The Wire

dataCon
The Wire Wrappers.

The Conductor.

Nearly any solid conductor will make satisfactory connections. Stranded wire can also be wrapped but it must be soldered for permanency.

Most Commonly Used Conductor Materials.

OFHC (Oxygen Free High Conductivity) copper is the most widely used conductor material; however, tough pitch copper, certain copper alloys and copper coated steel core conductor are also used.

Wire Finishes.

Silver plating and tin plating are the most common finishes used. Silver plated wire is more frequently used for automatic machine wrapping applications.

There is no evidence that indicates that a wire wrapped connection is better as a result of either tinning or plating the conductor. Many people specify tinning or plating on their wire so they can use the same wire for soldering as well as wire wrapping.

Preferred Conductors for Automatic Wiring Machines.

Silver plated OFHC copper conductor has certain characteristics that make it easier to use in the automatic machine. It forms a better pattern and lays in the channels formed by the rows of pins because it has less memory than the high tensile conductors. Higher run rates are usually obtained using OFHC copper conductor which in turn means lower wiring cost to the customer.

Wire Insulation Materials.

"Kynar", "Milene B", TFE "Teflon", and "Kapton" (H film) are the most widely used insulations.

We estimate that 90% of the wire used today for wrapping is "Kynar" insulated but each of the above mentioned materials has certain characteristics which may make it more appealing to use on some applications than others. The table below shows a comparison of the properties of the most commonly used wires:

Using Colored Insulations for Various Codes.

Different colored insulations within a level can be wrapped rather easily manually or with semi-automatic machines, however, it is difficult and costly to specify different color insulations within a level (layer) of wiring done on the automatic machine. Some customers specify that each level be a different color which can be done rather easily; however, there is very little benefit derived from this due to the uniformity of wiring that is achieved by the automatic machine.

Commonly Used Wire Sizes.

There are certain wire size, terminal size and terminal spacing combinations and limitations with each of the aforementioned methods which are described in the section on hardware. However, the following list shows the wire sizes that are within the capabilities of each method:

AUTOMATIC WIRING MACHINES	26-30 Gauge
SEMI-AUTOMATIC MACHINES	20-34 Gauge
MANUAL WRAPPING	20-34 Gauge

Wire Properties for Automatic Wrapping.

There are certain physical properties that are critical to automatic wrapping. They are:

1. Insulation diameter.
2. Insulation concentricity.
3. Insulation bond strength.
4. Insulation surface finish.
5. Insulation elongation.
6. Insulation cut through.
7. Minimum curl.
8. Continuous length.
9. Conductor elongation.
10. Conductor tensile strength.

Wrapping "Twisted Pair".

We can wrap twisted pair with our semi-automatic machines or manually. The automatic machine cannot handle twisted pair.

NOTE: Additional information on any specific wire type may be obtained by contacting us.

COMPARISON — 30 GAUGE WIRE

PROPERTY	KYNAR	KAPTON	MILENE	MILON	TEFZEL
Cond. Elongation	20% Min 30% Max	25% Min	6% Min	15% Min	25% Min
Cond. Tensile Strength	50,000 PSI Min	50,000 PSI Min	55,000 PSI Min	30,000 PSI Min	38,500 PSI Min
Ins. Tensile Strength	5000 lbs PSI Min	25,000 PSI Min	12,000 PSI Min	30,000 PSI Min	6500 PSI Min
Bond Strength	½ lb. Min 1½ lb. Max	½ lb. Min 1½ lb. Max	½ lb. Min 2½ lb. Max	¼ lb. Min 2½ lb. Max	½ lb. Min 2½ lb. Max
Operating Temp	105° Max	200° C	105° Max	105° Max	105° Max
Voltage Rating	300V RMS	N/A	500V RMS	500V RMS	500V RMS
Ins. Elongation	250% Min	75% Min	35% Min	30% Min	100% Min
Dielectric Constant	7.7 Max @/MHZ	2.4 Max @/MHZ	4.0 Max @/MHZ	2.6 Max @/MHZ	2.70 Max @/MHZ
Ins. Resistance (1000' @ 25°)	103.2 Max	100,000 MEG	2500 MEG Min	2500 MEG Min	1000 MEG Min
Cut - Thru	850 grams 1 Min @500V	2000 grams 1 Min @115V	1200 grams 1 Min @12V	750 grams 1 Min @12V	800 grams 1 Min @500V

The Terminal

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The Wire Wrappers.

