equipment memorandum

SOLDERLESS WRAPPED CONNECTIONS

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Figure 1. The Wire-Wrap tool.

AUTOMATIC ELECTRIC
Subsidiary of
GENERAL TELEPHONE & ELECTRONICS

1. INTRODUCTION

The operation of connecting wires to metal terminals in a central office is numerous and probably uncountable. Many connections are made at the factory and during installation of new equipment. But a substantial number are made during normal operation of a telephone exchange. Success in telephone operation depends on the performance of these connections.

In the past few years developments have been made in solderless wrap tooling and methods. The connection made by a solderless Wire-Wrap tool is fully equal to and in many ways superior to the wide spread conventional method of soldering terminal connections. It is the purpose of this Equipment Memorandum to examine, describe and evaluate the solderless wrap method of making electrical connections. It will attempt to show the operating telephone company how to use the equipment in making connections and why the change to solderless wrap has been made.

1.1 Solderless Wrap Development

The past 30 years have seen great progress in the design and manufacture of electrical devices. In the telephone industry strides have been made to increase service both by way of speed and availability. But even with this progress, little change has been made in the basic method of connecting wires to terminals. Hand wrapping and soldering of connections continue in general use. In cases where a connection had been power wrapped, the necessity for soldering remained. Past attempts at power wrapping did not eliminate the need of soldering for permanency.

The miniaturization of equipment, however, brought out the need for a solderless connection. This need was met with the Wire-Wrap tool (figure 1). After World War II developments in the design and tooling of the solderless wrap method made it possible to make solderless electrical connections. The need for hand wrapped and soldered connections is being eliminated. As born out by tests at Automatic Electric Company and Bell laboratories, the new tool design provides reliability of connections and speed of assembly.

1.2 What is Solderless Wrap?

As discussed briefly above, solderless wrap is a method of connecting a wire to a terminal without the use of solder. It consists of wire wrapped around a terminal to meet the requirements of a permanent electrical and mechanical connection under adverse conditions.

A solderless wrapped connection is accomplished by tools designed for ease and simplicity. As shown in figure 2, the connection is established by inserting a skinned wire into the wrapping bit. The wire is then anchored. The tool bit is then placed over the terminal and the tool trigger squeezed. The rotating wrapping bit winds the wire around the terminal to produce a permanent solderless connection. Detailed information on the capabilities of this method of wire termination and the exact method of procedure will be explained in a later section. It is introduced here to show the ease of connecting the wire to a metal terminal.

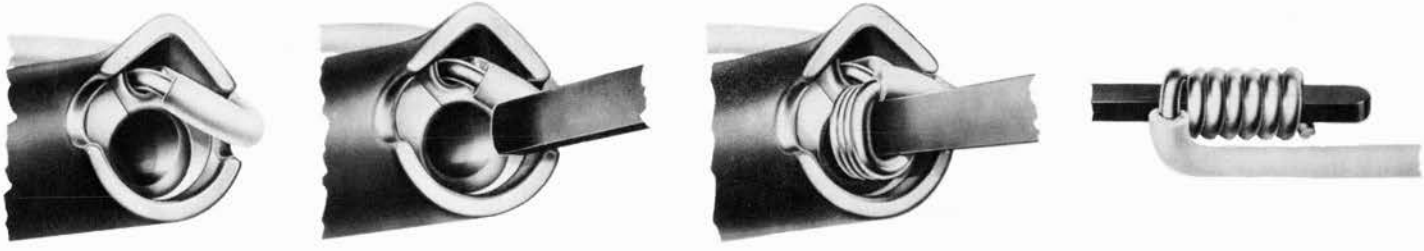


Figure 2. The procedure and method of making solderless wrapped connections.

1.3 What Solderless Wrap Accomplishes

Over the years the conventional solder connection has proved to be reliable. But this reliability has been attained at a cost. Solder connections are bulky. They may not be uniform throughout the equipment and they are comparatively slow to produce.

Solderless wrapped connections, on the other hand, require little space, achieve uniform connections, are faster and safer to make, and eliminate undesirable solder characteristics (splashes, heat, and clippings). Thus, with the new progress in tooling and design, connections as strong and free from electrical resistance as the best solder connection, have given reliability to solderless wrapped connections. Coupled with the accepted "time-space-labor" advantages, reliability equal to the solder connection has made solderless wrap both feasible and practical in the operating telephone enterprise.

1.4 Solderless Wrap Applications

Automatic Electric Company has studied solderless wrap for several years and has developed suitable terminal and wire specifications for use with various telephone equipment. Equipment under test has shown excellent results; and where applicable, the solderless wrap method will be expanded and the amount of equipment manufactured in this manner will be intensified.

2. TECHNICAL DESCRIPTION

This section will cover what makes a good connection in the telephone office and then will compare the solderless wrapped connection with the technically adequate connection.

Two methods are generally available for joining wires to terminals. They are the solder and pressure connection. Such pressure connections as the screw, plug, crimp, and wire nut lack the features of minimum size, contact area, cost, or ease of disconnection necessary for use with small gage wire in modern telephone equipment. Among the pressure connections, the solderless wrapped connection does meet the necessary requirements for use as a connection method. How the solderless wrapped connection meets these requirements will be covered in this section and other sections of this Equipment Memorandum.

When examining the solderless wrap method, a definition of a GOOD connection is needed first. Basically, the quality of a connection depends upon two factors: the contact area and contact pressure. As long as there is sufficient pressure and the atmosphere cannot enter the joint, the connection is considered good. If, however, the elastic energy which holds the two surfaces together is small, disturbances may cause a partial separation of the interlocking metal particles and thus effect a change in resistance. (Elastic energy essentially means ability of the wire and terminal to remain tightly wound over a long period of time.)

Any good connection, then, is one which not only has sufficient contact area and contact pressure, but also has sufficient elastic energy to maintain contact area and contact pressure throughout the desired life of the connection.

From these basic conditions of area, pressure and elasticity for a pressure connection, six technical requirements can be noted to determine just what is a good connection. A good connection must fulfill the following requirements in order to meet the specifications of telephone operating companies. The six requirements are:

(a) Metal-to-metal contact.

