ELECTRONIC WIRE & CABLE

A USER'S GUIDE: PERFORMANCE AND SELECTION

AT&T

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Preface

AT&T Network Systems has prepared this Electronic Wire and Cable manual for the express purpose of identifying the fundamental details which have established AT&T as a product leader in the industry.

Since this manual is intended to serve a variety of readers, few assumptions have been made relative to the reader's previous understanding of the subjects presented. As a foundation, the fundamental principles of electricity are reviewed to help identify cable design criteria.

The progressive stages of cable fabrication form the basic outline of this manual, tracing development from copper rod through completed multiconductor cables. Numerous drawings, charts, tables and graphs are used to enhance the reader's understanding. A collection of product photographs has been assembled to relate the concepts discussed to specific AT&T Electronic Cable and Wire (EC&W) offerings. A brief overview of transmission systems, without the complex higher mathematics, is presented to familiarize readers with the terms and concepts.

Industry standards-making organizations are identified along with appropriate standards which formulate basic cable requirements. AT&T's commitment to quality has combined these with additional in-house testing and controls to produce the finest products available. At AT&T, quality is a way of life.

AT&T Network Systems acknowledges the many staff members whose contributions have made this manual possible.

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SECTION 5

Multiconductor Cables

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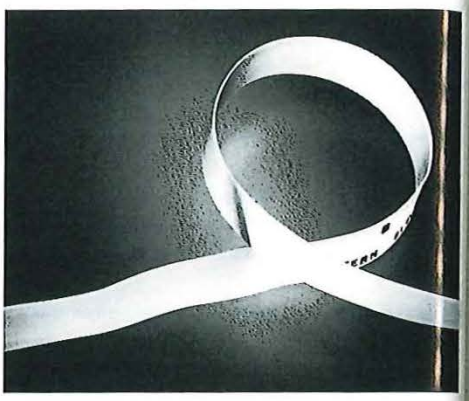
Multi-conductor Cables

In much the same way as insulation improves our ability to use conductors, the grouping together of insulated conductors to form multiconductor cables makes electronic wiring more practical. Consider the alternative of having tens or hundreds of individual insulated conductors each installed separately. A wide variety of multiconductor cable types exist – the following are representative.

Parallel Conductor Cables

As the name implies, the conductors in these cables are parallel to each other. Although this construction is most often associated with flat cables, parallel (or untwisted) conductors are also made into round cables.



AT&T 902A ribbon cable has 31 conductors, each 28 gauge.

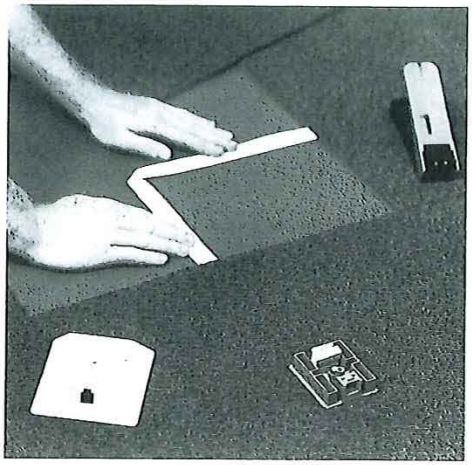
Flat Cables

In flat-cable construction, insulated or non-insulated conductors are arranged side-by-side and encased in a common jacket, which might be laminated, extruded or woven. Examples include ribbon cables, TUCC,® Twin-Axial and antenna lead wires.

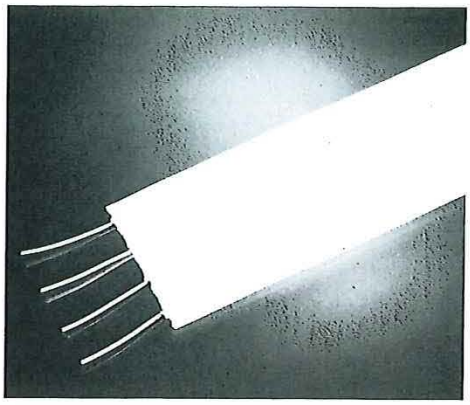
Advantages
Lower installed cost
Easier to install connectors
Good current carrying capacity
Excellent vertical flexibility
Relatively high mechanical strength due to large surface area
Excellent heat dissipation factor due to surface area
Space and weight reduction due to thin cross-section

Disadvantages
Shielding limitations (see above)
Low cut-through and abrasion resistance
Limited number of conductors in a cable (see above)

Ribbon cable production machine – copper conductors are sandwiched between insulating ribbons.



