.2. Required push surface area and assembly force varies with each type of connector and class.

4.1 MAXIMUM ASSEMBLY FORCE

Assembly force values are defined to accommodate strength capability for the working population. The maximum allowable assembly force is the peak force required to actuate the mechanical assist from its fully open position to its fully closed position. Under ideal conditions described in these guidelines, the maximum assembly forces shall not exceed 75 N. This includes the force required to release the mechanical assist from its pre-locked position for those connectors that do not have auto-release. When ideal conditions cannot be met, the allowable assembly force is reduced as shown in Tables 4.1 and 4.2.

4.2 CONTACT SURFACE CHARACTERISTICS

The contact surface is an essentially continuous plane upon which the operator can apply assembly force. Contact surface dimensions accommodate a gloved hand. The minimum contact surface area shall be met. These dimensions are provided in Tables 4.1 and 4.2.

Measuring contact surface area shall be done by defining acceptable contact surface areas based on criteria defined in Section 4.2.4. Acceptable contact surface areas need to account for reasonable areas of the connector an operator would interface with to manually connect. Sum the acceptable contact surface areas to determine total available contact surface area. Appendix B provides specific examples on calculating surface area for different connector scenarios.

- 4.2.1** For Class 1 connectors a minimum contact surface dimension of 3 mm, not including the edge radius, is required (see Figure 5). Any surface measuring less than 3 mm in width or breadth cannot be considered as part of the contact surface area.
- 4.2.2** For Class 2 and 3 connectors a minimum contact surface dimension of 5 mm, not including edge radius is required (see Figure 5). Any surface measuring less than 5 mm in width or breadth cannot be considered as part of the contact surface area.