Ergonomics Specification for Electrical Connections

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QUESTIONS REGARDING THIS DOCUMENT: (248) 273-2470 FAX (248) 273-2494
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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 mm^2 for a Fingertip hand posture, or 100 mm^2 (50 mm^2 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.

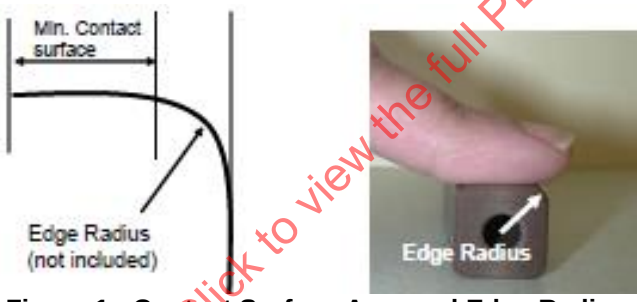


Figure 1: Contact Surface Area and Edge Radius

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 30º and 90º 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.

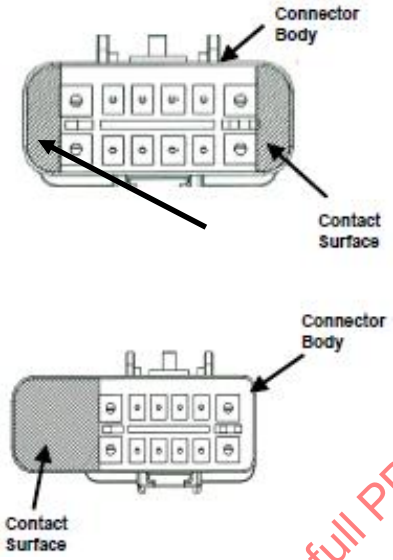
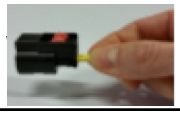
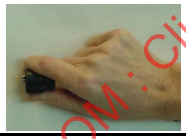
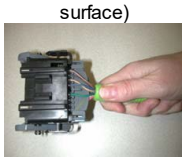


Figure 3: Contact Surface Area Examples

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 ≥ 30° 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	≤ 25N	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	≤ 45N	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	≤ 75N	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.

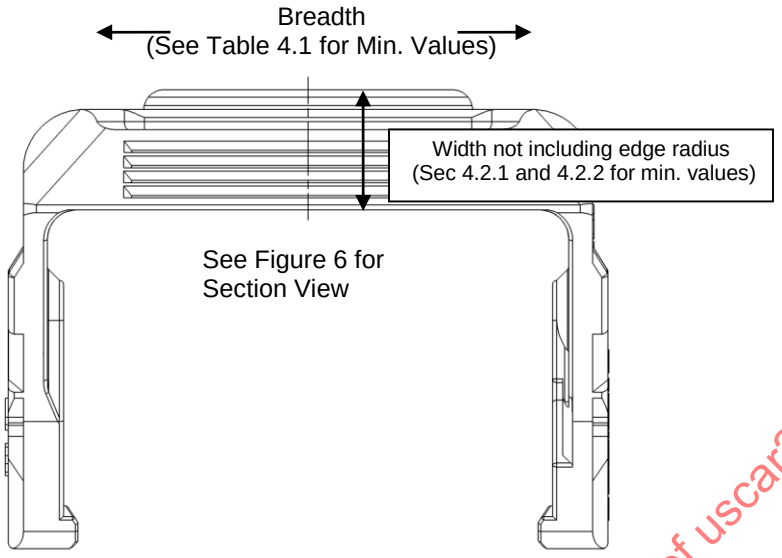


Figure 5: Lever Contact Surface Area

4.2.3 Design contact surfaces to be continuous or near continuous. Surface voids, though not desired, can be acceptable if one of the dimensions (breadth 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).

4.2.4 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 0.8mm is unacceptable (see Figure 1).

