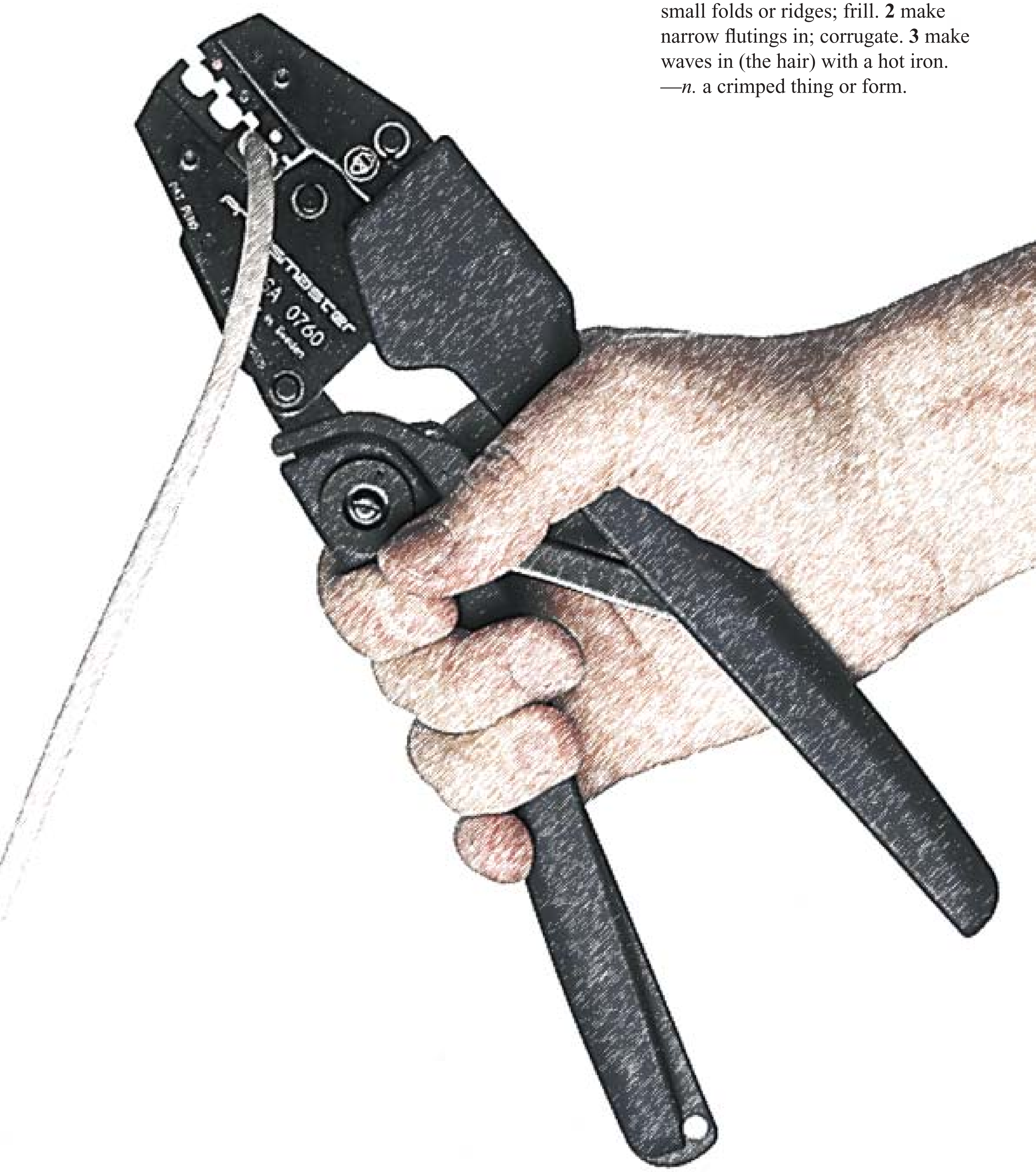
Crimp Terminations

A basic introduction to the crimping of connectors

crimp v. & n. — v.tr. **1** compress into small folds or ridges; frill. **2** make narrow flutings in; corrugate. **3** make waves in (the hair) with a hot iron. —*n.* a crimped thing or form.



pressmaster…

…designed, developed, patented, manufactured and marketed the first self adjusting, auto-sensing wire stripping tool in the 1960s

…designed, developed, patented, manufactured and marketed the first ratchet release mechanism crimp tool in the 1970s