Preferred Materials for Terminals.

Common materials used are beryllium copper, phosphor bronze, half-hard brass, copper-nickel, and nickel-silver alloys. Usually the configuration of the end opposite the wrap portion of the terminal dictates the type of material required. As an example, terminals that have a direct entry, such as the "tuning fork" concept, are usually phosphor bronze due to the spring requirement of the "tuning fork" portion of the terminal.

Plating Unnecessary.

There is no evidence that indicates that the connection is better as a result of tinning or plating of either the wire or terminal with the exception that certain combinations of plating materials have increased the rate of solid state diffusion of metals which is part of the solderless wrapping process.

Finishes Commonly Applied to Terminals.

Commonly used finishes are gold (TYPE I per Mil-G-45204), tin, tin-lead alloys and nickel. Gold plating is used for increased contact reliability where the opposite end of the terminal is a plug-in type contact.

Certain finishes, particularly hard gold plate, tend to lower the strip force (force required to move the connection on the terminal) of the connection. Special care should be used when using gold finish on one piece design terminals. Usually this type of terminal is heat treated to give it the necessary spring characteristic at the contact end. This, of course, also hardens the portion of the terminal that will be wrapped. The use of gold on this type terminal sometimes makes it difficult to meet even the minimum strip force requirements.

Length of Terminals for Wire Wrapping.

It is advisable to specify a terminal that has an adequate "wrappable terminal length" to allow for three connections even though the circuitry is designed to have no more than two connections per terminal. This permits the addition of wires on the third position (Z level 3) of the terminal in the event of engineering changes or field modification. The following table gives the recommended wrappable terminal lengths for three connections per terminal:

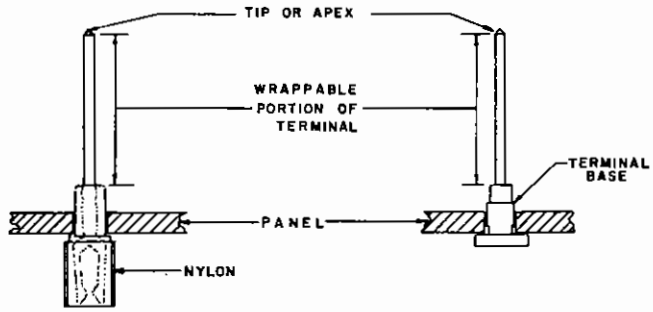
WIRE GAUGE	MAX. WRAPPABLE TERMINAL LENGTH (3 LEVELS)	MIN. WRAPPABLE TERMINAL LENGTH (3 LEVELS)
24 ga. & 26 ga.	.875"	.750"
28 ga.	.750"	.625"
30 ga.	.625"	.475"

Terminals longer than the maximums shown in the preceding table causes two problems:

1. The wrapping bits are designed so that the terminal hole in the bit will accept only terminals up to the maximum lengths shown above. If longer terminals are used, the first level connection cannot be placed near the surface of the board.
2. If the panel having the longer pins in it is to be automatic machine wrapped it is more difficult for the hardware manufacturer to maintain the pin straightness necessary for machine wrapping.

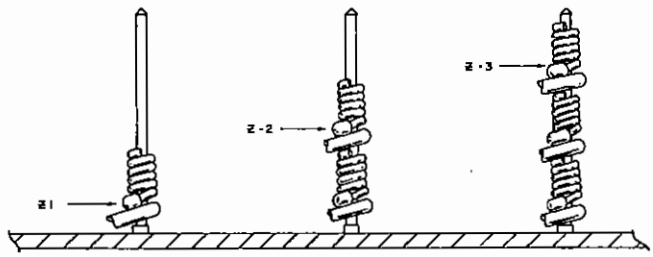
Defining the Term "Wrappable Terminal Length."