(b) High pressure contact.

(c) Gastight contact areas.

(d) Large contact areas.

(e) Mechanical stability.

(f) No localized stress concentrations.

2.1 Metal-to-metal Contact

This is a fundamental requirement for a good connection. If when the connection is made, the oxidation is not removed from the wire and terminal, variations in the

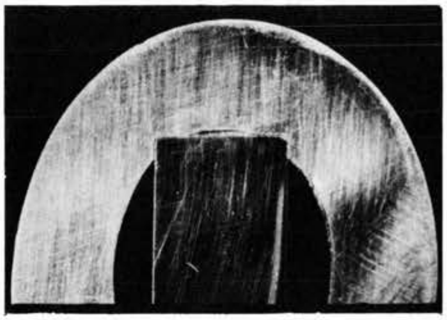


Figure 3. Cross section of wire and terminal showing metal-to-metal contact.

resistance will occur. A film that exists between the metals of the terminal and wire can produce noise in the telephone circuit. The less metal-to-metal contact, the more resistance and noise. Thus, a solderless wrapped connection must have characteristics that insure that all contact areas are metal-to-metal.

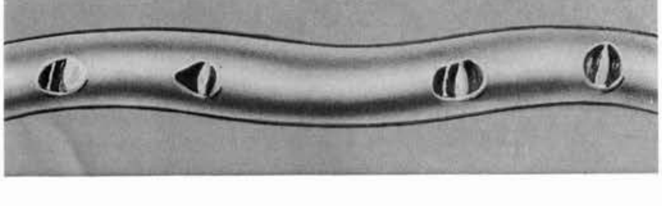
An examination of the solderless wrapped connection shows that because of the high tension exerted by the tool bit, there is a high shearing force at each of the four corners of the terminal when the wire is wrapped on. The shearing force scrapes off the surface films from both wire and terminal and gives a clean, bare, metal-to-metal contact. The equalized pressure of the tool and bit, no matter who the operator, insures that sufficient pressure is exerted on the wire and terminal to produce the shearing effect needed for metal-to-metal contact. Figure 3 shows a cross section through wire and terminal, and indicates intimate metal-to-metal contact.

2.2 High Pressure Contact

A high pressure contact maintained through time is essential for telephone terminal connections. If high pressure cannot be attained or maintained, the connection is clearly defective and not suitable for use. The maintenance of the high pressure connection is important. Mechanical disturbances, such as handling, vibration, temperature changes, and cold flow (creep), must not materially affect the pressure of the connection. If these disturbances do enter the connection sufficiently, corrosion can make the connection useless.

Research has found that the solderless wrapped connection has and maintains the high pressure requirement. The initial pressure connection in the center of the contact area is extremely high and fully sufficient to shear film for metal-to-metal contact. See figure 4 for an example of shearing and pressure qualities.

In contrast to the high pressures developed during the initial wrapping process, tests reveal that a drop in pressure is experienced almost instantly after the wrapping is completed. (This is caused by the cold flow of the copper wrapping wire.) But after the initial cold flow of the wire, the pressure value of the wire remains nearly constant for the life of the connection. This stabilization of pressure is well within the area of contact pressure that will keep corrosion out of the contact surfaces. The surfaces,



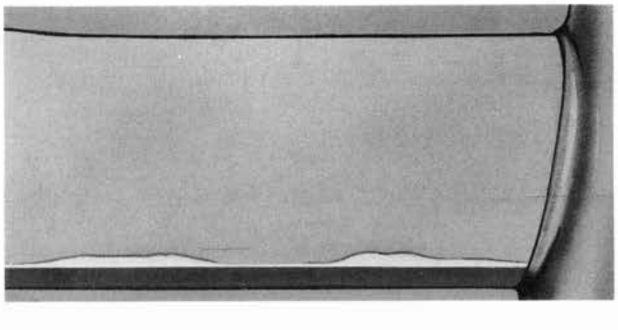


Figure 4. Pressure and shearing qualities of solderless wrapped connections.

in addition, do not loose the area factor discussed in section 2.4. The effects of handling, vibration, and temperature do not cause defective connections after the wire has stabilized.

2.3 Gastight Contact Areas

This requirement for a good connection is closely tied with the high pressure and elasticity requirements. When the wire and terminal are wound together, a gastight area of sufficient size must be maintained over time for a good electrical and mechanical connection. The gastight area must be stable in spite of corrosion or relaxation of internal stresses in the wire or terminal. The gastight area must also be large enough so that any decrease over time will not markedly change the characteristics of the connection. If an acidic agent which can discolor all the non-gastight areas is applied to the terminal and the clean area measured, the size should not vary markedly over time.

Experiments with thermal shock, temperature cycling, humidity, moist hydrogen sulfide, and vibration indicate that the solderless wrapped connection stands up even better than the soldered connection. Figure 5 shows the effects of moist hydrogen sulfide on a metal terminal. Note the gastight areas where the pressure connection kept out the corrosive material. This test was made on an "accelerated" life basis that simulated many years in excess of normal connection life.

2.4 Large Contact Areas

As stated in the introduction to this section, a large contact area is a basic requirement for a pressure connection. The effective contact area relative to the cross-sectional area of the wire is of great importance since it controls the resistance of the connection. It must remain uniform in size, metallically bright and not be affected by temperature changes, vibration, and handling. Figure 6 shows the contact area for a solderless wrapped connection.

As seen from figure 6, the contact area is tied intimately with pressure. If the force holding the wire and terminal together is small, only the high spots of the surfaces touch. If currents flow through such a connection with small effective contact areas, the connection may develop heat and melt the metal at the high spots. This type connection is unsatisfactory for telephone terminal connection. Thus, to have an effective connection, it is necessary to press the two metal parts together with a force high enough so that all particles of the area are intimately interlocked and free from insulating impurities. Coupled with a force strong enough to attain this essentially gastight area, the contact produced in the solderless wrapped connection must be equal to or greater than the cross-sectional area of the wire.