4.2.5 An optional end stop may be used to help prevent the thumb/finger(s) from sliding off of the lever. An end stop is defined as a ridge perpendicular to the push surface located at the distal edge of the surface. Dimensions of this feature are shown in Figure 6.

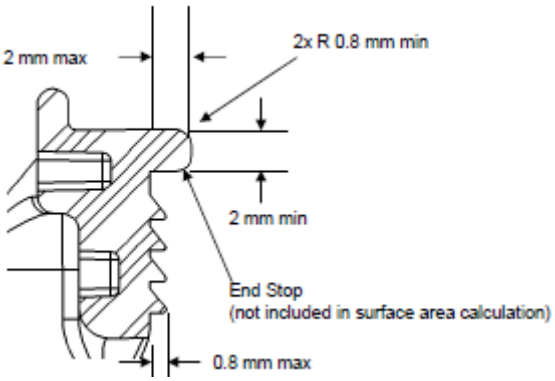


Figure 6: Section View – Dimensions of Optional Contact Surface Features

4.3 LEVER LOCK CONNECTORS

Lever lock connectors are the most common type of mechanical assist connector. Two different lever designs have been accounted for, constrained and unconstrained. Constrained levers drive a larger breadth dimension to allow for a finger(s) to fit within the structure of the lever. See Figures 7 and 8. See Table 4.1 for design requirements.

Figure 7: Constrained Lever Lock Connector example: Fingers / thumbs are constrained within the structure of the lever.

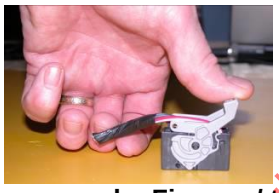


Figure 8: Unconstrained Lever Lock Connector example: Fingers / thumbs are not confined to the space between the lever arms.

TABLE 4.1 LEVER LOCK CONNECTOR DESIGN GUIDELINES

Class	Maximum Assembly force	Typical Hand Posture Options for Design	Constrained		Unconstrained	
			Minimum Contact Surface Area	Minimum Contact Surface Dimension	Minimum Contact Surface Area	Minimum Contact Surface Dimension
1	≤ 25N	Finger tip	60 mm^2	3 mm width 19 mm breadth	15 mm^2 	3 mm width 5 mm breadth
2	≤ 45N	1 Finger or 1 Thumb	115 mm^2	5 mm width 23 mm breadth	70 mm^2 	5 mm width 14 mm breadth
3	≤ 75N ** ** Non-neutral postures or forces applied in an upward or lateral direction requires further analysis	2 Fingers	210 mm^2 	5 mm width 42 mm breadth	160 mm^2	5 mm width 32 mm breadth

4.4 SLIDE LOCK CONNECTORS

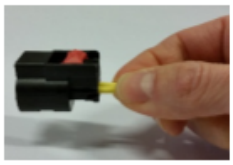
Slide lock connectors are specialized types of mechanical assist connector which utilize postures and force applications similar to hand plug connectors. Design slide lock connectors to meet the requirements in the Table 3.1.

4.4.1 Slide lock applications where the connector is not stabilized / mounted typically require the opposing thumb to stabilize the part. Additional surface area of 100 mm^2 shall be provided opposite the slide mechanism for the thumb.

4.5 CAM INSERTION CONNECTORS

Cam insertion connectors are another specialized type of mechanical assist connector which utilize postures and force applications similar to hand-plug connectors. See Table 4.2 for design requirements.

TABLE 4.2 CAM INSERTION CONNECTOR DESIGN GUIDELINES

Class	Maximum Assembly Force	Typical Hand Posture for Design	Minimum Contact Surface Area	Minimum Contact Surface Dimension	Grip Span
1	≤ 25N	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.		
		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	≤ 45N	Hand grasp (power grip without optimally angled push surface) 	100 mm^2 With a minimum of of 50 mm^2 push surface provided on each opposing grip surface	5 mm	0 -15 mm or 50 - 75 mm
3	≤ 75N ** ** Non-neutral postures or forces applied in an upward or lateral direction requires further analysis	Hand grasp (power grip with optimally angled push surface) 	150 mm^2 With a minimum of 50 mm^2 push surface provided on one side (for the thumb)	5 mm	75 mm max
		Hand grasp (power grip without optimally angled push surface) 	150 mm^2 With a minimum of 50 mm^2 push surface provided on each opposing grip surface	5 mm	15 - 50 mm

4.6 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 (Table 4.1 and 4.2). Disengagement forces are applicable for cyclic assembly tasks. Non-routine repair tasks do not apply to this standard.