…designed, developed, patented, manufactured and marketed the first ergonomic crimp tool in the 1980s

…designed, developed, patented, manufactured and marketed the first truly portable, micro-hydraulic crimp machine in the 1990s

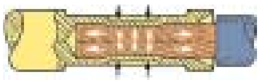
At the start of the new millennium pressmaster designed, developed, patented, manufactured and marketed the…

…to be continued

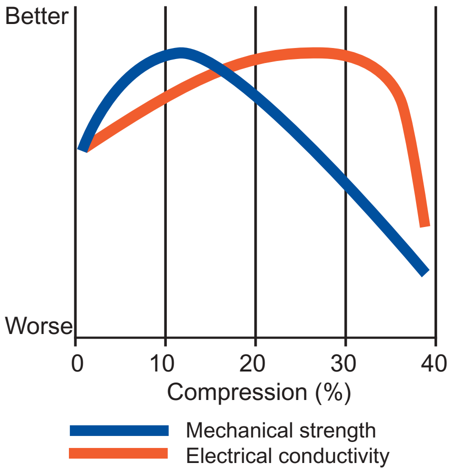
Contents

What is Crimping?

Crimping is a method of permanently joining wires/cables to connectors whereby the conductor is inserted into a barrel of the connector which is then compressed about the wire to form a solid joint.
Technically the two parts are deformed at such a high pressure that a cold flow of the material is accomplished, oxide layers are broken up and a high quality gas tight connection is obtained, the mechanical and electrical properties of which exceed those of the wire itself.



It is a side affect of the cold flow process that mechanical strength and electrical conductivity both increase with compression (and elongation), which is expressed as the amount that the cross sectional area of the material(s) have been reduced expressed as a percentage. The following graph shows the effect relative to compression:



In general, the mechanical strength of the connection is greatest when the total copper cross section area has been reduced by 10%. With less compression (undercrimp) the wire will often slide out of the terminal. With too much compression (overcrimp) the strands of the wire have a tendency to break.

In a similar way, one will find that the maximum conductivity occurs at a compression of about 30% (an over crimp). This is caused b a more efficient demolition of the oxide layers between the terminal and the wire at a more brutal deformation.

Optimal deformation is the compromise between electrical requirements against mechanical specifications. Our graph shows that the optimum crimp compression for many types of connectors lies between 10-20% of the initial cross-section.

The amount and type of deformation must be engineered to provide the optimal electrical and mechanical characteristics required for a particular application.

Why Crimp?

Every schoolchild who has ever inserted unterminated wires into a screw terminals will readily understand the difficulty in successfully connecting wires using this method; wires break and fall off! To overcome these problems connectors have been developed over the last century that ensure a proper electrical connection. Today crimping is the predominant method of fixing a connector to a wire or cable for the following reasons:

Tried & Tested - worldwide use in every industry has given rise to the establishment of International Standards.

Low connector/installation cost - volume production of connectors reduce part costs and tools/machines are readily available for low to high volume.

Reliable - proven for over 100 years.

Fast - speedy connections are assured using the latest crimp and strip tool designs.

Readily available - connectors are manufactured for virtually every area of application

Simple control and verification - from visual to laboratory techniques

No heat or chemicals required - a safer method to others.

Low skill installation - modern crimp tools are designed to minimize the risk of human error.

Environmentally friendly - no harmful gasses are given off as is the case with soldering.

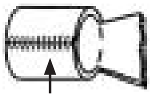
In essence, crimping is relatively inexpensive compared to other alternatives and it's tried, tested and proven to meet the requirements of the most demanding of the 21st centuries applications.

There are literally tens of thousands of different types of crimp connector manufactured today. However the end user normally only has to choose between different manufacturers as the front end of the connector is determined by what it must be connected to and the back end by what type of wire must be put into it.

Some of the most common types are as follows:

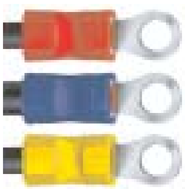
Un-insulated closed barrel connectors/terminals

can be manufactured from sheet or tube brass and copper, crimps are normally indent or hex for the larger sizes. Available as rings, forks, pins, blades, splices, snap-on tabs and receptacles, bullets and sockets etc. The seams of sheet connectors are normally brazed together to ensure a better crimp.