1) AT&T TUCC® flat cable has four pairs of insulated conductors.



2) TUCC® installation makes it easier to place phone or data connections where they are needed.

TUCC® (**T**elephone **U**nder **C**arpet **C**able) has set the standard for under-carpet installations. Familiar applications for other ribbon cables include desktop computers, both internally and for peripheral connections, and inside computer printers and typewriters to power and control the traveling printhead or daisy wheel assembly.

Lack of shielding (to minimize interference) has been a limitation, but new braided shield sleeves provide a promising answer to that problem. The other major obstacle for flat cables is the practical width limit of about 50 conductors. Termination of flat cables is typically accomplished with self-aligning compression connectors which pierce the insulation.

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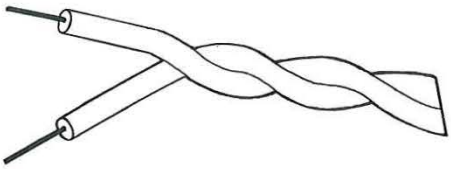
Twisted Pair Cables

Most of the cables within the scope of AT&T's EC&W product line utilize the twisted pair construction. Production of small cables of this type involves twisting individual pairs and grouping of those twisted pairs to form either a cable or a unit for a larger cable.



A typical twisted pair (exaggerated for clarity).

The two main reasons for twisting pairs of conductors are to minimize or eliminate crosstalk and to decrease unbalanced mutual capacitance.

Crosstalk is signal interference between adjacent pairs, which may be caused by pickup of either unwanted signals from adjacent pairs of conductors or stray energy from nearby cables. This interference primarily results from the magnetic field which surrounds any current-carrying conductor.

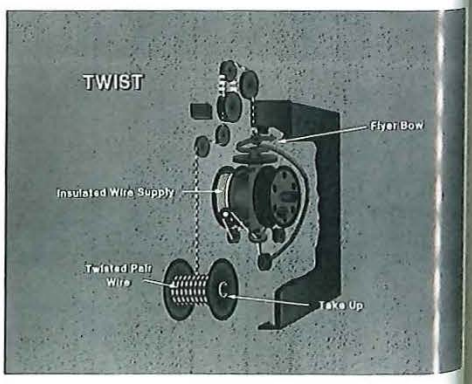
Unbalanced mutual capacitance of the pairs in a cable creates a capacitive effect which transfers undesirable signals and noise between the pairs.

Both crosstalk and unbalanced capacitance are affected by the type, length and direction of twist.

To provide maximum separations within a cable, different pairs are given different twist lengths within a standard range. Generally, a counterclockwise (left-hand) twist with twist lengths between 1.5 inches and 5.5 inches is used. Adjacent pairs are generally designed to have twist length differences of at least ½ inch.

The Pair Twisting Process

Some cable production machines both twist the individual wires into pairs and combine them to form a cable of up to 25 pairs. Primarily for larger cables, other machines combine pre-twisted pairs which are created on high speed machines called twisters.



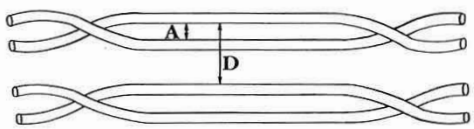
Graphic shows internal details of twister.

Production line of twisters. Each is constructed as shown in the graphic.

Tight Twisting

Tight twisting, where pair twist lengths are less than one-half inch, is an increasingly popular option, particularly in the "high tech" computer field. Tight twisting of pairs increases the separation of pairs in a cable making pair identification easier and reducing crosstalk.

Tight twisting also tends to preserve the shape of the cable better. Longer twists can become flattened and deformed as they are packed in a cable, whereas shorter, tighter twists are less likely to deform.



Two twisted pairs – exaggerated to show distances as specified below.

$$\text{Crosstalk} = \frac{A^2}{D^2} \times \cos(\text{twist angles})$$

Where **A** = Distance between conductors of a pair
D = Distance between pairs

The greater the value of "D" in proportion to "A", the lower the crosstalk value. Very low, even negative crosstalk values are desirable.