5. DESIGN GUIDELINES – TWIST LOCK CONNECTORS

Electrical connectors which require a twisting motion for assembly are not recommended. If this connector design is selected, the maximum assembly torque is limited to the amount of torque that can be generated by the hand/wrist for engagement of the connector.

5.1 TORQUE REQUIREMENTS

The amount of assembly torque cannot exceed **1.5 Nm maximum** to fully engage the connector. The degree of rotation to secure the connector is ideally 90 degrees or less, and shall not exceed 180 degrees.

5.2 CONTACT SURFACE CHARACTERISTICS

5.2.1 Surface area shall meet the minimum allowable contact surface area and grip span requirements as specified in Table 5.1. A minimum contact surface dimension of 3 mm, not including the edge radius, is required (see Figure 1). Any surface measuring less than 3 mm in width or length cannot be considered as part of the contact surface area.

5.2.2 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).

5.2.3 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 0.8mm is unacceptable (see Figure 1).

TABLE 5.1 TWIST LOCK CONNECTORS

Maximum Assembly Torque	Typical Hand Posture for Design	Minimum Contact Surface Area	Grip Span
≤ 1.5 Nm	Lateral key grip 	150 mm^2 with at least 50 mm^2 provided on one opposing grip surface (for the thumb)	50 mm maximum

5.2.4 If a tab is provided on the twist lock connector for use as a lever to assist in locking the connector, then it is considered to be mechanical assist connector (see Figure 11). The direction of force application changes from a twist of the connector to a linear push/pull of the tab. Therefore the maximum assembly force and contact surface area from Table 4.1 would supersede the requirements from Table 5.1.

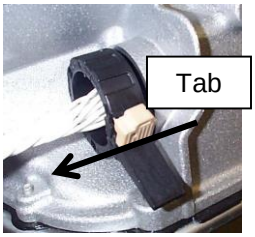


Figure 9: Twist Lock Connector with Tab

6. TESTING – HAND-PLUG AND MECHANICAL ASSIST CONNECTORS

Perform testing of the hand-plug and mechanical assist assembly force as specified in SAE-USCAR-2. Additional requirements may apply as specified in that document. For lever lock connectors, the optimum set-up to determine lever actuation force is such that force is applied perpendicular to the lever push surface and continues in an arc about the rotational axis of the lever. For slide lock style connectors, assembly force shall be measured in-line with the direction of push.

7. DESIGN GUIDELINES - CPA (CONNECTOR POSITION ASSURANCE)

The following guidelines apply to CPA devices:

7.1.1 Make the minimum contact surface area at least 15 mm^2 with a minimum dimension 3 mm, not including the edge radius (see Figure 1).

7.1.2 Any surface measuring less than 3 mm in width or length cannot be considered as part of the contact surface area. Larger surfaces are preferred if possible.

7.1.3 Contact surfaces shall be optimally angled between 30° and 90° (perpendicular) from the direction of force insertion (see Figure 2).

7.1.4 Design the CPA actuation force to meet the requirements in Table 7.1 (see SAE/USCAR-2 Misc. Component Insertion for additional information). The force should be measured in the direction of CPA travel.

7.1.5 Design the CPA with no sharp edges or hard contact points on the part itself or along the travel path. An edge radius less than 0.8 mm is unacceptable.

