RADSOK®

HIGH AMPERAGE ELECTRICAL TERMINALS

TECHNICAL BRIEF

Revised: May 2001

DISCLAIMER

The information presented herein is believed to be correct at the time of printing and has been compiled from data collected from various sources. This information is not warranted to potential buyers of RADSOK® electrical terminals. Every user of these electrical terminals must determine the RADSOK® suitability for their own applications.

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# Table of Contents

What is a RADSOK® Terminal? ................................................................. 5
Key Features of the RADSOK® Terminal ................................................. 5
Applications Requiring Quick Connection .............................................. 6
RADSOK® Terminal Product Range and Available Options ..................... 6
Application Details for the RADSOK® Terminal .................................... 7
Typical Applications for the RADSOK® Terminal .................................. 8
Choosing the Proper RADSOK® Terminal Size ..................................... 8
Technical Description of the RADSOK® Terminal ................................. 8
- Explanation of RADSOK® Terminal Components & Manufacturing ..... 8
- Hyperbolic Grid Twist of RADSOK® Terminal .................................. 9
- RADSOK® Terminal Principal .......................................................... 10
Terminal Materials ................................................................................... 12
Plating ....................................................................................................... 13
High Temperature and the Effects on the RADSOK® Terminal ............. 14
Crimping of RADSOK® Terminals ......................................................... 15
Cable Selection ...................................................................................... 15

**Appendix** ............................................................................................... 17
Dimensions of RADSOK® Receptacle and Pin Connector .................... 17
RADSOK® Press-Fit Assembly Information ........................................... 17
RADSOK® Ampacity Chart ................................................................. 19
Test Data for Various RADSOK® Terminals ......................................... 20
WHAT is a RADSOK® TERMINAL?

RADSOK® means Radial Socket and is a registered trademark of KÖNNEKTECH, Inc. The RADSOK® terminal is a patented high performance hyperboloid socket and pin style electrical contact system for applications 30 amps and above. Hyperboloid connectors offer superior performance when compared with standard pin and socket connectors. In the RADSOK® terminal, multiple contacting elements are hyperbolically arrayed around the inner diameter of the socket. In addition, each of the contact elements is skewed with respect to the axial direction of the terminal. The result is the multiple contact surfaces, comprising what is referred to as the “grid.” This is illustrated in Figure 1.

![RADSOK® Terminal Grid](Image)

When viewing the grid profile, a hyperbola shape is seen that is the basis of the unique RADSOK® terminal. The hyperbolic configuration results in a mechanical interference between an inserted pin and the contact elements. When a pin is inserted into the socket, the contacting elements of the grid mechanically wrap around the pin providing pressure (normal force) necessary for a superior electrical connection.

The grid of the RADSOK® terminal is manufactured from highly conductive, high tensile strength beryllium copper. The high flexible modulus properties of beryllium copper result in excellent electrical contact when formed into the hyperbola shape. The grid is produced by a progressive die in high-speed four-slide stamping machines, which assures part uniformity. The housings are copper barrels produced on extremely accurate transfer presses. These manufacturing methods result in a high quality electrical terminal that is cost competitive while out-performing all other forms of terminals.

KEY FEATURES of the RADSOK® TERMINAL

- Low Contact Resistance and High Current Capacity
- Adjustable Insertion/Extraction Force
- Vibration Resistance/Off Axis Insertion Tolerance
- Excellent Durability
- Self cleaning

**Low Contact Resistance and High Current Capacity** – The RADSOK® terminal grid provides a greater surface area of electrical contact per contacting element than standard terminals. RADSOK® terminals do not relax as a result of repeated insertion, which occurs in standard terminals. The associated millivolt loss that is common in standard terminals due to repeated insertion relaxation does not occur in the RADSOK® terminal. The result is superior electrical transfer that does not deteriorate from repeated insertion.

**Adjustable insertion/extraction force** – The insertion/extraction force of the RADSOK® terminal can be adjusted to some degree by adjusting the coatings used to plate the grid and the pin. It is possible to
customize the materials and coatings used for the RADSOK® terminal to optimize the relationship between performance objectives and cost. Typically, an insertion force of at least 1.5 pounds is necessary to assure operational integrity of the RADSOK® terminal.

**Vibration Resistance/Off Axis Insertion Tolerance** - The hyperbolic grid of the RADSOK® terminal assures full contact with an inserted pin. Tests have confirmed that when subjected to vibration, this hyperbolic elastic grid maintains electrical continuity. This unique feature also provides for some axial misalignment without sacrifice of electrical contact.

**Excellent Durability** - Certain applications require repeated insertion/extraction cycles. The opportunity to customize the selection of material and plating combinations to maximize the cost versus performance required is unique to the RADSOK® terminal. Low cost designs capable of thousands of cycles while maintaining high and consistent conductive characteristics can be achieved when RADSOK® terminals are customized to a specific application.

**Self-Cleaning** - Ideally, care should be taken to assure that electrical terminals remain clean and free of contaminants to prevent voltage loss and heating. The design of the RADSOK® terminal provides a degree of self-cleaning. As the pin is inserted into the socket, the grid elements provide a wiping action that remove minor contaminants from the pin. The spaces between the grid elements provide space for contaminants.