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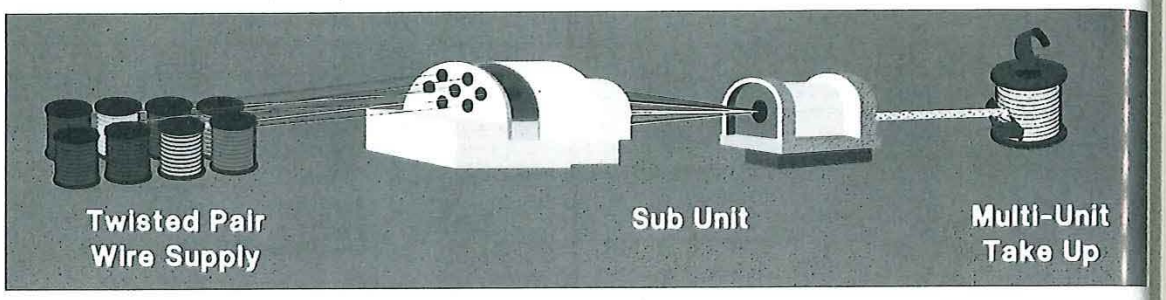
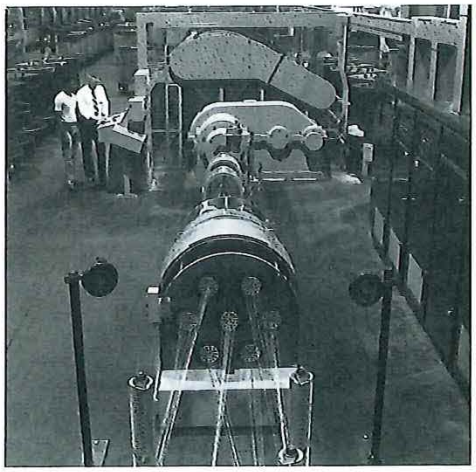
Cable Core Units

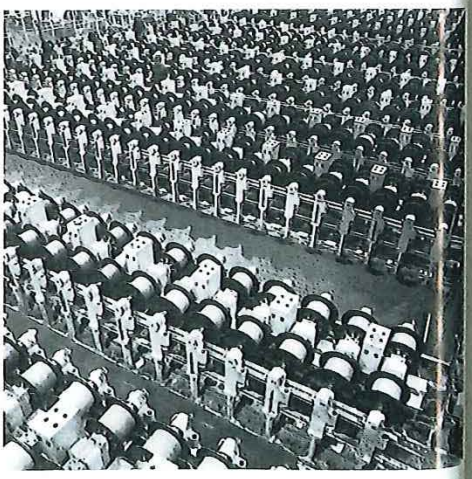
The next step in the cable making process after pair twisting is the forming of **units**, which consist of up to 25 pairs each. These **units** can comprise a relatively small cable with the addition of shielding (if desired) and a cable jacket, or they can be combined to form larger pair count cables. Those designated for use in **multi-unit** construction are wrapped with color coded binders to identify each unit.



Simplified graphic of stranded line – pairs combine into units.



25 insulated pairs enter the stranding machine which forms them into one unit.



High volume production facilities – rows of tandem groups of 25 reels, each a twisted pair, feed into the stranding machines.

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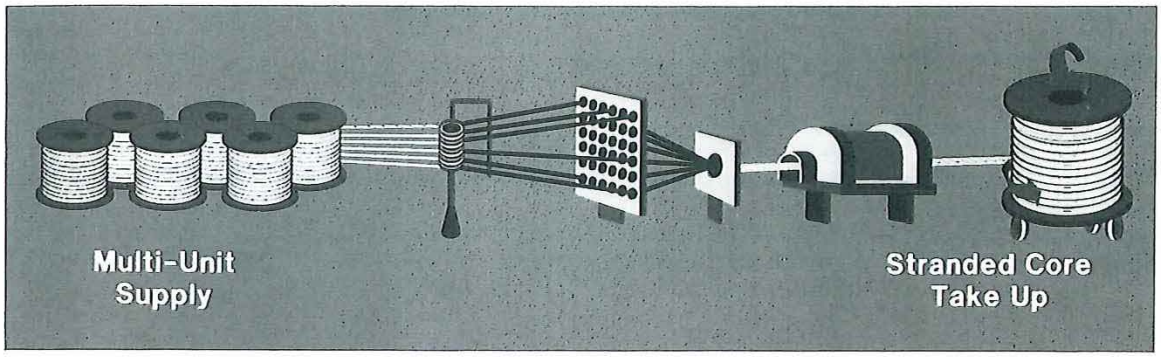
Multi-Unit Cable Cores