In the solderless wrapped connection this requirement can be achieved. Using 24 gage wire with six turns of wire around the terminal, the effective contact area of the connection is 1.3 times the cross-sectional area of the wire. Any tarnish area that may possibly develop over a long period would not hamper the connection. Also, heat cannot develop as resistance is kept to a minimum. The ratio may even be higher when it is considered that in area calculation only the middle four turns are counted. Any participation in the connection which the outside turns may take, would add to the ratio of contact area to wire cross section area.

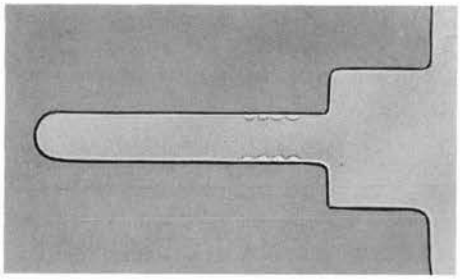


Figure 5. Corroded terminal after unwrapping. Note bright spots showing gastight areas.

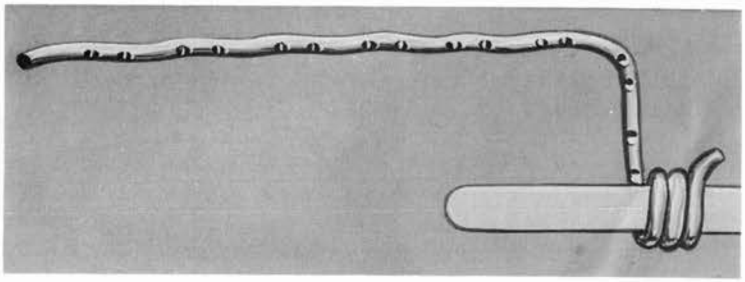


Figure 6. Unwrapped portion of wire showing pattern and area of a solderless wrapped connection.

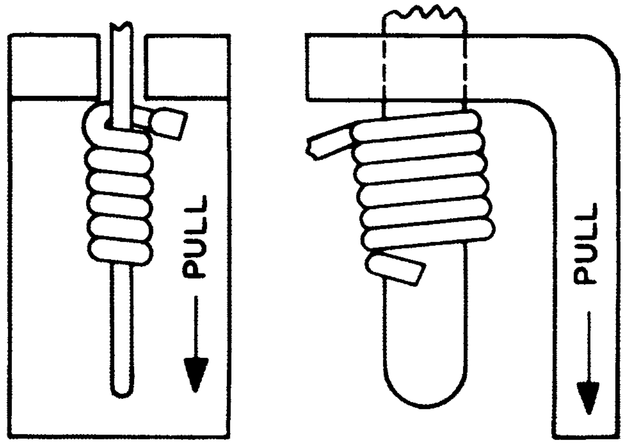


Figure 7. Connection stripping method.

2.5 Mechanical Stability

A pressure connection must be mechanically stable. Normal handling of equipment during shipment, installation, and maintenance must not dislodge the wire and break the points of intimate contact.

Although a pressure connection may have all the essential requirements of a good connection at the time of manufacture, it must be able to maintain these requirements over the expected life span of the connection. When a pressure connection is subjected to high temperatures, the pressure at the joint is relaxed. Virtually the same condition exists if normal temperatures and time are applied; the pressure of the wire on the terminal decreases. However, it has been shown that the relaxation of pressure in a solderless wrapped connection is not large enough to influence resistance during many decades of use.

Further influence is also placed on the connection through time. The metals of the wire and terminal allow solid state diffusion to take place. Solid state diffusion is a basic consideration in evaluating the solderless wrapped connection. The high stress placed on the metal of the terminal and wire gives intimate metal-to-metal contact. Over a period of time (around 18 months), solid state diffusion appears. This counteracts any pressure loss and strengthens the joint mechanically as well as electrically. Thus, although pressure of the solderless wrap decreases after manufacture (cold flow), the metal of the wire essentially is stabilized over decades of time. The added plus factor of solid state diffusion insures the connection for long life.

In testing for mechanical stability, a stripping force is exerted against the connection on the terminal. See figure 7 for a view of the method used to strip off the solderless wrapped connection. Failure to meet the stripping test for mechanical stability cuts considerably the life of the solderless wrapped connection. It should be noted that a correctly applied solderless wrapped connection can have a degree of mechanical stability where the stripping force needed to remove the wire is equal to or greater than the tensile strength of the wire (the strain needed to break the wire).

2.6 No Localized Stress Concentrations

Stress concentrations also form an important part of the technical requirements. It is equally important when a comparison is made between solder and solderless wrapped connections.

In vibration tests where conventional soldered connections were compared with solderless wrapped connections, it was found that solderless wrapped connections outlast soldered connections. The ability of the wrapped connection to withstand vibration breakage comes about because in the soldered connection the bending stresses are concentrated at the point of "emergence" of the wire from the solder. That is, a sudden change in cross section from wire to solder lump localizes the stresses at a very small area (see figure 8).

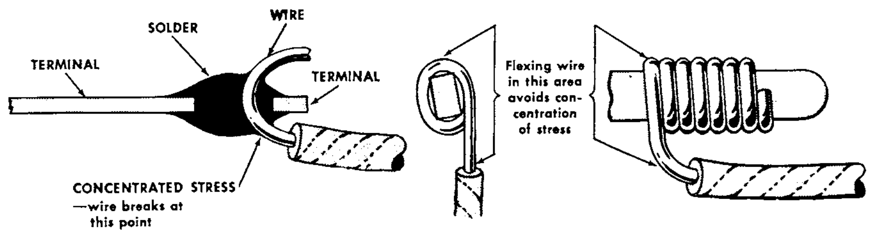


Figure 8. Stress areas for conventional solder connection and solderless wrapped connection.

In the solderless wrapped connection there is no sudden change in cross section and therefore no localization of stresses. Also the stresses tend to be distributed over the entire first turn of the connection. In the conventional solder connection, there is a vibration stress concentration at the junction of the wire, solder, and terminal.