**APPLICATIONS REQUIRING QUICK CONNECTION**

Since the RADSOK® terminal does not rely on mechanical fasteners for electrical connection, the terminal can be installed or disconnected quickly without the need of special tools. This results in shorter assembly time and easier component removal. When a threaded style terminal is not properly installed, [over or under torque] electrical contact properties can be compromised. Results can be contact overheating, contact housing damage, and ultimate failure of the electrical connection. Use of the RADSOK® terminal eliminates this variability since achievement of an acceptable level of torque is not required. The SurLok™ positive retention feature can be added to increase the robustness of the assembly operation. This feature is recommended when individual electrical connections are required and retention is not available via a contact housing.

**RADSOK® TERMINAL PRODUCT RANGE and AVAILABLE OPTIONS**

The RADSOK® terminal can be made in any size greater than 3.6mm pin diameter. Presently available and in production are 6.0mm, 8.0mm and 10.3mm cartridges. Designs and prototypes have been made of the following sizes:

- 3.6mm
- 4.3mm
- 6.0mm “short”
- 10.3mm “short
- 12.3 mm
- 14.0mm
- 17.9mm
- 23.0mm
- 40.0mm

New designs are constantly being developed with the 3.6mm terminal expected to be the next size available for production.

**Some options available with the RADSOK® terminals include:**

- Holders to connect the RADSOK® terminal to wire or cable.
• **SurLok™** positive retention feature. This is a detent-locking feature that snaps “home” and reduces the likelihood of inadvertent decoupling. This feature can also be used to provide confirmation that the connector is fully mated.

• **SealTac™** ingress protection. This is a seal option that protects the contact interface from the environment. In its simplest form, the seal is a die-cut EPDM washer inserted into the entry end of a closed end RADSOK® cartridge that seals against the pin when inserted.

• Data terminals -- Some applications require voltage monitoring at the connector. This feature allows voltage monitoring via a standard 0.25-inch-spade terminal that can be attached to larger terminal sizes.

The RADSOK® cartridge can be incorporated into conductive housings or holders and be terminated with a threaded fastener, a crimp barrel, a finger crimp, or any of several other termination methods (See Figure 2).

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### APPLICATION DETAILS for the RADSOK® TERMINAL

The 6mm, 8mm, and 10.3mm RADSOK® cartridges are presently tooled for production. Other sizes have been developed and will be available, as customers require. Besides the basic cartridge, the RADSOK® terminal can be designed to incorporate other features, which enhance the terminals flexibility and appeal such as the **SurLok™** and **SealTac™** features.

There are three options to consider when specifying RADSOK® terminals:

- Purchase RADSOK® terminals for inclusion in an assembly.
- Purchase RADSOK® terminals assembled into holders ready for crimping or fastening to cable or other components.
- Purchase assemblies from KONNEKTECH with the RADSOK® terminal incorporated.

For applications requiring RADSOK® terminals only, recommended assembly procedures are included in the “Guidelines for RADSOK® Terminal Assembly”, located in the Appendix. This document also includes recommended press fit dimensions to install the RADSOK® Terminal cartridge into conductive holders. The “Dimensions of RADSOK® Terminal, Pin and Receptacle” document found in this manual provides additional dimensions to aid manufacturing cartridge holders and pin specification development. For custom applications, KONNEKTECH offers a complete in-house terminal development and prototype department. The RADSOK® terminal is ideally suited for applications requiring quick connect or disconnect with high current flow. The two basic terminal configurations are in-line and 90°. These configurations refer to how the axis of the cartridge is oriented with respect to the cable conductor. With in-line, the RADSOK® terminal is on the
same axis as the conductor, or in-line to the conductor.

For 90° configurations, the RADSOK® terminal axis is 90° or perpendicular to the conductor. There are numerous options to consider when designing the cartridge holders for each of the configurations. The holders can be made as metal stampings, impact extrusions or from CNC machining, depending on the quantity and style required.

**TYPICAL APPLICATIONS for the RADSOK® TERMINAL**

- Battery (cell) terminals
- Battery-to-battery connections
- Bus bar connections
- Alternator connections
- Automotive power handling connections
- Electronic Communication Power Handling
- APU Power connections

**CHOOSING the PROPER RADSOK® CONTACT SIZE**

It is important to understand the pin diameter is the referenced RADSOK® terminal size. For example, a 6 mm RADSOK® terminal refers to 6 mm pin. When determining the proper RADSOK® terminal size to use, it is important to know the following parameters for the application:

- Steady state current flow requirements
- Expected ambient temperature
- Acceptable temperature rise
- Environment

The above four items are inter-related to each other. When an electric current flows through a terminal, there is a corresponding rise of temperature in the terminal. This is called Joule or $I^2R$ heating. As temperature increases, the contact will not be capable of carrying the same current flow. As ambient temperature increases, the capability of a contact to carry current that would be possible at a lower ambient temperature decreases. This can be referred to as contact derating.