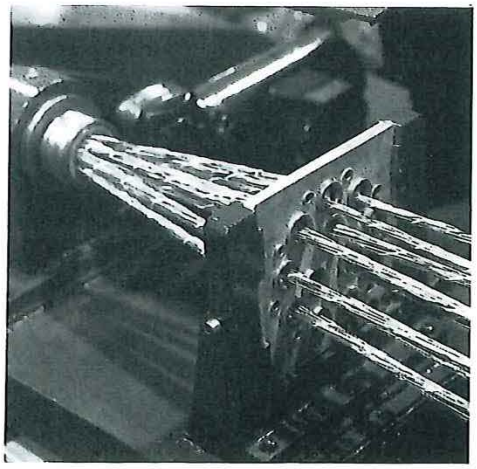
Cables with more than 25 pairs are constructed by combining **units** (25 pair each typical) to form **multi-units** (100 pair each typical). Medium size cables, from 26 to 100 pairs, are made by combining preformed **units**, which are usually 25 pairs each. For cables with larger numbers of pairs, 100 pair **multi-units** (each is 4 units) are cabled or "stranded" together by larger cabling machines. Cables of up to 600 pairs can be produced in this fashion and maintain color code identification.

For even larger cables, 3,600 pair exchange cable, for instance, each 600 pair **super unit** is wrapped with a color coded **super binder**, and then cabled together to form one large cable core. The two construction methods used to produce a cable core, discussed on the next page, are similar to those used in producing stranded conductors.



Simplified graphic of cabling line – multi-units (100 pairs each) combine into cable or super units.

Preformed units (25 pairs each) spin off reels (left) and enter the cabling machine in the background.



Preformed units are guided into the cabling machine.

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Bunched Core Cable

A bunched core cable consists of multiple units, simply collected together to form a cable. A slight twist is usually imparted to facilitate handling.

For a cable with equal number of pairs, bunched core construction produces a smaller overall cable diameter than the concentric core design does.

Because separation of pairs is reduced, electrical performance can be degraded. This bunched cores design has lower material and processing costs than the concentric core construction which follows.

Advantages
Smaller overall cable diameter
Lower material cost
Lower processing cost

Disadvantages
Electrical performance may suffer due to the reduced separation of pairs
Less uniform overall cable appearance
Pair identification can hamper splicing and termination

Concentric-Core Cable

There are two kinds of concentric-core cables:

A **true concentric-core cable** consists of a central unit with units spiraled around it, with subsequent layers wrapped in alternating directions.

A **unilay concentric-cores cable**, on the other hand consists of the same central unit with units spiraled around it, but all subsequent layers are wrapped in a single direction.

The degree of flexibility in a concentric-core cable depends on the lay (or wrap) length. A shorter lay length provides greater flexibility. The flexibility of the concentric-core design is ideal for large cable applications requiring flexibility for bending and being pulled into tight fitting locations.

The helical layering produces better separation of the twisted pairs for lower crosstalk values. Termination and splicing are also simplified because pairs can be easily identified.

Advantages
Increased flexibility
Excellent electrical performance

Disadvantages
Higher material costs
Higher processing costs

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Fillers

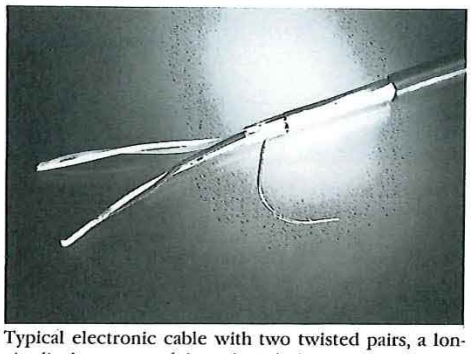
For some cables, stringlike fillers are added between units to achieve better symmetry or to provide better conductor separation. These fillers can also act as cushions for cables subjected to flexing and impact in heavy-duty applications.