No excessive embrittlement of the wrapped wire is another characteristic of the solderless wrapped connection. In contrast to the conventional solder connection, the solderless wrapped connection cannot become embrittled by a change in metallic structure. In the solder connection the heat of the solder can change the metallic structure of the wire and cause embrittlement. Since no heat is involved in the solderless wrapped connection, embrittlement of this type cannot occur.

In solderless wrapped connections embrittlement of the wire can occur when the wrapping tool bit radius is too small. If it is small enough, very high tension can be developed in the wire while wrapping. It can even be sufficient to break the wire. Although this type wrap achieves high tensions in the wire and gives good stripping qualities, the wire can become embrittled; and under vibration and handling stress it may break. A practical requirement to eliminate excessive embrittlement is that the connection be capable of withstanding unwrapping without wire breakage.

2.7 Summary of Technical Requirements

This section has stressed the technical requirements necessary for a good solderless wrapped connection. Its purpose is to acquaint the reader with the necessary background for evaluating the solderless wrap method. The following sections will deal specifically with the tools and methods used and recommended by Automatic Electric Company.

As seen in the discussion here, the requirements for solderless wrap are strict. And because a satisfactory design of tools and development of methods have been attained, all technical requirements for a good pressure connection can be met with the solderless wrapped connection. By meeting these requirements this method can substantially surpass the conventional solder method of wiring terminals. Some of the more important factors that prescribe the use of solderless wrap are outlined below.

(a) No solder disadvantages (heat, clippings, splashes, operator burns).

(b) Saving in material and labor.

(c) Easy to disconnect the wire from the terminal.

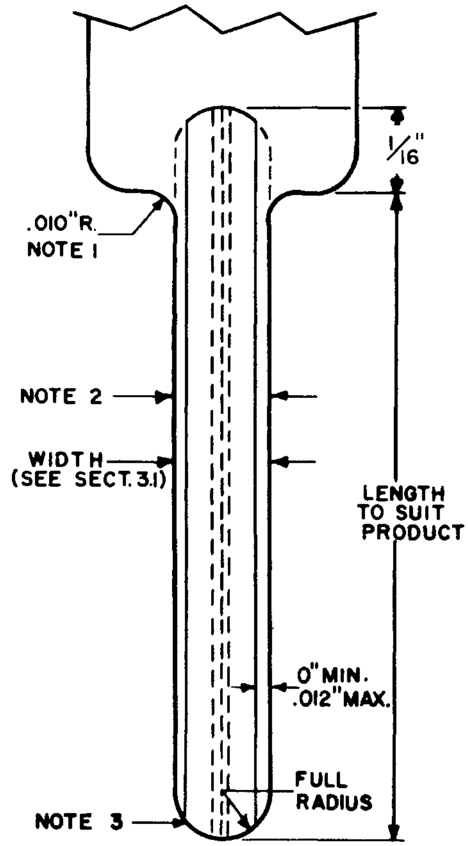
(d) More compact connections.

(e) Uniformity of connections with calibrated tools.

(f) More resistance to handling and vibration stresses.

3. CONNECTION STANDARDS

In order to meet the technical requirements described in section 2, Automatic Electric Company has introduced standards covering the type of wrap and terminal that will be used in solderless wrapped connections. These standards are set up to insure that the

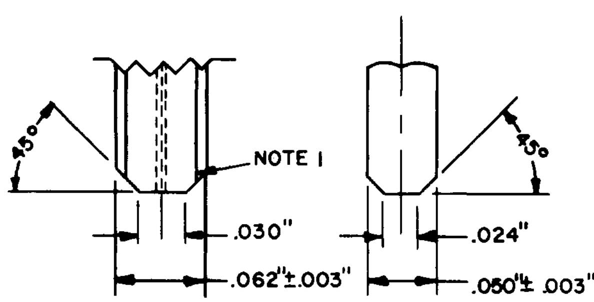


Note 1. Sharp corners are permissible.

Note 2. The edges of the terminal shall be parallel within .002".

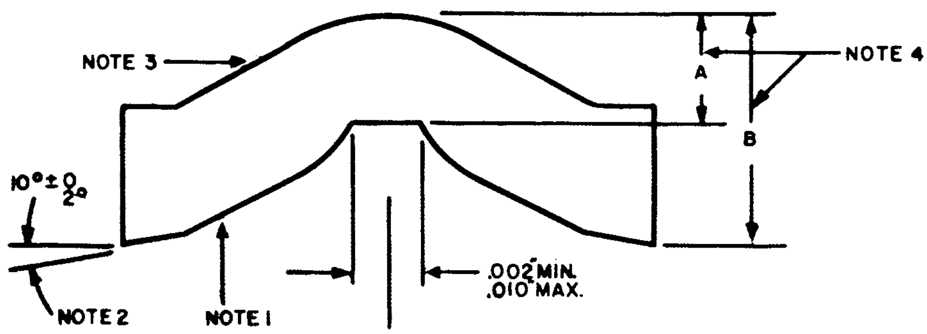
Note 3. Emboss at extreme end of terminal may be stopped 1/32" from end of terminal or may be distorted due to blanking; but tolerance on width of terminal must not be exceeded.

Figure 9. Preferred design of terminal (embossed type shown).



Note 1. Emboss at extreme end of terminal may be stopped 1/32" from end of terminal or may be distorted due to blanking; but tolerance on width of terminal must not be exceeded.

Figure 10. Optional design for lead on terminal.



Note 1. Concave side of emboss may be partially plane or curved.

Note 2. The 10° angle is preferred on nickel silver terminals. Brass and phosphor bronze terminals may have 0° angle.

Note 3. Embossing may be on either side of terminal.

Note 4.

Nominal Terminal Thickness (Embossed)	Diameter A Minimum	Diameter B ± .002"
.010"	.0090"	.021"
.0126"	.0104"	.024"
.0159"	.0128"	.027"
.020"	.0160"	.031"

Figure 11. Cross section of embossed type terminal.

solderless wrapped connection will meet the general requirements of a pressure connection and also attain or surpass the quality of the best solder connection.