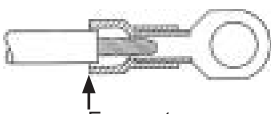
Pre-insulated closed barrel connectors/terminals

as above but with an integrated insulation



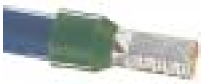
cover which is also crimped to the wire insulation to improve pull-off strength and reduce bending stresses. Some types have an additional barrel which extends over the insulation to give additional vibration resistance. The crimp profiles are normally oval or ovaloid. The insulation is colour coded to indicate the wire sizes covered: Red 0.5-1.5mm^2, Blue 1.5-2.5mm^2 and Yellow 4.0-6.0mm^2.

The inner edges of the insulation are often flared outwards to allow for easy wire entry into the connector.



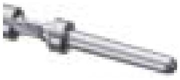
A feature of un-insulated and pre-insulated barrel connectors is that they must be correctly aligned when crimping (seam at top centre) to ensure that the brazed seam is not damaged.

Ferrules, bootlace ferrules, end terminals



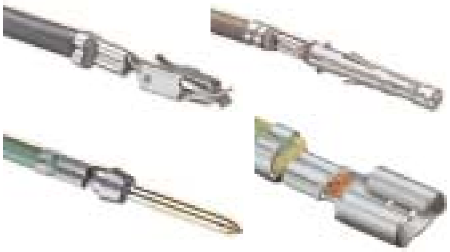
can be either pre- or non-insulated and differ from the above in that only the conductor area is crimped to a trapezoid cross section. These are used to improved conductivity and maintain conductor stranding ensuring a positive connection with terminal blocks etc. Note that wire size colour coding can differ from country to country and amongst different manufacturers.

Turned Pin Contacts

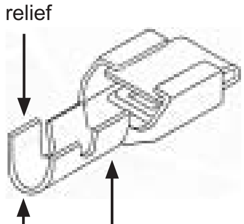


are of very high quality (and cost!) and are available in male and female configurations for high density modular plugs and sockets. The crimp profile is normally square or 4-way indent. Due to the small size of these connectors locators are normally provided on crimp tools to secure the connector in position.

B, F or Wrap Over Connectors

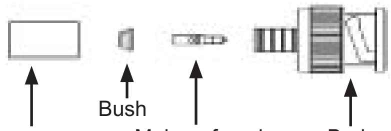


so called because of the profile they give from the back, side or means of gripping the wire, are available in literally 1,000s of configurations. The crimp profile is normally B shaped in cross section although as shown top right can be wrapped around the insulation. Normally manufactured from strip material and produced in high volumes off multiple progression tooling, some types can be a combination of turned pin and stamping as shown bottom left. These connectors are relatively cheap to manufacture and because they can be supplied in chain form (joined together) they are ideal for high volume production using fully automatic cut, strip and terminate machines. Note however that the crimp form itself is one of the most difficult to achieve, especially when using a manual hand tool required for service and repair. With this type of connector there is no natural stop for the wire to sit against, therefore tool manufacturers often integrate wire stops and/or locators onto the crimp dies to correctly position wire and connector.



Coaxial and Fibre Optic Connectors

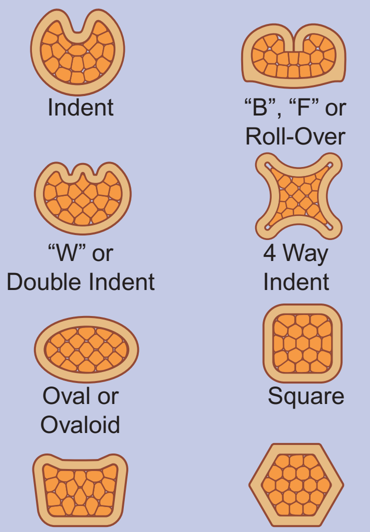
BNC, F, N, SMA, SMB, SMC, ST and TNC amongst many other types, however these connectors are always matched to specific cable types. Coaxial connectors normally require two crimps, one on the centre pin and another over the braid sleeve whilst fibre optics usually only need a sleeve crimp.The crimp profile is normally a hexagon but can be square or round.



FCC68 Modular Plugs (RJ and Western Electric)

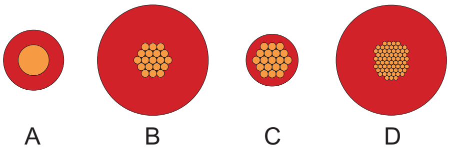
although the front end of these connectors are largely standardised by International specifications, the bodies differ greatly from manufacturer to manufacturer and there are different requirements for screened and unscreened types. These connectors are not really crimp connectors at all but are Insulation Displacement Connectors (IDC) whereby the contacts have sharp forked prongs which when punched down onto the wire, scrapes away the insulation and makes contact with the conductor. However standard crimp tooling is used to effect the termination which normally requires three punches: Primary and Secondary strain reliefs and contacts. Shielded connectors will normally require an additional sleeve crimp.