7.1.6 Unobstructed: The fully seated CPA push surface should be either flush or protruding above the surrounding surface of the connector. The flush condition includes a CPA surface that is even with or recessed beyond the surrounding surfaces up to a maximum of 1mm. A minimum of 3x5mm of the CPA push surface must be free of any obstructions with the connector body or wires through the length of travel:

i) On at least three sides (see Appendix C- Example 1 and 2).

ii) On two adjacent sides (see Appendix C- Example 3).

Obstructed: A minimum 3x5mm dimension of the CPA push surface is not accessible as defined above. In instances where the CPA must be recessed or shrouded between *opposing* surfaces or sides, adequate access for finger actuation must still be provided (see Appendix C- Example 4). The length of travel of the CPA will determine the minimum dimension between the opposing surfaces/sides:

i) CPA travel distance ≤ 7 mm requires 15 mm minimum dimension between opposing surfaces/sides.

ii) CPA travel distance > 7mm requires 19 mm minimum dimension between opposing surfaces/sides.

If the CPA travel path starts in a recessed condition (versus flush or protruding), 19mm must be provided between the restricted or opposing surfaces/sides regardless of the travel distance.

Appendix C provides additional CPA evaluation examples including an unacceptable design as illustrated in Example 5. Note that other considerations apply when evaluating accessibility to surrounding components outside of the connector/wires.

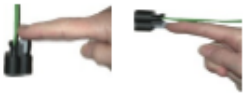
7.1.7 The design should provide for audible/ tactile feedback, but shall provide visual indication that the CPA is closed. Examples of visual indication include, but are not limited to, designing the push surface of the CPA flush to the

surrounding surface, designing the push surface to have a shoulder that rests on the surrounding surface or providing a contrasting color between the CPA and the connector housing.

7.1.8 Serrations, knurls, ridges, etc. are permissible and if used, shall have a maximum height of 0.8 mm (see Figure 6).

7.1.9 Integral CPAs are preferred over tethered designs.

Table 7.1 Connector Position Assurance

Class	Maximum Assembly Force	Typical Hand Posture for Design	Minimum Contact Surface Area	Minimum Contact Surface Dimension
1	≤ 25 N	Fingertip push (with optimally angled push surface) 	15 mm^2	3 mm

8. HAND CLEARANCE GUIDELINES

While it is important that designers of electrical connectors utilize the design specifications outlined in the previous sections, the adherence to these specifications alone will not prevent the occurrence of unacceptable electrical connections during the assembly process. The next critical element is the packaging or working area in which the electrical connection is made. The presence of surrounding parts or structures can compromise the hand clearance available to the Operator. This section provides hand clearance dimensions to the design engineers for use early in the design/assembly of the vehicle.

In the design and packaging of electrical connectors, hand clearance and push surface area will directly impact the hand posture utilized by the Operator. Hand posture, force and push surface area are interrelated variables. Push surface area and corresponding assembly effort requirements will enable the design engineer to identify how much hand clearance is required. If the required hand clearance cannot be met, a less desirable hand posture may be needed (ex. pinch grip vs. hand grip) and the maximum permissible force would be reduced. Failure to provide adequate hand / finger clearance increases the risk of occupational injury, poor quality (disconnects, partial connections, no connections) and time for assembly.

8.1 GLOVES

An allowance has been added to all hand clearance requirements in this section which reflects the use of gloves during assembly. Based upon a sampling of typical work gloves used in vehicle and powertrain assembly plants, a 2 mm glove thickness was applied. Additional clearance may be required if glove thickness is greater than 2 mm.

8.2 HAND-PLUG CONNECTORS

Hand clearance for each class of hand-plug connectors is defined based upon a selection of typical hand postures used for assembly. The minimum hand clearance requirements for each posture are shown in Figures 10-14 on the following pages. It is important to note that the hand clearances shown are in the final assembly position. Additional clearance may be required in order to position the connector. All clearance areas must be kept clear of sharp edges or objects.