3.1 Terminal Design

A terminal design is necessary so that a suitable relationship between the wire and terminal can be controlled for the best possible connection. Generally, a terminal makes a reliable connection when it has one or more edges crosswise to the axis of the wire. The terminal must be small enough to fit into the wrapping bit, yet large enough to withstand the stresses placed upon it.

Automatic Electric Company accepts three metal raw materials for solderless wrap terminals. They are brass, nickel silver, and phosphor bronze. On nickel silver terminals, no finish is required before fabrication on telephone equipment. The brass and phosphor bronze terminals, however, must be coated with an accepted finish. These terminals are coated with either electro-tin or blanked from solder coated material.

Beside terminal composition, the terminal form is important in meeting the requirements of size and stress placed upon it by the tool bit. Figures 9, 10 and 11 show the dimension requirements of the solderless wrap terminal. For terminals thinner than 22 gage (.025"), the structure must be embossed. In addition to the embossed structural characteristic, width plays an important part in producing an acceptable terminal. For terminals thinner than 18 gage (.040"), the width must be .062" ± .003". For terminals 18 gage and over, the width requirement is reduced to .050" ± .003". Even more important than exact terminal width is terminal width evenness along the entire length. The terminal edges must be paralled (no taper).

3.2 Solderless Wrap Standards

Along with the wire and terminal relationship, the standards of the connection itself must be controlled adequately for an electrical and mechanical connection which can meet the general technical requirements of section 2.

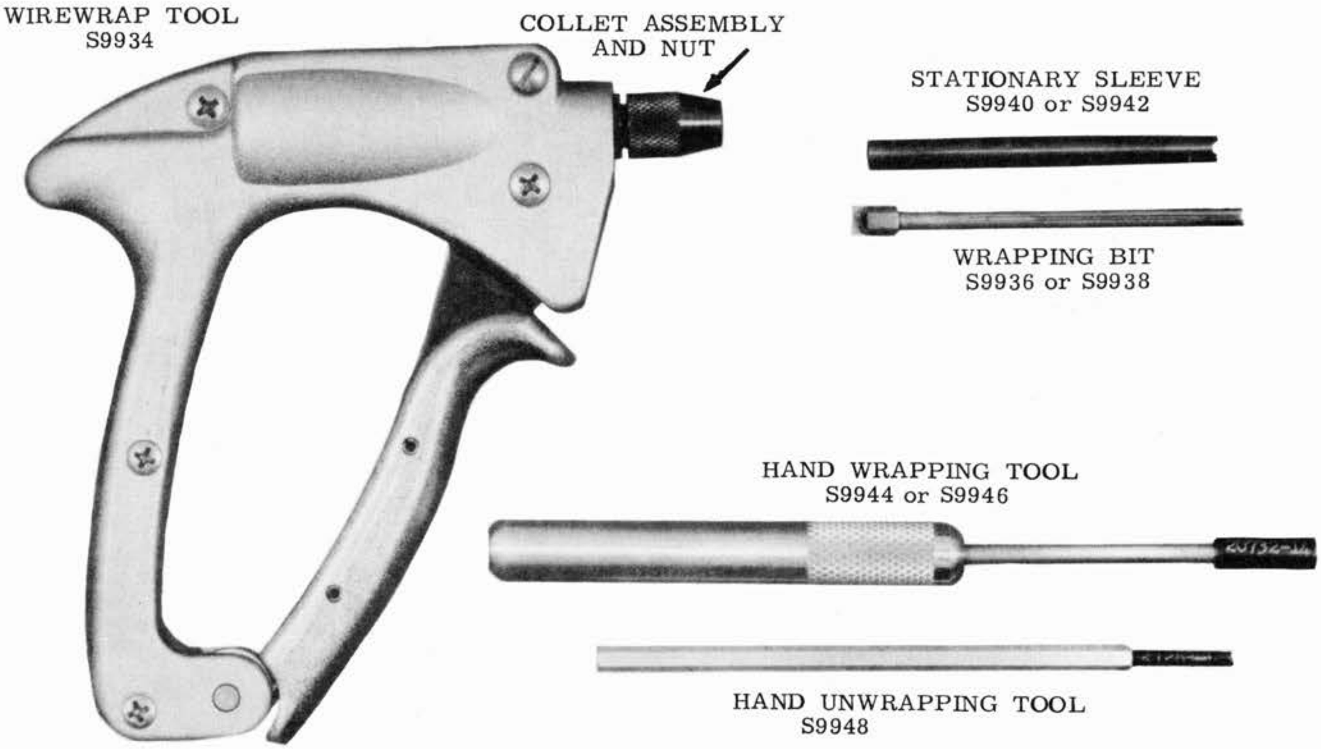


Figure 12. Solderless wrapped connection tools.

WIRE-WRAP* TOOL LISTING

A. E. Co. Catalog No.	Description
S9934	Tool, Wire-Wrap, Gardner-Denver, size 14H-1B.
S9936	Tool, Wrapping Bit, 24AWG wire A-17612-2. For use with S9934 tool.
S9938	Tool, Wrapping Bit, 22AWG wire A-18362. For use with S9934 tool.
S9940	Tool, Stationary Sleeve, 24AWG wire 17611-2. For use with S9934 tool.
S9942	Tool, Stationary Sleeve, 22AWG wire 18840. For use with S9934 tool.
S9944	Tool, Hand Wrapping, 24AWG wire, Gardner-Denver A-20557-12.
S9946	Tool, Hand Wrapping, 22AWG wire, Gardner-Denver A-20557-14.
S9948	Tool, Hand Unwrapping, 20 through 26AWG wire, Gardner-Denver A-20285-L.

****Registered trademark of Gardner-Denver Company.***

Automatic Electric Company uses only 22 and 24 gage tinned, solid copper wire for solderless wrapped connections. Six full turns on the terminal are used for the 24 gage wire, while the 22 gage wire needs only five full turns. No overlapping must be encountered in the turns, and spaces between all INSIDE wraps of the connection must be less than .005'' as gaged by eye.

Another important standard is the stripping force needed to remove the wire from the terminal. Twenty-four and 22 gage wire must be able to withstand six and eight pounds of stripping force, respectively. In addition, 22 gage wire should be wrapped on terminals of .025'' or thicker. Any connection not meeting these requirements must be soldered.