Commonly used fillers include polyethylene and twisted polyethylene monofilaments, vinyl, cotton and jute.

Core Wraps

A core wrap is an isolating layer wrapped over a core of insulated conductors. The wrap can be applied either helically (spiral wrapped) or longitudinally (lengthwise).

Core wraps are applied prior to shielding and/or jacketing a cable core.



Typical electronic cable with two twisted pairs, a longitudinal core wrap (clear plastic), drain wire, foil shield and jacket.

The following are the main reasons for applying core wraps.

Protection – Core wraps protect the cable core from both stress and heat during application of the shield and/or jacket in the manufacturing process. They also provide the finished cable an extra measure of protection from stress and heat.

Uniformity – Use of a core wrap improves roundness to give the cable a more uniform appearance. This is especially important for a smooth jacket finish in unshielded cables.

Improved Dielectric Strength – Core wraps, especially those made of PVC or polyethylene, help to isolate the cable core from electrical discharges in the environment. When used with shielding they will improve shield-to-conductor breakdown strength.

Types of Core Wraps

A variety of tape materials are used for core wraps based on the requirements of the application.

Polyester Tapes – Polyester core wraps add extra mechanical strength to the cable and aid in subsequent manufacturing steps, such as shielding and jacketing. They have high tensile strength (25,000 psi typical). Dielectric strength is 7500 volts per mil of thickness. Polyester wrap has an operating temperature of −60°C to 150°C (−76°F to 302°F).

Heat Tapes – These are core wraps specifically designed to increase the heat resistance of a finished cable. They serve to retard flame and smoke generation.

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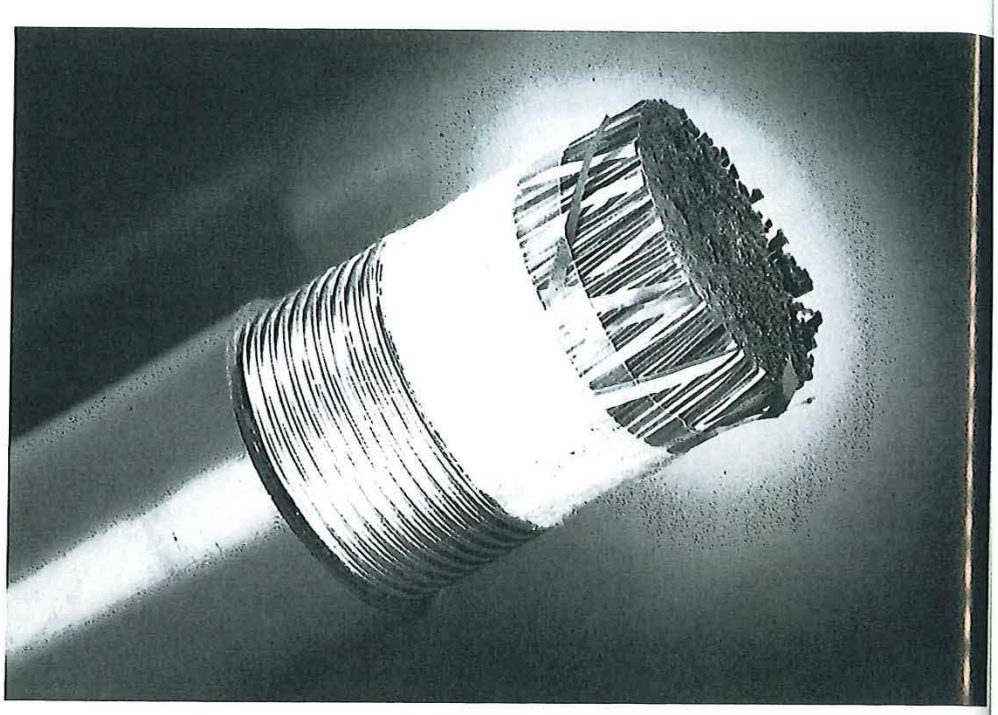

This riser cable consists of 1,800 pairs of dual insulated (expanded polyethylene with PVC skin) 24 gauge conductors. Note the cluster appearance due to the units and multi-units which form the cable core. A double core wrap is used – one clear, and one "mat wrap".

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