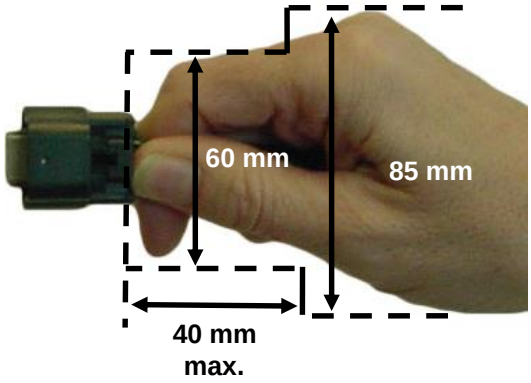


Figure 10A: Hand Grasp Clearance
(Side view – Hand in line with connector)

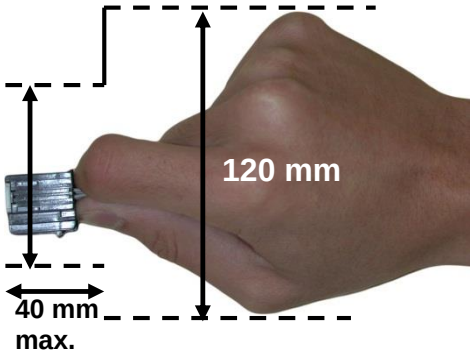


Figure 10B: Hand Grasp Clearance
(Top view – Hand in line with Connector)

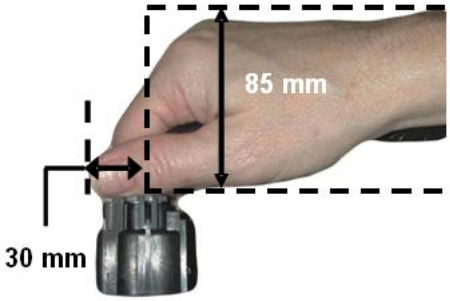


Figure 10C: Hand Grasp Clearance
(Side view – Hand 90º to Connector)

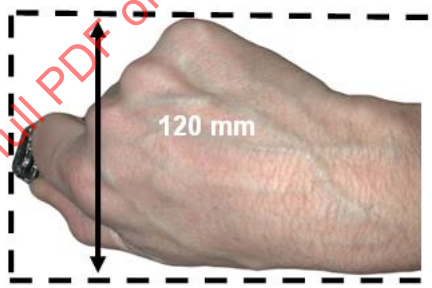


Figure 10D: Hand Grasp Clearance
(Top view – Hand 90º to Connector)

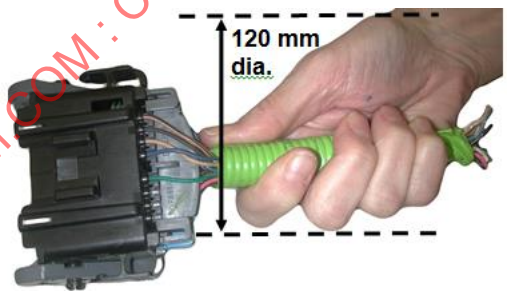


Figure 11: Hand Grasp Clearance with Bundle

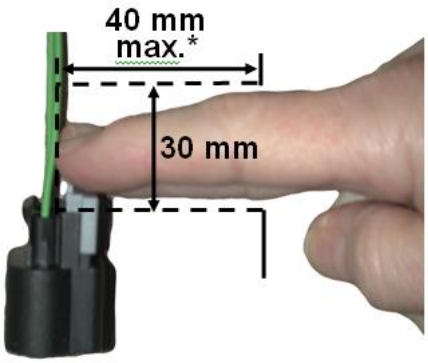


Figure 12A: Two Finger Push Clearance
(Side View)