Some connections are not acceptable for solderless wrap. Listed below are some of the characteristics of an UNACCEPTABLE solderless wrapped connection.

(a) Not enough turns for the gage wired used.

(b) Overwrapping of turns on the connection.

(c) Overlapping of one connection onto another.

(d) Open inside turns on a connection (greater than .005'' as gaged by eye).

(e) Rewrapping wire used previously on a solderless wrapped connection.

4. TOOLS AND OPERATION

4.1 Tools

Few tools are necessary for the telephone company's operation in making solderless wrapped connections. Figure 12 pictures the tools recommended by Automatic Electric Company for wrapping a connection within the central office of a telephone operating company. And shown below figure 12, is a table showing Automatic Electric Company catalog numbers and brief descriptions of the available Wire-Wrap tools for wrapping and unwrapping solderless connections.

To make a solderless wrapped connection, only three tools are required: the Wire-Wrap tool (S9934), a wrapping bit (S9936 for 24AWG wire or S9938 for 22AWG wire), and a stationary sleeve tool (S9940 for 24AWG wire or S9942 for 22AWG wire). For "hand" unwrapping or wrapping, the hand unwrapping tool (S9948) and hand wrapping tool (S9944 for 24AWG wire or S9946 for 22AWG wire) are also available (although not necessary). This complement of tools is all that is necessary for solderless wrapped connections.

4.2 Preparing for Wire-Wrap Tool Operation

When preparing for solderless wrap operation, the following steps will help to quickly ready the tool for wrapping connections. First, grasp the Wire-Wrap tool (S9934) in the hand much as if it were a gun; then loosen the collet nut by turning it counterclockwise. This nut is located on the barrel end of the Wire-Wrap tool (see figure 12).

Next, insert the wrapping bit tool into the collet assembly (use S9936 for 24AWG wire or S9938 for 22AWG wire). After the bit is in place and it is noted that a trigger squeeze will turn the bit, insert the stationary sleeve tool (S9940 for 24AWG wire and S9942 for 22AWG wire). The stationary sleeve is placed over the wrapping bit and inserted into the collet assembly. When the sleeve is properly located, the V-shaped portion of the sleeve front tip will be on top and directly over the groove running the length of the wrapping bit.

The tool preparation is completed for solderless wrap operation by tightening the collet nut. The nut does not have to be extremely tight; a snug fit is sufficient.

NOTE: If the trigger is sluggish upon release, loosen the collet nut. Then, tighten the nut gradually while alternately squeezing and releasing the hand trigger of the Wire-Wrap tool.

4.3 Operation of the Wire-Wrap Tool

This section will describe the operation of solderless wrapping a terminal with the Wire-Wrap tool. Sections 5 and 6 will also discuss the solderless wrapped connection. However, these sections will show and list some of the "do's" and "don't's" of solderless wrap applications. This section will cover how to do the job and briefly cover some of the things to watch for in using the Wire-Wrap tool.

In following this discussion, refer to figure 13. This series of photos covers pictorially the complete cycle of solderless wrapping a terminal.

Figure 13a shows the assembled Wire-Wrap tool tip. The V-shaped outer tool is the stationary sleeve. Note that the bottom of the sleeve tip is curved while the top is V-shaped. Also, note that the sides of the sleeve have notches. The interior portion of the tool tip pictured in figure 13a is the tool wrapping bit. It has a terminal hole and a wire hole. When the Wire-Wrap tool trigger is squeezed, the bit turns counterclockwise (front view - figure 13); the stationary sleeve remains in place and does not move.

The appropriate wire is inserted into the wire hole as the first step in making a solderless wrapped connection (figure 13b). Only the skinned portion of the wire is inserted into the hole. Also, caution should be exercised that the wire is inserted fully into the bit and not pulled part way out when the wrapping operation is started.

After the wire is inserted into the wrapping tool, the wire is bent back through the slot of the stationary sleeve (see figure 13c). Note that the bare wire does not pass outside the slot. The insulation covering should be seated against the tool bit sleeve. When the wire is bent back and through the stationary slot, the anchor process has been completed and the operation is ready for terminal insertion.

The Wire-Wrap tool at this stage is placed over the terminal (see figure 13d). Be sure that it is inserted far enough into the tool so that the wrapping process can be completed. When the tool, wire, and terminal have been properly positioned, the trigger is squeezed. This wraps the wire around the terminal.

The pressure placed on the trigger will not change the pressure on the connection. As long as the pressure on the trigger is a steady pull throughout the wrapping cycle, the final connection will have equal pressure both within the wraps themselves and between different connections. Figure 13e shows the tool, terminal, and wire in the wrapping cycle.

After the necessary wraps have been completed, the tool is withdrawn. Figure 13f shows a finished connection. See the following sections for photos and discussion of acceptable and unacceptable connections. NOTE: While the wrapping operation is essentially simple,