"Wrappable Terminal Length" is the portion of the terminal which is suitable for making connections. In other words, the wrap cannot extend on the tip or apex of the terminal or the base of the terminal which does not meet the terminal requirements. See examples below:



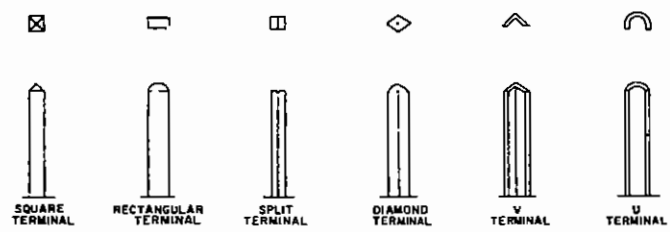
Defining the Term "Z Level."

The term "Z Level" refers to the position of the connection on the terminal with respect to the surface of the panel. The Z-1 Level is the connections closest to the surface of the panel. Z-2 is directly above the Z-1 position and Z-3 is directly above the Z-2 position. Reference to following illustration:



Kinds of Terminal Configurations that Can Be Wrapped.

Any terminal which has two or more contacting edges crosswise to the axis of the wrapped wire is satisfactory for a wrap. Types of terminals in everyday use include square, rectangular, embossed, serrated, V-type, U-type, diamond and split terminals. Examples of these configurations are as follows:

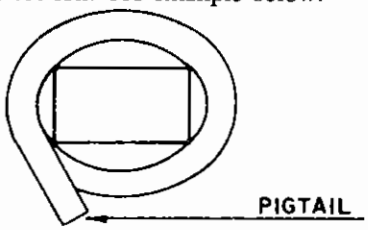


Preferred Terminal Configurations.

Square terminals have some advantages over other types. Although the advantages are not always significant when making wire wrapped connections with hand tools, they become of major importance with the use of semi-automatic and automatic wrapping machines. Some of these advantages are as follows:

1. The natural wrapping motion of a wire on a square terminal is in a circular pattern. A rectangular cross-section terminal, particularly one with a large width-to-thickness ratio results in an elliptical wrap with constant variation of radius.

2. A rectangular cross section, which causes an elliptical pattern results in the possibility of the tip of the wire being wrapped to project beyond the connection circumference. This condition is referred to as a "pigtail" and is less likely to occur with the circular wrap pattern around a square cross-section. See example below:



3. A square cross-section has a more uniform section modulus in all directions. This is useful in initially positioning the terminal relative to its "true position" and also tends to make the terminal more rigid during the wrapping operation.
4. The square terminal has far less tendency to twist about it's axis than does the rectangular cross-section.
5. The square terminal lends itself to a symmetrically pointed tip for lead-in to the wrapping bits.
6. The strip force values obtained on square terminals is usually more consistent than those obtained from rectangular terminals or similar cross-section.

"Rule of Thumb" for Determining the Terminal Size.

Terminals must be of sufficient strength to withstand the torsion of wrapping the wire. As a general rule, the terminal thickness should not be less than one conductor diameter and the terminal width should not be more than double the terminal thickness. The list below gives the most commonly used square and rectangular terminal sizes:

SQUARE TERMINALS
- .045 Sq.
- .025 Sq. (.0340 ± .0015 diagonal)

RECTANGULAR TERMINALS
- .035 x .050
- .031 x .062
- .023 x .050
- .020 x .030 (.0340 ± .0015 diagonal)

It should also be kept in mind that the selection of a terminal size that is unique to the industry may require special wrapping bits for the wrapping. Special bits are long lead time items which may affect your production schedule.

Other Requirements that a Terminal Should Meet.

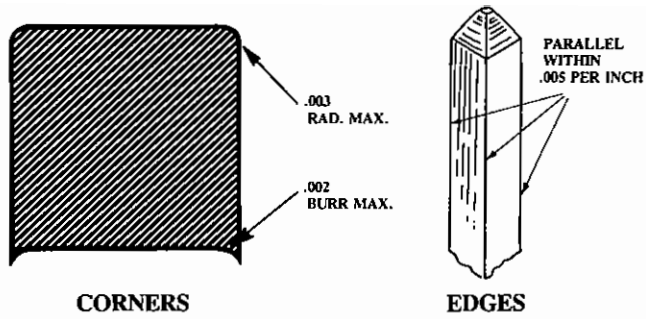
There are requirements for terminal corners, terminal edges, tip configurations, terminal retention and terminal replaceability.

Terminal Corners

The corner radii of the terminal should not exceed .003". Maximum edge burrs should not exceed .002".