Data has been collected on several RADSOK® terminal sizes. Some data, including current-temperature data that shows the temperature rise performance of each terminal size at a specified load is available. This stabilized temperature rise data is presented in graphical form in the APPENDIX and can be used as a tool to determine an appropriate RADSOK® terminal size.

When sizing a RADSOK® terminal for a particular application, it is important that the resulting terminal temperature be compatible with the working environment.

**TECHNICAL DESCRIPTION of the RADSOK® TERMINAL**

**RADSOK® Terminal Assembly and Manufacturing Process**

To understand the RADSOK® terminal principle, begin with the assembly and manufacturing process. The patented hyperboloid design of the RADSOK® makes it a unique socket and pin connector. Expensive hyperboloid terminals produced by araying wire in a radial configuration within the connector have been available for some time.

The RADSOK® terminal is uniquely different from older hyperboloid designs that require the wires to be assembled in place by some type of stitching process. These wires
are assembled in place on a form that wraps around the inserted pin (see Figure 1). The RADSOK® terminal was developed to achieve the favorable conductive and low insertion characteristics of the hyperboloid wire terminal designs at a lower cost utilizing state-of-the-art manufacturing systems.

The heart of the patented RADSOK® terminal is referred to as the "grid." The "grid" is produced in a progressive die and is manufactured from high strength yet highly conductive beryllium copper (BeCu). The ladder-like configuration of the grid can be seen in Figure 3.

The grid is then rolled into a cylinder. The finger-like extensions (see Figure 3) on one side of the grid are flared radially outward 90 degrees from the cylinder (see first image on left of figure 4). The formed grid is then inserted into a tube that is referred to as the inner barrel. This can be seen in figure 4, the second image. In the next step of the assembly process, the flared end of the assembly is pressed into a larger tube called the outer barrel. Parts for this operation can be seen in figure 4, depicted by the third and fourth images.

The grid fingers are now firmly secured on one end of the terminal. Next, the fingers on the opposite end of the terminal are flared in a similar fashion. In the next step the hyperbolic characteristic is introduced to the grid. While the twist on the grid is held, the other half of the outer barrel is pressed over the grid fingers, securing them and locking the grid twist in place. The sixth image in figure 4 shows the completed and patented RADSOK® terminal cartridge.

A new version of this design that replaces the 2 outer barrels with a single barrel has recently been patented and will soon be in production. This new design results in less part complexity and allows the assembly process to be streamlined and highly automated.

Hyperbolic Grid Twist of RADSOK® Terminal

Taking a closer look at the grid, a graphical approach will be used shown in Figure 5. Line A depicts a single grid element prior to grid twist. Line A’ is the skewed element that results when the twist is placed on the grid. The twist is stipulated by the rotational angle θ and is typically 45 degrees.

Further observation of figure 5 shows that A’ is slightly longer than A indicating that the grid elements of the terminal are in tension. The two-dimensional top view in figure 5 shows that the grid element forms a chord on the circle. If the element is ar-
rayed around the center of the circle and cylinder of the three-dimensional view, the hyperbolic profile takes shape as shown in figure 6. The waist or neck where the inner diameter of the cylinder is reduced can be clearly seen.

![Figure 6: Hyperbolic Profile](image)

The RADSOK® terminal is designed to have a slight clearance between the outer diameter of the pin and pre-twisted inner diameter of the socket. Referring back to figure 1, as the pin is inserted into the socket, the pin displaces the radial grid elements, placing additional tension on the connection.

![Figure 7: Grid Element Force Distribution](image)

**RADSOK® Terminal Principle**

Figure 7 shows the forces acting on a grid element after the RADSOK® terminal is formed into a hyperbolic grid. The force exerted on the pin is referred to as the normal force. This means that the force is perpendicular to, or normal, to the object. This force is the basis for good electrical conduction and therefore is critical to achieving low electrical resistance.

When two flat electrically conducting bodies are in contact with one another, the actual contact area is limited. Even surfaces polished with great precision will exhibit peaks and valleys under a microscope.

When two flat surfaces are in contact, only the peaks of these surfaces are actually touching. These areas of contact are referred to as asperities or “a” spots. As the normal forces between these surfaces increase, so will the cross sectional area of the a-spots. A depiction of this can be seen in Figure 8.

![Figure 8: Contact of Flat Surfaces](image)

These asperities are the actual contact interfaces between a pin and receptacle elements through which electrical current flows. The lines illustrate how electrical current flows through these asperities. Increasing the normal force increases the cross sectional area of the a-spots in the valleys which were not touching prior to the introduction of force, resulting in additional a-spots contacting. The additional contact decreases the millivolt drop of the terminal and reduces heat build-up.

Resistance in the terminal is also decreased by the additional asperities where resistance is the property that opposes electrical current flow. There are several
components of resistance associated with electrical terminals. The first is the material resistance comprising the terminal. This property is referred to as “bulk resistance” and is defined by Equation 1.

**Equation 1**

\[ R_B = \rho \frac{L}{\text{area}} \]

Where: \( \rho \) (rho) is the material resistance. Units are ohm-centimeters (\( \Omega \)-cm)

\( L \) = Length of the conducting material

\( \text{Area} \) = Cross-sectional area of conductor

Resistance is a material constant and is related to material conductivity (Equation 2).