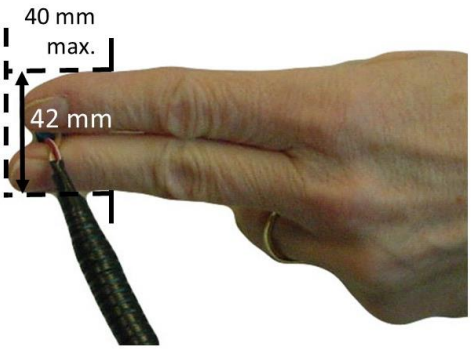


Figure 12B: Two Finger Push Clearance
(Top View)

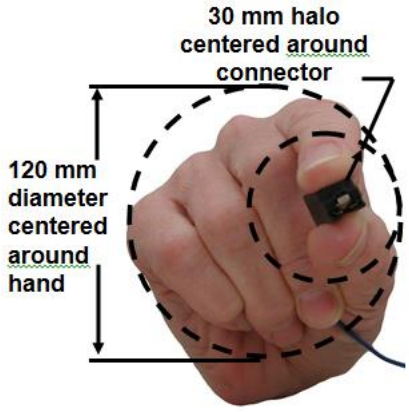


Figure 13: Pinch Grip Clearance (Front View)

Figure 14: Pinch Grip Clearance (Side View)

Note: For Figures 12A, 12B, 13 and 14, whole hand clearance of 120 mm diameter must be provided for depths greater than 40 mm to accommodate the hand.

8.3 MECHANICAL ASSIST CONNECTORS

Hand clearances for each class of mechanical assist connector are defined based upon a selection of typical hand postures used for assembly (See Figure 15). For the purposes of assembly, the connector needs to be placed before the mechanical assist can be actuated. Therefore, hand-plug clearances as defined in Section 8.2 shall be used to determine acceptable hand clearances. Additional clearances are required for the swing path of lever lock type mechanical assist connectors.

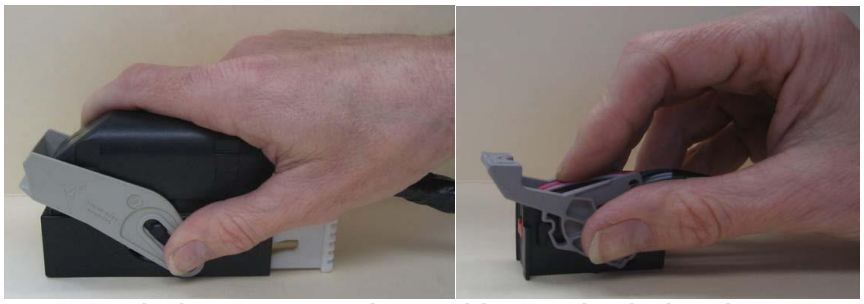


Figure 15: Typical Postures used to position mechanical assist connectors

8.3.1 The clearance for the swing path of lever lock connectors is given in Figures 16 and 17. The required clearance is dependent upon the direction of actuation. The swing area of the lever shall be kept clear of sharp edges or objects.