Terminal Edges

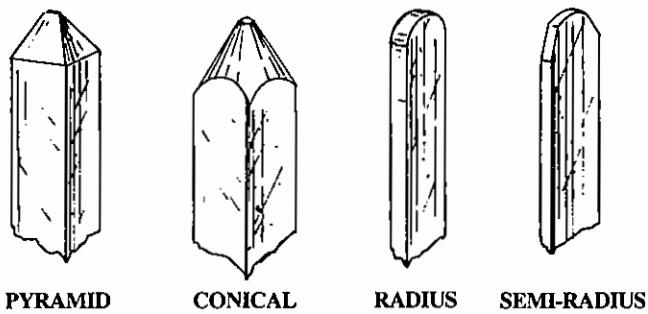
The Terminal Edges must be parallel within .005" per inch.



Tip Configuration

A taper or lead-in should be provided on the terminal tip. The purpose of this taper is to assist in getting the terminal into the terminal hole of the wrapping bit. The maximum tip flat for terminals used in machine wrapping 26 gauge and larger wire is .015" x .015". For 30 gauge machine wrapping, the tip flat must not exceed .010" x .010".

Common tip configurations are shown below:



Terminal Retention

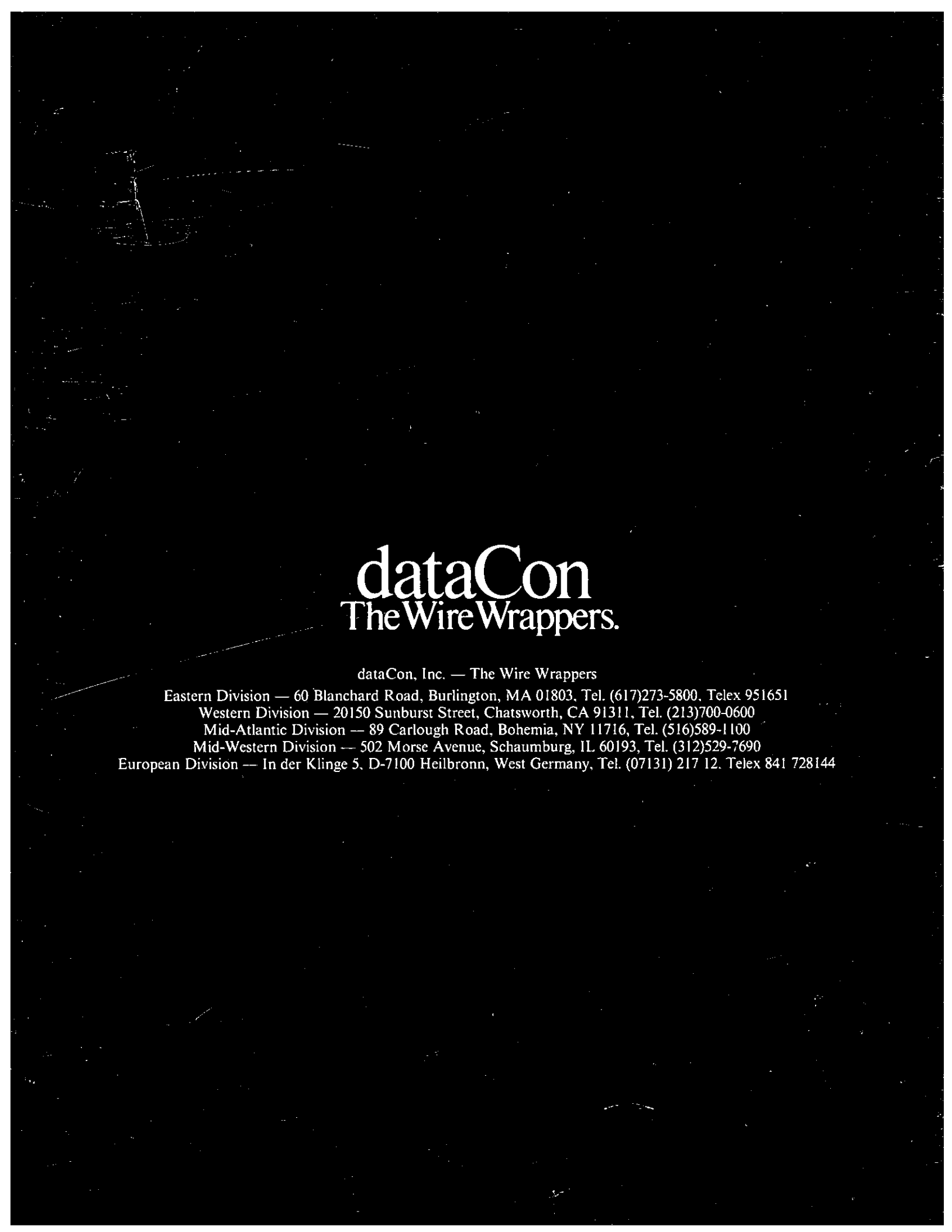
When the wire wrapping operation is performed by an automatic wrapping machine, it is essential that the terminals meet minimum retention force. The wrapping tools are placed over the pins automatically and if a pin is not straight (within the location tolerances for automatic wrapping), the force of the tool coming down on the pin (even though it's minimal) may unseat it. The following rules apply to all automatic machine wrapped terminals:

Terminals for 26 ga. wrapping and larger should be capable of withstanding an axial force of 15 pounds.

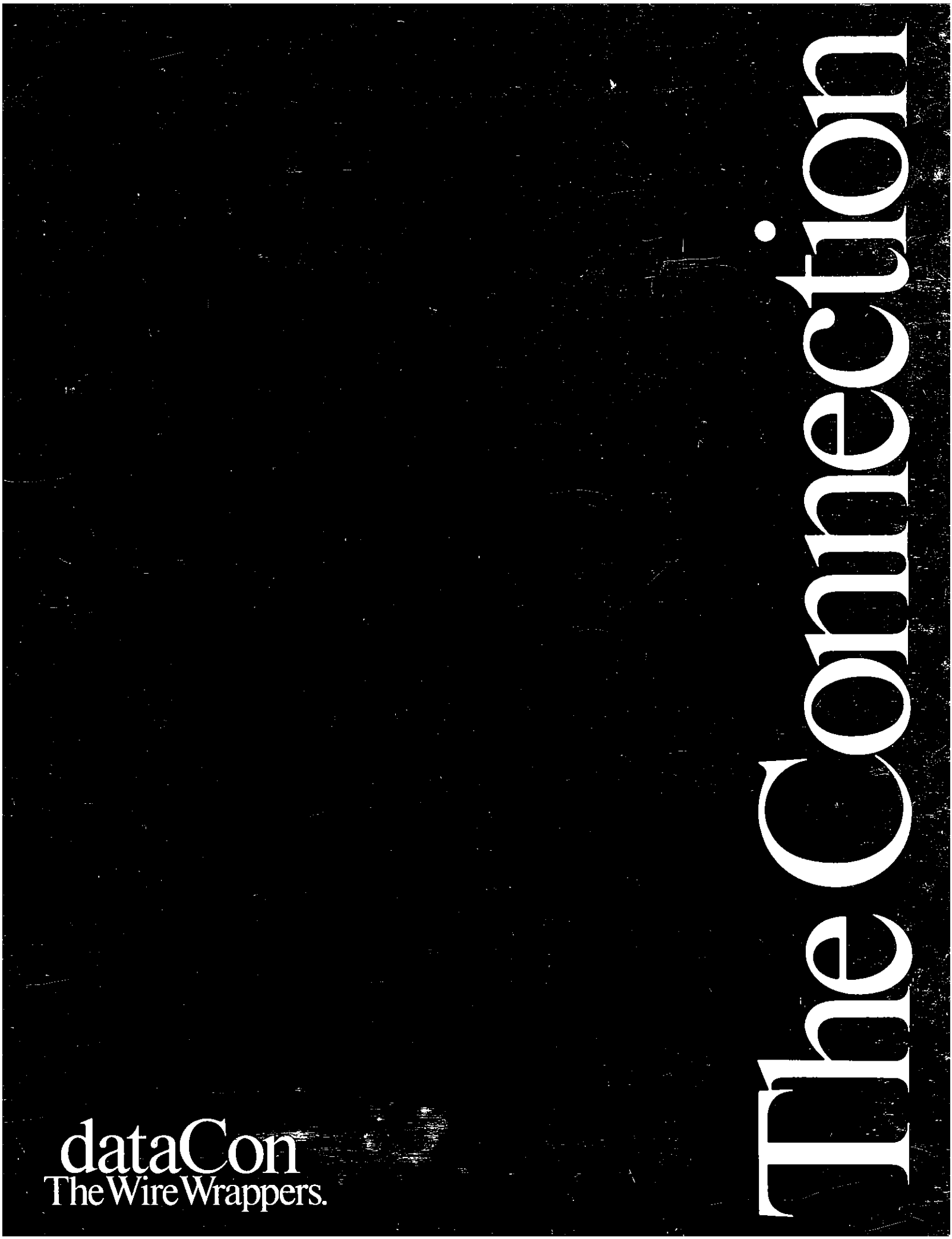
Terminals for 30 ga. wrapping should be capable of withstanding an axial force of 7 pounds.