**Equation 2**

\[ \rho = \frac{1}{\sigma} \]

Where: \( \sigma \) (sigma) is the conductivity of the material. Units are mho-cm or cm/ohm (cm/\( \Omega \)).

The resistance corresponding to the a-spots is referred to as the constriction resistance. This is so named because the a-spots constrict the flow of current between the contacting surfaces. According to Bowden and Tabor [1], constriction resistance is proportional to normal force and is shown below by Equation 3.

**Equation 3**

\[ R_c \propto \frac{1}{\sqrt{N}} \]

Where: \( N \) = Normal Force

With the RADSOK® terminal, the normal force can be altered by increasing or decreasing pin diameter. However, as noted below, the relationship between pin size and contact resistance should be carefully considered to assure that optimum performance is achieved. Additional effort required to insert the pin is directly proportional to normal force as shown by Equation 4. Equation four is derived from the forces depicted in the free-body-diagram in Figure 9.

**Equation 4**

\[ N = \frac{F}{\mu} \]

Where: \( N \) = Normal Force

\( F \) = Pin Insertion Force

\( \mu \) (mu) = Coefficient of Friction

Contact or constriction resistance is related to the applied normal force per Equation 3. After a certain point, increasing insertion force and corresponding normal force results in diminishing returns in decreasing the contact or constriction resistance.

Figure 10 shows that the optimum balance between insertion force and contact resistance for the 10.3 mm RADSOK® occurs around 45 degrees of grid rotational twist.

The third source of resistance is associated with films or oxides that may form on the surfaces between the mating surfaces. This is referred to as film resistance or \( R_F \). The wiping action of the RADSOK® terminal reduces these films during pin insertion/extraction. In addition to the self-cleaning action of the terminal, higher voltages typically associated with the use of the RADSOK® terminal puncture these films.
The total resistance associated with the RADSOK® Terminal is then:

$$R_T = R_B + R_C + R_F$$

Using materials with high electrical conductivities can minimize $R_B$. Typical values of electrical conductivities for several metals are listed in Table 1. The table is organized in decreasing order of conductivity, silver being the best electrical conductor.

<table>
<thead>
<tr>
<th>Material</th>
<th>Resistivity (ohm-meter)</th>
<th>Conductivity (mhos/meter)</th>
<th>Relative Conductivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silver</td>
<td>1.59E-08</td>
<td>6.30E+07</td>
<td>1.06</td>
</tr>
<tr>
<td>Copper</td>
<td>1.68E-08</td>
<td>5.96E+07</td>
<td>1.00</td>
</tr>
<tr>
<td>Gold</td>
<td>2.21E-08</td>
<td>4.52E+07</td>
<td>0.76</td>
</tr>
<tr>
<td>Aluminum</td>
<td>2.65E-08</td>
<td>3.77E+07</td>
<td>0.63</td>
</tr>
<tr>
<td>Beryllium Copper</td>
<td>3.45E-08</td>
<td>2.90E+07</td>
<td>0.49</td>
</tr>
<tr>
<td>Beryllium</td>
<td>3.56E-08</td>
<td>2.81E+07</td>
<td>0.47</td>
</tr>
<tr>
<td>Zinc</td>
<td>5.90E-08</td>
<td>1.69E+07</td>
<td>0.28</td>
</tr>
<tr>
<td>Brass</td>
<td>6.16E-08</td>
<td>1.62E+07</td>
<td>0.27</td>
</tr>
<tr>
<td>Nickel</td>
<td>6.93E-08</td>
<td>1.44E+07</td>
<td>0.24</td>
</tr>
<tr>
<td>Iron</td>
<td>9.61E-08</td>
<td>1.04E+07</td>
<td>0.17</td>
</tr>
<tr>
<td>Platinum</td>
<td>1.05E-07</td>
<td>9.52E+06</td>
<td>0.16</td>
</tr>
<tr>
<td>Palladium</td>
<td>1.05E-07</td>
<td>9.49E+06</td>
<td>0.16</td>
</tr>
<tr>
<td>Phosphor-Bronze</td>
<td>1.15E-07</td>
<td>8.70E+06</td>
<td>0.15</td>
</tr>
<tr>
<td>Tin</td>
<td>1.16E-07</td>
<td>8.62E+06</td>
<td>0.14</td>
</tr>
<tr>
<td>Lead</td>
<td>2.08E-07</td>
<td>4.81E+06</td>
<td>0.08</td>
</tr>
<tr>
<td>Beryllium Nickel</td>
<td>2.46E-07</td>
<td>4.07E+06</td>
<td>0.07</td>
</tr>
<tr>
<td>Stainless Steel (301)</td>
<td>7.14E-07</td>
<td>1.40E+06</td>
<td>0.02</td>
</tr>
</tbody>
</table>

All values based on room temperature (~20°C). The relative conductivity is based on copper.