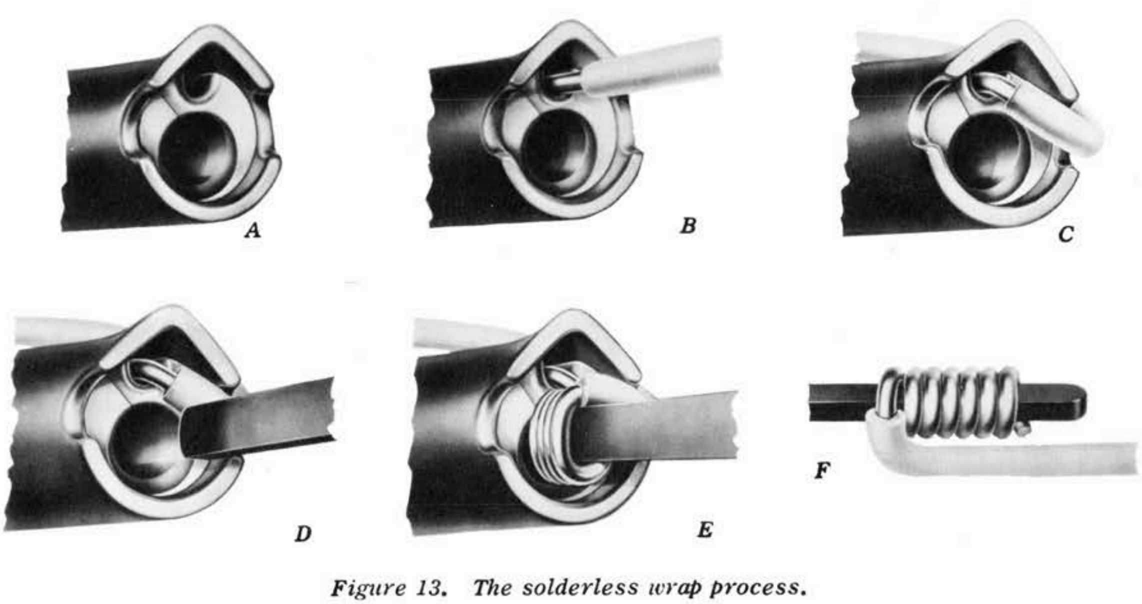


Figure 13. The solderless wrap process.

it does represent a new technique and its proper use requires training personnel in the use of new tools and proper inspection procedures.

4.4 Use of Hand Wrapping Tool

If the hand wrapping tool (S9944 or S9946) is used for making a connection, the method of application is quite similar to the Wire-Wrap application discussed above. However, there are a few minor changes. The hand wrapping tool is one piece and does not have moving parts. Thus, in contrast to the Wire-Wrap tool, the hand wrapping tool has a tool bit and sleeve that are united (figure 12). Also, no slots exist on the sleeve portion as they did on the Wire-Wrap tool.

To operate this tool, the stripped wire is inserted in the wire hole and then folded back. Since the slots of the sleeve do not exist, the wire is folded over the sleeve at the very tip of the tool. After wire insertion and fold back, the tool is inserted over the terminal as in figure 13d. The wrap is then completed by turning the wrapping tool clockwise. NOTE: It is recommended that the hand wrap type of connection be soldered.

To unwrap any solderless wrapped connection, several methods are available. For example:

(a) The connection can be unwrapped by hand without any tools.

(b) The connection can be unwrapped with an available tool such as a long nose pliers.

(c) The connection can be unwrapped with the hand unwrapping tool (S9946).

With the unwrapping tool, the terminal is inserted into the tool, and the tool is turned counterclockwise. The spiral effect of the tool unwraps the solderless connection. Figure 12 shows the hand unwrapping tool.

5. QUALITY CHARACTERISTICS

The actual appearance of a group of terminals probably can present the best approach to what the characteristics are of a good terminal connection. This section will show a series of photos, both good and bad, of connections made with the Wire-Wrap tool. It will also discuss causes for incorrectly made solderless wrapped terminals.

Acceptable Wire-Wrap connections are shown in figure 14. Special note should be given to the first connection. Here it may appear that the .005'' maximum clearance between winds of the wire has been violated. However, by referring to section 3.2, it is seen that the tolerance is applicable to the inside turns only. Thus, the terminal shown in the first photo of figure 14 is acceptable.

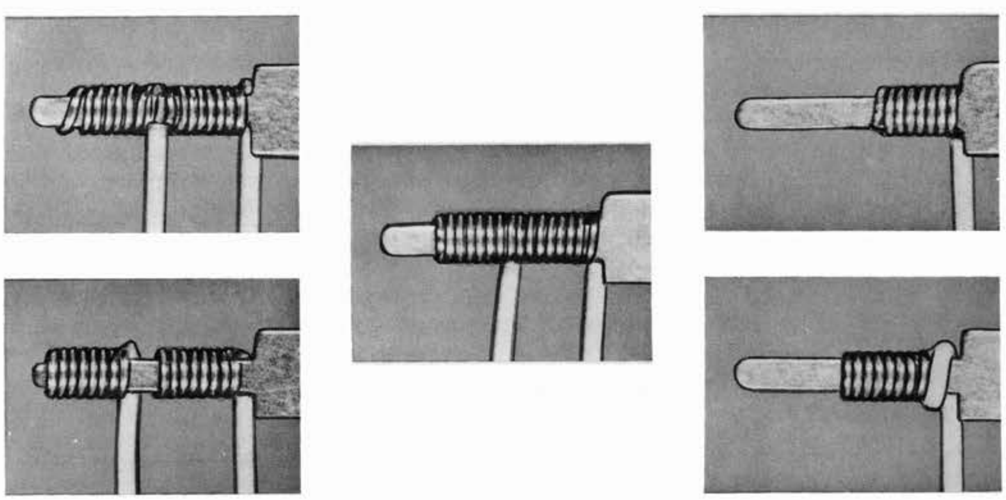


Figure 14. Five views of acceptable solderless wrapped connections.

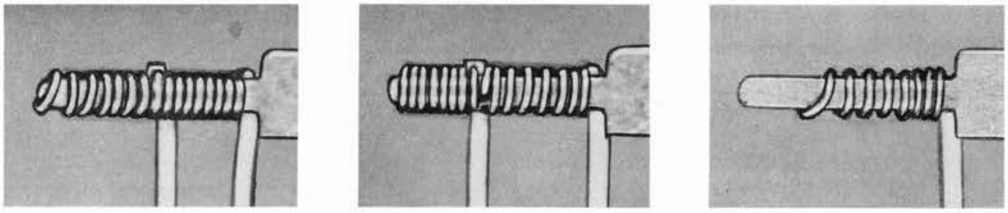


Figure 15. Open spiral.

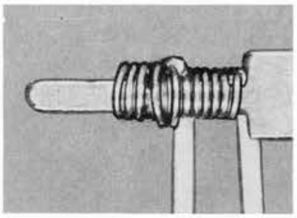


Figure 16. Overlap.