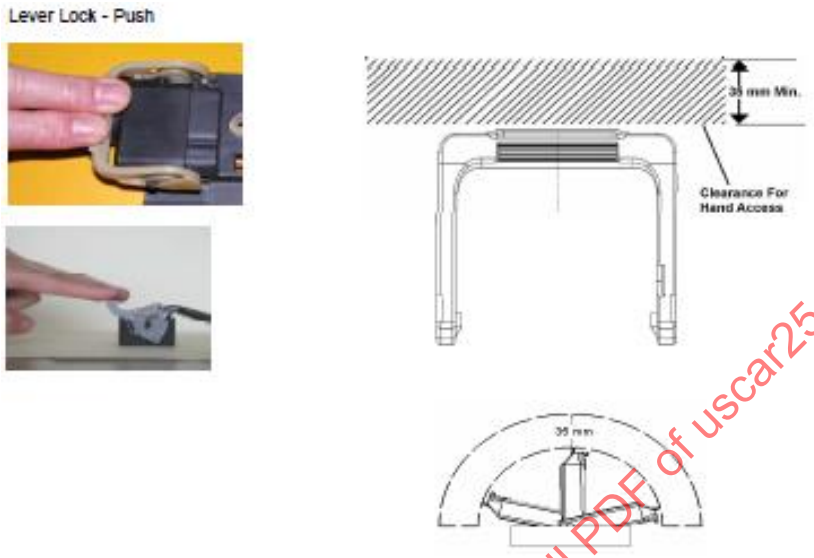


Figure 16: Lever Lock Swing Path and Clearance – Push

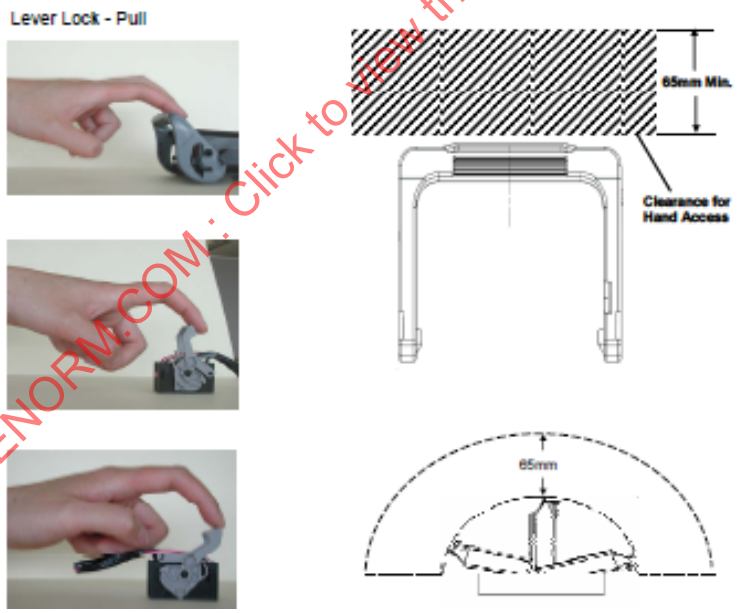


Figure 17: Lever Lock Swing Path and Clearance - Pull

8.4 TWIST LOCK CONNECTORS

Twist lock connectors require use of the whole hand for actuation. A 30 mm halo shall be provided for the thumb/fingers with a 120 mm minimum diameter required for the hand (See Figure 18).

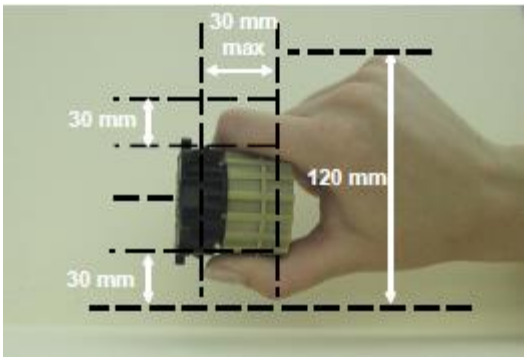


Figure 18: Twist Lock Connector Clearance

9. REVISIONS

This standard was approved by USCAR in September 2008.

Any revisions since that date have been incorporated into the specification. Revisions which altered the content of the specification are recorded below:

DATE	SECTION	SUMMARY OF CHANGES	NOTES
2008-09-26	All	None	
2016-2-1 (Revision 2)	Section 3.1, 3.2, 4.3, 5.1, 7, 8.2 Appendix A, C and D	These sections were completely re-written and updated.	USCAR-12 Electrical Connector Design Criteria has been updated. Contact EWCAP for future changes.

Appendix A: Glossary

Connector position assurance (CPA) – A lock on the latch that holds the two halves of a connector together or holds a connector to an electrical device. This is usually an optional feature. It prevents accidental release of the connector latch and serves as an indicator of full connector mating.

Constrained Lever Lock – A raised or angled structure on the side of a lever arm that limits or constrains the fingers/thumbs within the structure of the lever during actuation. The raised or angled structure may be added to provide additional strength and robustness and can be the swing arm of the lever as well.