**Table 1: Conductivity of Sample Metals**

**TERMINAL MATERIALS**

Materials for the RADSOK® terminal are chosen based on electrical, mechanical and thermal properties. Ideal materials would have the highest values for each of these parameters. With electrical terminals, a balance between these parameters must be maintained because a high value in one area can mean a low value for another parameter for the same material. For instance, a material with a desired high electrical conductivity typically has lower value for material strength.

To aid in identifying the components of the RADSOK®, Figure 11 shows a cut-away view of the terminal.

![Figure 11: RADSOK® Cross Section](cross-section-view-of-the-radsok-contact)

**TERMINAL GRID**

The grid of the RADSOK® Terminal is fabricated from a beryllium copper alloy. This alloy provides excellent tensile or flex modulus properties required to provide a high degree of contact normal force. Table 2 shows the properties of the beryllium copper used for the RADSOK® terminal.

<table>
<thead>
<tr>
<th>Property</th>
<th>C17410 1/2HT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal</td>
<td>135</td>
</tr>
<tr>
<td>Conductivity BTU/(ft•hr•F)</td>
<td>50% IACS</td>
</tr>
<tr>
<td>Electrical Conductivity, min.</td>
<td>80-100 ksi</td>
</tr>
<tr>
<td>Hardness</td>
<td>89-98 HRB</td>
</tr>
</tbody>
</table>

**Table 2: Beryllium Copper Mat'l Properties**

**Corrosion Resistance of Beryllium Copper.** Beryllium copper alloys are compatible with aqueous solutions of most alkali hydroxides, hot or cold, except for ammonium hydroxide that can cause stress cracking. The alloy also resists corrosion in cold, concentrated sulfuric acid and hot or cold diluted sulfuric acid. This alloy also exhibits a low rate of corrosion in salt-water environments.

Exposure to the above-described solutions forms a thin passive film on the surface of metal. This film will grow in the presence of water or oxygen. This film growth takes
place at the expense of the base metal that is dissolved through corrosion. Protection against corrosion can be accomplished through plating, which is discussed later.

**BARRELS**

The inner and outer barrels of the RAD-SOK® terminal are made from copper due to its' high electrical and thermal conductivity.

**HOLDERS**

Depending on the customer specifications and manufacturing process, the terminal holder is made from copper or copper alloy. If the holder is turned on a CNC lathe or Screw Machine, Tellurium copper is used because of its machining ability. Impact extrusions or stampings can benefit from copper’s ductility and therefore CDA110 or equivalent is typically used. Brass is commonly used in electrical terminals, which do not require a high level of conductivity, and 360 Brass is usually specified for RAD-SOK® components.

The RADSOK® cartridge is typically press-fit into the holder, which provides an electromechanical means of terminating the cartridge. This termination may be via a threaded fastener, a finger grip, or a wire barrel for crimping to wire. Copper is the best material with respect to electrical conductivity, however it is more expensive than other available materials such as brass and may not be required to achieve the design objectives of a given application. Copper is also the best choice for metallic holders that incorporate wire barrel crimps. Copper is more ductile and is more formable than brass that is harder and tends to crack.

**PLATING**

Plating involves depositing a layer of metal on the exterior surface of an object. Electrical terminals are generally plated to increase the terminal’s mechanical life, electrical properties and resistance to corrosion.

There are two methods of plating:

1. **Electroplating**
2. **Electro-less Plating**

Submersing an object in a chemical bath called electrolyte performs electroplating. The object to be plated is connected to an electrode in the bath. Another electrode composed of the plating metal is also submerged into the bath. Electrical current is passed through the bath, causing plating metal to deposit and adhere to the objects surface. The electroplating method leaves thicker deposits on sharp exterior edges. For instance, if a copper plate were electroplated with silver, the outer edges would have a thicker deposit with the middle of the surface receiving a thinner deposit. Typically, the ratio of thickness between edge deposits and center deposits is approximately 2 to 1. Care must be taken when plating blind holes. Electrical current flowing through the electrolyte will not flow easily into the hole resulting in a thinner deposit decreasing in thickness towards the bottom of the hole.

**Electro-less plating** is performed without an externally applied voltage to deposit metal. This method results in plating deposits being more evenly deposited onto irregular surfaces and into blind holes. Electro-less plating is normally a more expensive process than electroplating.

**PLATING THICKNESS**

Plating thickness should be sufficient to achieve the desired operational parameters of a product. Because all metals are porous to some degree, metal deposits should be thick enough to minimize the porosity of the plating deposit. When plating an electrical terminal, the projected mechanical wear (insertion/extraction) and the conductivity required in the terminal application should be considered when determining the plating material.
**PLATING MATERIALS**

Table 3 includes several metals used for electrodeposits with some of their properties listed in decreasing order of electrical properties.