Terminal Replacement

Occasionally a terminal may be broken off prior to or during the wrapping process, during a wiring change, during systems test or field repair modifications. Therefore, it is advisable to select a terminal that is individually replaceable. This eliminates the need to replace an entire connector which could have as many as a hundred wires on it which would have to be removed and replaced making the replacement a costly and time consuming operation.



dataCon, Inc. — The Wire Wrappers
Eastern Division — 60 Blanchard Road, Burlington, MA 01803, Tel. (617)273-5800, Telex 951651
Western Division — 20150 Sunburst Street, Chatsworth, CA 91311, Tel. (213)700-0600
Mid-Atlantic Division — 89 Carlough Road, Bohemia, NY 11716, Tel. (516)589-1100
Mid-Western Division — 502 Morse Avenue, Schaumburg, IL 60193, Tel. (312)529-7690
European Division — In der Klinge 5, D-7100 Heilbronn, West Germany, Tel. (07131) 217 12, Telex 841 728144


The Connection
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The Wire Wrappers.

A wire wrapped connection is a permanent gas tight electrical connection. It consists of a helix of continuous solid uninsulated wire tightly wrapped around a suitable terminal. It is considered a "pressure connection".

The wrapping bit wraps the wire around the terminal with pressures which may go as high as 100,000 P.S.I. at the center of the contact area. This high pressure causes indentation of wire and terminal. Cold flow of the conductor causes this pressure to drop to approximately 30,000 P.S.I. where pressure stabilizes and remains constant.

Wire wrapped connections meet all the requirements of a good electrical connection. The following table shows a comparison of these requirements to some other common pressure connections:

CHARACTERISTIC	FAHNESTOCK CLIP	TAPER PIN	CRIMP	WIRE NUT	SCREW	WIRE WRAP
A Large Contact Area			X	X	X	X
B High Contact Force			X	X	X	X
C Long Life			X	X	X	X
D Small Size		X	X			X
E Mechanically Stable			X		X	X
F Easily Disconnected	X	X		X	X	X
G Low Cost						X

The "Standard" Wrap and the "Modified" Wrap

A *"Standard Wrap"* is a wrapped connection that has only the prescribed number of turns of bare wire wrapped around the terminal. A *"Modified Wrap"* is a wrapped connection that has not only the prescribed number of bare wire turns; but also has a minimum of one-half turn of insulation wrapped around the terminal. A "Modified Wrap" made with solid wire will withstand more vibration then welded or soldered stranded wire of equal size (*).

(*) Ref. to Bell Labs. MM-54-2332-8 dated 3 November 1964.

Wire Wrapped Connections Widely Accepted.

To the best of our knowledge, the Underwriters' Laboratories have not refused the use of wire wrapped connections on any manufacturer's product submitted to Underwriters' Laboratories for approval.

The wire wrapped connection has been approved by various branches of the government and military services. Mil Standard 1130 has been issued to cover the wire wrapped connection for use by the military services. In addition, the Navy has it's own specification (WS 6119) which is also commonly used. Many companies involved in military projects such as Sentinel, Polaris, Poseidon, Apollo, Sam D, Minute Man, Comlog Net, Bemews and Hawk have been given approval to incorporate wire wrapped connections into their equipment.