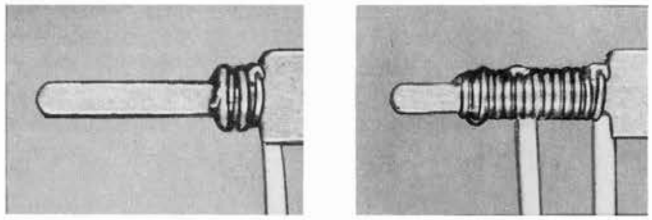


Figure 17. Overwrap.

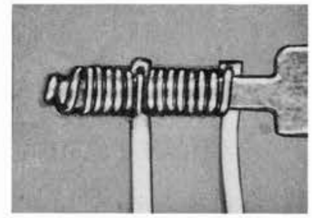


Figure 18. Improper spacing.

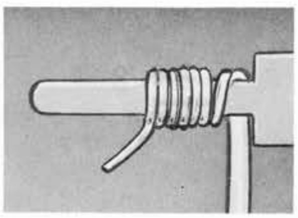


Figure 19. Pigtail.

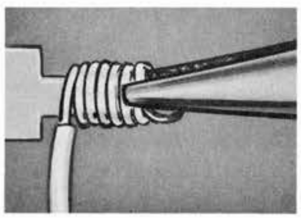


Figure 20. Plier pinching.

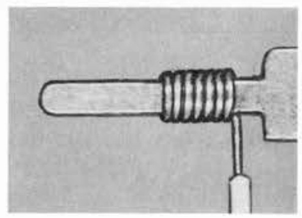


Figure 21. Exposed skinner.

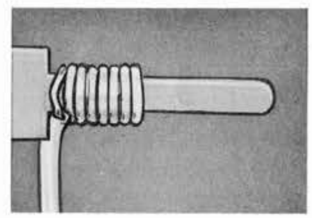


Figure 22. Nicked insulation.

Figures 15 through 22 reflect terminal wrappings which do not meet specifications for solderless wrapped connections; they should be replaced or soldered as required.

Figure 15 shows three variations of an open spiral connection. Each has more than .005'' as gaged visually between the inside turns. This unacceptable condition is usually caused by starting to remove the Wire-Wrap tool from the terminal before the wrap is completed.

Figures 16 and 17 show two very similar unsatisfactory characteristics of a solderless wrapped connection. The terminal wrap in figure 16 has the unfavorable characteristic called overlap. It shows two connections overlapping each other. Figure 17 shows an overwrap where individual winds on a connection are overwrapped on other winds. Both the conditions of overlap and overwrap are caused by too much forward force being placed on the Wire-Wrap tool by the operator. Overlap can be traced, in addition, to the pulling out of the wire before connection completion.

Another improper spacing characteristic of a solderless wrapped connection is pictured in figure 18. In this case the last wrap on the terminal is too close to the end. And the first wrap on the terminal has been started too far along the terminal's length. This condition is caused by the operator not inserting the tool far enough over the terminal.

Figure 19 is a variation of the open spiral characteristic shown in figure 15. Here, the tool also has been removed prior to the completion of the wrap. But in this case an excessive pigtail has been the result of the incomplete operation. Figure 20 shows what should not be done when a pigtail type or other unacceptable connection is made. The use of pliers or disturbing a completed connection is never authorized. If a connection is disturbed in any way, the connection should be soldered.

All of the wraps shown in figures 15 through 20 are unacceptable for use as solderless wrapped connections. Each must be soldered to achieve a connection acceptable for a stable electrical and mechanical terminal and wire connection. If desired, they may also be replaced by a solderless wrapped connection. In this case the old unacceptable wrap must be stripped off, the used wire cut-off, and a new solderless wrapped connection completed. NOTE: A section of wire previously used must not be reused for a solderless wrapped connection. If an old wire is used for a connection, the connection must be soldered.

The two terminal connections pictured in figures 21 and 22 cannot be soldered. They must be replaced. Figure 21 shows an exposed skinner over 1/8''. It is caused by not inserting the wire into the wrapping bit; or it may be caused by pulling the wire partially out of the wrapping bit hole after insertion. Figure 22's unacceptable characteristic also makes replacement necessary. It cannot be soldered. As shown, the insulation has been nicked. This condition is generally caused by not positioning the wire in the sleeve wire notch of the wrapping tool.

6. PRACTICAL SUGGESTIONS FOR SOLDERLESS WRAP

This section will list some of the ''do's'' and ''don't's'' of solderless wrap. It is inserted to help the central office maintenance man make good solderless wrapped connections. By following the suggestions listed here and the methods previously described, the solderless wrapped connection can be used to its fullest advantage.

(a) *Use only 24 or 22 gage tinned solid copper wire.*

(b) *Be sure there is a minimum of six full turns for 24 gage wire and five full turns for 22 gage wire. Solder any deviations.*

(c) *Be sure the wraps are close wound with each of the spaces between the INSIDE wraps less than .005'' as gaged by eye.*

(d) *Limit connections made with 24 gage wire to terminals .010'' or thicker. Solder any deviations.*

(e) *Limit connections made with 22 gage wire to terminals .025'' or thicker. Solder any deviations.*

(f) *Use only approved terminal forms (see section 3.1).*

(g) *Do not use the skinned portion of a used wire for a terminal connection. If an old wire is used, it must be plier-wound for a minimum 1-1/4 turns and soldered. Or, for a solderless wrapped connection, cut-off the skinned portion of the used wire and reskin.*

(h) *Solder overwrapping of any turns on a connection.*

(i) *Solder overlapping of one connection onto another.*

(j) *Solder open spirals greater than .005'' as gaged by eye.*

(k) *Solder all connections on a terminal if any connection on that terminal has been soldered.*

(l) *Solder a minimum of two adjacent turns for wrapped connections requiring soldering.*

(m) *Be sure the axial pulling force on the wire will not tend to unwrap the connection. Wires should be dressed at right angles to the terminal axis.*

(n) *Limit to 1/8'' the distance from the end of the wire insulation to the terminal.*

(o) *Provide a minimum clearance of 1/64'' between the wire end (pigtail) and adjacent components.*

(p) *Do not nick, flatten, or bend the wire before using. Solder any connection with these irregularities.*

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