<table>
<thead>
<tr>
<th>Electrodeposits</th>
<th>Electrical resistance (µΩ/cm)</th>
<th>Thermal Conductivity, %Ag</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silver (Ag)</td>
<td>1.59</td>
<td>100.0</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>1.692</td>
<td>91.8</td>
</tr>
<tr>
<td>Gold (Au)</td>
<td>2.44</td>
<td>70.0</td>
</tr>
<tr>
<td>Nickel (Ni)</td>
<td>7.8</td>
<td>14.2</td>
</tr>
<tr>
<td>Tin (Sn)</td>
<td>11.5</td>
<td>15.5</td>
</tr>
</tbody>
</table>

Table: Plating Metal Material Properties

Typically, and depending on the application and environment, RADSOK® terminals are plated with silver or tin. The plating uses and benefits follow.

**Silver** is a general purpose plating frequently used when the electrical terminals must carry high voltage with low conductive loss. It can be noted in Table 3, that silver provides the best electrical and thermal properties of all available plating metals. Silver forms a surface film of sulfide when exposed to a sulfide atmosphere, but is typically broken down when high currents are passed through. Surfaces can be protected from tarnish by applying a chromate coating, which has minimal effects on contact resistance.

**Tin** is a frequently used plating material for RADSOK® terminals when the connection is not subject to a considerable amount of mechanical cycling or vibration. Tin is vulnerable to a phenomenon called fretting corrosion. When exposed to air, tin rapidly oxidizes. Minute movement between contact surfaces can expose a plated surface to air. When tin plating is exposed to air, tin oxide forms. Tin oxide is brittle, and when more movement occurs, the oxide is fractured further exposing the plated surface to air. This process may repeat over time and can lead to plating failure. Application of lubrication to the contact surfaces can reduce the occurrence of fretting corrosion from occurring. Due to its high ductility, tin plating is a good choice for metal parts that will be bent or formed after plating. Tin plating can also be used to eliminate galvanic couples between dissimilar metals. Rapid plating deterioration will also occur if tin plated contacts are allowed to arc or if temperatures exceed 100°C.

**Nickel** can be deposited by electroplate and electro-less methods. Nickel is typically used as an under plate for precious metal deposits such as silver. Copper as a base metal tends to migrate through metals plated on its surface. Nickel provides a migration barrier to the copper. Electro-less nickel-phosphorous must be avoided as a plate metal due to its high resistance. As the phosphorus content of the plating solution increases, so does the electrical resistance. Electro-less nickel-boron is acceptable, however it is a more expensive material than nickel-phosphorous.

**HIGH TEMPERATURE EFFECTS on THE RADSOK® TERMINAL**

When copper and copper alloys are used as spring members, like the grid of the RADSOK® terminal, attention must be paid to a mechanical property known as stress relaxation. When spring copper, such as the beryllium copper of the RADSOK® terminal, is subjected to high temperatures due to environment, electrical heating or a combination of the two for extended periods of time, some stress relaxation may occur.

The inserted pin in the RADSOK® terminal imparts a spring like stress as it opens the grid. This stress is necessary for the RADSOK® to function properly. When high temperature is involved, over time, the spring elements may decrease or relax.
Stress relaxation is a function of temperature and time. The effect of high temperature exposure for extended time periods when the RADSOK® grid is stressed from pin insertion is additive. The result of the two factors can be predicted through the use of Larson-Miller parameters. This is a graphical approach shown in figure 12.

To determine stress relaxation resistance:

1. Choose accumulated exposure time on right-hand axis of the graph.
2. Draw a horizontal line from the time determined above to the appropriate temperature line (indicated on top of graph).
3. Draw a vertical line from the point determined in 2 to the stress relaxation curve.
4. From the point of intersection on the stress relaxation curve determined in 3, draw a horizontal line to the left-hand side of the scale and read the value of remaining stress.

It is recommended to keep the RADSOK® terminals extended heat exposure below 120°C (248°F) for maximum life. Some applications may involve higher operating temperatures. Given the temperature and the continuous time at that exposure, the remaining stress in the grid can be predicted using the Larson-Miller parameters. The remaining stress should be greater than 80 percent for the desired time-temperature exposure.

It is not recommended that RADSOK® terminals be soldered, welded or brazed to cable or other conducting bodies. If it is absolutely necessary, measures must be taken to keep the RADSOK® terminal as cool as possible to minimize stress relaxation.

This manual provides additional dimensions to aid manufacturing cartridge holders and pin specification development. For custom applications, KONNEKTECH offers a complete in-house terminal development and prototyping department. Applications requiring quick connect or disconnect with high current flow. The two basic types of terminal configurations are in-line and 90°. These configurations refer to how the axis of the pin and the cable are oriented.

**CRIMPING of RADSOK® TERMINALS**

Crimping of the RADSOK® terminal is an important element of the electrical connection. KONNEKTECH will provide a complete assembly to customers if required. For customers that desire to produce their own assemblies, crimping guidelines for RADSOK® terminals have been prepared.

**CABLE SELECTION**

Carefully select an appropriate electrical cable. The cable should be rated to carry the required current on a continuous basis at a specified resulting temperature based on the cable’s insulating material. The cable should be properly sized for the application and electrical contact being used. Some welding cable is manufactured with the insulating jacket material actually bonded to the conductor strands. This type
of cable is intended for other applications and should not be used with RADSOK® terminals. Cables with a 600 volt UL rating or better are recommended.