The EIA (Electronic Industries Association) has issued Standard RS-280 covering the wire wrapping process. Copies can be obtained from:

Electronic Industries Associates
Engineering Department
11 West 42nd. Street
New York 26, New York

Wire Wrapped Connections Extensively Tested

The connection holds up extremely well when exposed to conditions of high temperature, corrosive atmosphere and high humidity. The wire wrapped connection was subjected to extensive tests by Bell Telephone Laboratory to assure that the connection would have a forty year life expectancy. In these tests which include thermal shock, corrosive atmospheres and high humidity, together with plucking the connection at intervals, it was found that there was no appreciable increase in the amount of resistance in the connection. The high pressure contact between wire and terminal form a permanent gas tight connection and excludes any possibility of damage to the connection through exposure to corrosive atmospheres.

U.S. Naval Avionics Facility at Indianapolis (NAFI) has done extensive testing and has concluded that the connection is *virtually indestructable*. A copy of this report (TR-1242) may be obtained by writing:

Administrator
Defense Document Center for Scientific
and Technical Information CDDC
Building No. 5, Cameron Station
Alexandria, Virginia 22314

There is no need to be concerned about corrosion due to electrolysis between wire and terminal. In general, the material used for terminals and the material used for the conductor are very close together in the electromotive series; and, therefore, there is only a very slight amount of electrolysis which can take place. Any electrolysis which does take place is not at the contact areas since the pressure there is so high that the corrosive atmosphere cannot penetrate.

Reliability: Wire Wrapped Connections vs. Soldered Connections.

The failure rate of the wire wrapped connection is considered to be one-tenth of that of the best solder connection. The projected failure rate for wire wrapped connections established for several of the military projects is one in a hundred thousand connections. This compares with one in ten thousand connections for a solder connection. Another company expressed the failure rate of a solder connection to be .0008%/1000 hours operation.

The wire wrapped connection is considered to have a failure rate of .000037%/1000 hours. In spite of this predicted failure rate and with better than 100 billion connections in the field today, we have never had a reported failure of a solderless wrapped connection. *YOU CAN'T DEVELOP AN ACTUAL FAILURE RATE UNTIL YOU GET A FAILURE!*

Quality: Easy to Check.

The quality of an individual connection is a function of the condition of the bit, wire and terminal being used. A periodic check of the stripping forces on a sample number of connections made by each wrapping bit used in production will satisfy the Quality Control Department as to the capabilities of an individual bit to continue to make good connections. In addition to the strip force test, a number of sample connections are given the unwrap test to ensure that the radius of the wrapping bit is not producing too great a tension of the wire.

Easy to Service.

The connections can be unwrapped with an unwrap tool or a pair of needlenose pliers. If the same portion of wire which was wrapped around the terminal is to be reused, it must be soldered when replaced. If the wire is of sufficient length, a new portion of wire can be stripped and wire wrapped on the terminal. Inexpensive manual wrapping tools are available for field service personnel.

Minimum Wire Turns.

The following table shows the minimum number of conductor turns used on most applications. Certain special applications use fewer turns than shown in the following table:

WIRE GAUGE	MIN. NUMBER OF CONDUCTOR TURNS
18 Ga.	4
20 & 22 Ga.	5
24 & 26 Ga.	6
28 & 30 Ga.	7
32 Ga.	8

14FV Automatic Machine Wire Sizes.

We can wrap 26 ga., and 30 ga. wire using the 14 FV Gardner Denver Automatic Wire Wrap Machines. The following table shows the proper wire size, terminal size and terminal grid combinations for automatic wrapping:

WIRE SIZE	TERMINAL SIZE	TERMINAL GRID
26 Ga.	.045 Sq. .035 x .050 .031 x .062 .023 x .050	.200 Sq. .250 Sq. .250 Stag
30 Ga.	.025 Sq. .020 x .030	.150 Sq. .125 Sq. .100 Sq. .150 Stag .100 Stag

We also have the capability of wrapping all other applications such as .156 terminal spacings or applications where a unique wire size and terminal grid is used or where multi-wire sizes within a panel configuration are required with our semi-automatic wrapping equipment.

Twisted pair or twisted triplets can not be wrapped with the automatic machine but can be with our semi-automatic stations. Stranded wire also can be wrapped using semi-automatic or manual tools but it must be soldered after wrapping.

Although it is not possible to make a solderless wrapped connection using a round terminal, it is practical in some cases to use a tool for connecting wires or resistors to round or pin type terminals, then solder the connection for permanency. This is referred to as a wrap-solder connection.