Contact surface area – The area available on the connector housing, mechanical assist, or wire harness bundle that the finger/thumb or palm shall make contact with when exerting force for insertion or mating of the connector.

Finger push – Application of force by the finger pad(s) or tip(s).

Grip span – The distance between the thumb and opposing finger(s) which are in contact with the connector housing, mechanical assist, or wire harness bundle.

Grip surface – A contact surface that is not optimally angled and requires a pinch grip in addition to the force required for insertion.

Hand clearance – The amount of space required for access to assemble a connector as defined by either large male (95th percentile) for openings or small female (5th percentile) for reach.

Hand grasp – A grip which allows the hand to fully surround the connector housing or wire harness bundle.

Hand-plug connectors – An electrical connector which requires an Operator to manually assemble two connector halves or a connector to a device/header without the use of a mechanical assist.

Key grip – Grasping of a connector housing or wire harness bundle between the thumb and the side of the index finger.

Maximum assembly force – The force required to mate male and female connector halves or to completely seat a connector in a device/header.

Mechanical assist connector – A means of minimizing the Operator effort required to mate two connector halves or a connector to a device/header. Typical means are a bolt, cam, slide, or lever.

Neutral wrist posture – A posture which aligns the hand and forearm naturally with minimal radial/ulnar deviation or flexion/extension of the wrist.

Optimally Angled Push Surface – A surface angled between 30° and 90° (perpendicular) from the direction of force insertion (see Figure 2).

Pinch grip – Grasping of a connector housing or wire harness bundle between the thumb and one or more fingers.

Power grip – Type of grip in which the thumb, fingers, and palm of the hand form a clamp around the object.

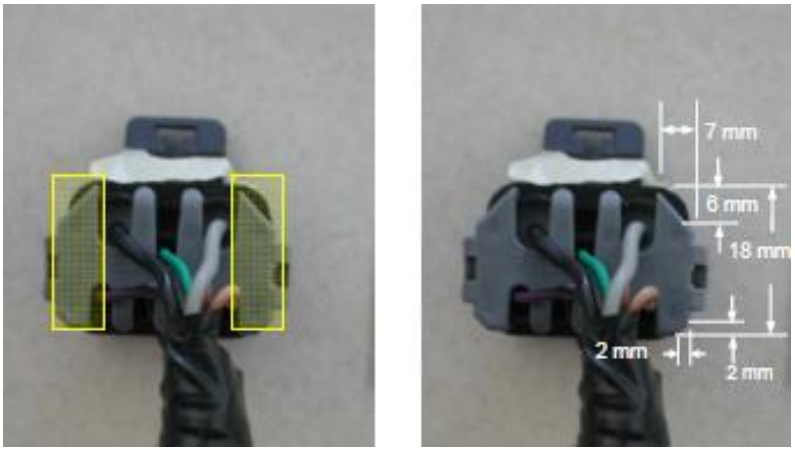
Push surface – A contact surface that is optimally angled which provides an area for application of force in the direction of insertion.

Unconstrained Lever Lock – No raised or angled structure is present on the side of a lever arm allowing the fingers to extend beyond the confines of the lever arm during actuation.

Appendix B: Surface Area Calculations

Example 1

Right and left sides used as push surface



Push surfaces on two sides of wire bundle
Measure length and width as shown on each side of bundle; add together for total push surface area
(7 x 18) – (0.5(7 x 6) – (0.5(2 x 2)) =103 mm² right side surface area
(7 x 18) – (0.5(7 x 6) – (0.5(2 x 2)) =103 mm² left side surface area
Total Surface Area 103+103 = 206 mm²

Example 2

Top and bottom used as push surface

Push surfaces on top and bottom of wire bundle

Measure length and width as shown on the top and bottom of the bundle, add together for total push surface area.
Note – If gaps are ≥ 5 mm the surface is not considered continuous. If gaps are between 3 mm and 5 mm the surface can be considered continuous but the gap is not included in the surface area total (gaps ≤ 3 mm can be included in the total surface area).