**Stripping of Cable**

First, cleanly and squarely cut the end of the cable being stripped. Next strip the Insulating jacket from the end of the wire, allowing for approximately a 2mm assembly clearance. Care should be taken to ensure the bundled copper strands comprising the conductor remain intact during the jacket stripping process. See Figure 13. Not more than 10% strand loss is usually permitted.

![Figure 13: Barrel Crimp Cross-Section](image)

**Cable Inspection**

After stripping, visually inspect the conductor for signs of contaminants. The stripped cable must be free from insulating material and have a shiny metallic appearance, free of oxides. Oxides on the conductor will increase the electrical resistance of the crimp, resulting in heat generation at the crimp.

**Terminal Crimping**

For optimum electrical performance, insert the stripped cable to the full depth of the wire barrel, taking care that all conductor strands are inserted. Make the crimp in the wire barrel area, close to the opening. The crimp length should be short of the wire barrel depth by about 2 millimeters. Crimping beyond this depth can result in a poorly crimped connection and may result in barrel cracking.

**NOTE:**

Soldering or Welding of the RADSOK® cartridge is not recommended! If soldering or welding cannot be avoided, care must be taken to keep the RADSOK® cartridge temperature as low as possible to avoid “spring (stress) relaxation” damage.

**Crimping Tools**

There are many types of crimp tools. Only use tools specifically designed to crimp electrical connectors. Tools used for crimping should also be appropriate for a given wire barrel size. Hand operated crimp tools are available from the following sources:

- Anderson Products Division of Square D
  P.O. Box 455
  Leeds, Alabama 35094
  Phone: (205) 699-2411
  Fax: (205) 699-7603

- Burndy Corporation
  U.S. Electrical Division
  Customer Service Department
  101 E. Industrial Park Drive
  Manchester, New Hampshire 03109
  Phone: (800) 346-4175

- Quick Cable Corporation
  2501 Eaton Lane
  Racine, Wisconsin 53404
  Phone: (414) 637-8363/(800) 558-8667
  Fax: (414) 637-8610

Model VC6-3 Versa-Crimp® hydraulic hand operated compression tool with type VCHTG Direct Reading Pressure Gauge by Anderson Products is currently being qualified for crimping RADSOK® terminals.

Hex crimps can be provided by KONNEKTECH on a variety of barrel crimps up to 2/0 cabling. KONNEKTECH can also develop tooling for customers who desire to crimp their own products.
APPENDIX

Dimensions of RADSOK® Cartridge and Pin

<table>
<thead>
<tr>
<th>SIZE (mm)</th>
<th>Diameter A</th>
<th>Pin Function Length</th>
<th>Diameter B</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.0</td>
<td>6.0 (0.236&quot;)</td>
<td>21.84 (0.860&quot;)</td>
<td>9.53 (0.375&quot;)</td>
<td>21.84 (0.860&quot;)</td>
</tr>
<tr>
<td>8.0</td>
<td>8.0 (0.315&quot;)</td>
<td>25.65 (1.010&quot;)</td>
<td>13.49 (0.531&quot;)</td>
<td>25.65 (1.010&quot;)</td>
</tr>
<tr>
<td>10.3</td>
<td>10.3 (0.406&quot;)</td>
<td>28.19 (1.110&quot;)</td>
<td>17.04 (0.670&quot;)</td>
<td>28.19 (1.110&quot;)</td>
</tr>
<tr>
<td>14.0</td>
<td>14.0 (0.551&quot;)</td>
<td>35.56 (1.400&quot;)</td>
<td>22.10 (0.870&quot;)</td>
<td>35.56 (1.400&quot;)</td>
</tr>
</tbody>
</table>

Notes:
1. The functional length does not include the male pin end radius.
2. Radius should be at least 1.0 mm.
3. The center ½ of the RADSOK® grid legs comprise the “functional length” of the cartridge.

Recommended RADSOK® Press-Fit Assembly Procedure

The following should be used as a guide for the purpose of assembling RADSOK® cartridges into connector bodies. The information contained herein provides recommended press-fit and terminal pin dimensions for optimum mating and electrical performance.

1. RADSOK® holder or sleeve should have a slight lead-in chamfer for ease of assembly.
2. Size of the cavity should have 0.025 to 0.076 mm (0.001 to 0.003") interference fit with respect to the outside diameter of the RADSOK® cartridge.
3. Use a square machine vice or arbor press for pressing RADSOK® cartridge into holder.
4. DO NOT use a hammer to install RADSOK® cartridge into holder.
5. Dimension “D”, the holder outer diameter, should be determined considering allowable temperature rise for desired electrical current and metal being used. The interference fit should be decreased within the 0.025 mm (0.001”) to 0.076 mm (0.003”) range as wall thickness increases.

6. The RADSOK® cartridge should be pressed far enough into the holder so that the center seam of the cartridge (see figure above) is buried by 3.0 mm if possible.

<table>
<thead>
<tr>
<th>RADSOK® Terminal</th>
<th>RADSOK® Holder Press Fit Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size, mm</td>
<td>Dimension C (±0.000/-0.001 in.)</td>
</tr>
<tr>
<td>6.0</td>
<td>9.50</td>
</tr>
<tr>
<td>8.0</td>
<td>13.44</td>
</tr>
<tr>
<td>10.3</td>
<td>16.99</td>
</tr>
<tr>
<td>14.0</td>
<td>17.42</td>
</tr>
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</table>
## RADSOK® Ampacity Chart

### SOLID BARE COPPER WIRES

<table>
<thead>
<tr>
<th>AWG</th>
<th>Diameter</th>
<th>Cross Sectional Area</th>
<th>Nominal Dia.</th>
<th>60°C (140°F)</th>
<th>75°C (167°F)</th>
<th>90°C (194°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>inches</td>
<td>mils</td>
<td>mm</td>
<td>in²</td>
<td>circ. mils</td>
<td>mm²</td>
</tr>
<tr>
<td>8</td>
<td>0.1285</td>
<td>128.5</td>
<td>3.264</td>
<td>0.013</td>
<td>16,510</td>
<td>8.37</td>
</tr>
<tr>
<td>7</td>
<td>0.1443</td>
<td>144.3</td>
<td>3.655</td>
<td>0.016</td>
<td>20,820</td>
<td>10.55</td>
</tr>
<tr>
<td>6</td>
<td>0.1620</td>
<td>162.0</td>
<td>4.115</td>
<td>0.021</td>
<td>26,240</td>
<td>13.30</td>
</tr>
<tr>
<td>5</td>
<td>0.1819</td>
<td>181.9</td>
<td>4.620</td>
<td>0.026</td>
<td>33,090</td>
<td>16.77</td>
</tr>
</tbody>
</table>

### STRANDED FLEX CABLE (Class M)

<table>
<thead>
<tr>
<th>AWG</th>
<th>Diameter</th>
<th>Cross Sectional Area</th>
<th>Nominal Dia.</th>
<th>60°C (140°F)</th>
<th>75°C (167°F)</th>
<th>90°C (194°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>inches</td>
<td>mils</td>
<td>mm</td>
<td>in²</td>
<td>circ. mils</td>
<td>mm²</td>
</tr>
<tr>
<td>4</td>
<td>0.2043</td>
<td>204.3</td>
<td>5.189</td>
<td>0.033</td>
<td>41,740</td>
<td>21.15</td>
</tr>
<tr>
<td>3</td>
<td>0.2294</td>
<td>229.4</td>
<td>5.827</td>
<td>0.041</td>
<td>52,620</td>
<td>26.67</td>
</tr>
<tr>
<td>2</td>
<td>0.2576</td>
<td>257.6</td>
<td>6.543</td>
<td>0.052</td>
<td>66,360</td>
<td>33.62</td>
</tr>
<tr>
<td>1</td>
<td>0.2893</td>
<td>289.3</td>
<td>7.348</td>
<td>0.066</td>
<td>83,690</td>
<td>42.41</td>
</tr>
</tbody>
</table>

### 3.6mm RADSOK® (10.2 mm²)

- Smaller wire sizes are also compatible with the 3.6mm RADSOK®.

### 6.0mm RADSOK® (28.3 mm²)

- The 3.6mm RADSOK® may also be used with #7 or #6 depending upon the application.

### 8.0mm RADSOK® (50.3 mm²)

- The 6.0mm RADSOK® may also be used with #4 or #3 depending upon the application.

### 10.3mm RADSOK® (83.3 mm²)

- The 8.0mm RADSOK® may also be used with 1/0 depending upon the application.

### 14.0mm RADSOK® (154 mm²)

- The 10.3mm RADSOK® may also be used with 4/0 depending upon the application.

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*SINGLE INSULATED CONDUCTORS IN FREE AIR - AMBIENT TEMPERATURE OF 30°C (85°F)*
**RADSOK® PERFORMANCE DATA**

Temperature Rise of 14.0 mm RADSOK® Terminal in Free Air

Terminals attached to #4/0 AWG Cable
Ambient Temperature: 25°C

**INSERTION FORCE WITH & WITHOUT LUBRICATION**

Effect of Lubrication - 10.3mm w/ Ag Plating

- Force w/Lube
- Force w/o lube

Insertion Cycle #
TEMPERATURE RISE DATA - CURRENT OVER TIME

10.3mm RADSOK® Data in BLUE 450A
8.0mm RADSOK® Data in GREEN 375A
6.0mm RADSOK® Data in RED 300A

Degrees (Celsius)

Time (minutes)
TEMPERATURE RISE DATA - RADSOK® vs. Split Pin Terminal

Optimum 6.0 mm RADSOK Configuration
ANOVA - Combined Outputs
10.3mm Sn Plated RADSOK

- Mating Cycles: 21%
- Error: 4%
- PIN Finish: 24%
- Pin Diameter: 8%
- Grid Twist: 43%

Histogram - Twist Control w/o Plating

Microvolt Drop/Amp vs. Insertion Force - Initial

10.3mm, Tin Plated RADSOK with Tin Plated Pin, Measured Across 9' 2/0 cable + crimp + RADSOK + crimp + 9' 2/0 cable