Some Common Crimp Profiles (Cross Sections)



Wire and Cables

The problem with wires and cables is that all of the following cross sections (shown at 4x actual size) are the same!



That is, they are all 18 AWG insulated equipment wires selected from the standard ranges of two of the worlds largest wire manufacturers. Yet the cross sectional area (csa) of B and C is 18% greater than that of A; the effective outside diameter of the conductors of D is 38% bigger than A; and the outside diameter of B is 2x that of C. There is nothing wrong with any of these wires, they are all manufactured to very tight standards, however this does illustrate the possible problems in specifying the right wire for a job.
A further complication is that nominal csa bear little relation to actual csa, this is because nominal sizes (18AWG, 2.5mm^2) are based upon the conductivity of a standard copper of this size, the same wire with a high conductivity copper would have a smaller csa.

Conductors
Cross sectional conductor area, conductor material and conductor plating are determined by application. Conductor materials might be copper, silver, aluminium and steel (glass and plastic in Fibre Optics). Plating can be tin, silver, copper and nickel. The shields of coaxial and multi core cables are formed from braided copper or foil.

Stranding
The amount of stranding is determined by how flexible the wire is required to be. A single core would normally be considered rigid, 7 strands as semi-rigid and 16 strands and more as flexible. A test lead (probe wire) for example might have 384 strands on a 0.75 mm^2 wire. The cores of a data cable may be further twisted, normally into pairs, to affect the inductance of the cable and therefore its speed.

Insulation
Insulation is also chosen for the application but also for protection against the environment in which it is to be used. They go from very soft materials such as silicon and neoprene, through PVC, Vinyl and Polypropolene to very hard insulation such as PTFE (even copper tube is used for microwave coax). Some wires are even double or treble insulated with different types of material and cables can be armoured with a steel wire.
Note - the loose covering of multi core and fibre optic cables is normally referred to as a sheath

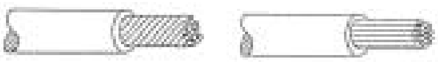
It is simply inconceivable that connector manufacturers could make all connector types specific to all wire and cable sizes and types. The costs would be prohibitive and the number of connectors bewildering. Therefore manufacturers compromise and try to make the largest number of wires fit into the smallest number of connectors.

Luckily for end users the better connector manufacturers always specify the wire range that will fit into a specific connector. However this variance has considerable implications for tool manufacturers when designing appropriate crimp dies.

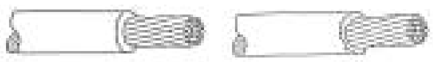
For the end user the principal concerns once a wire or cable has been selected is to ensure that it is properly prepared to fit the appropriate connector. This means that it must be stripped back to expose a length (or lengths for coax) of conductor(s) which will have been specified by the connector manufacturer.

Apart from producing the right strip length the key requirements for a good strip are:
- *the conductor(s) must not be cut, nicked or scraped in any way. Ensure that strands are not pulled out of the wire end which would indicate nicking.*

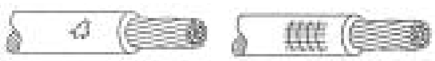
- *the lay (twisting) of conductors must be maintained. They should not be over twisted or straightened.*



- *the insulation should be cut clean and square to the wire, without undue stretching of the insulation material. Beware, manually setting a strip length of 5mm on a gauge does not guarantee that this length will be achieved. All insulations stretch to some extent when the waste slug of material is pulled off the wire (unless the insulation is completely cut through which is almost impossible to achieve in practice).*



- *the remaining insulation should not be scared or cut. Grip marks are acceptable provided the insulation returns to its original shape in due time.*



- *the conductors should be clean. Ensure that there are no remaining scraps of insulation trapped between conductors and brush away any powder deposits (powder is often included in cables to stop cores/conductors from adhering to the insulation).*

Some Common Wires and Cables

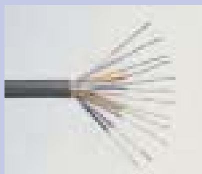

Flexible Mains Cable


Equipment Wire


Conduit Cable

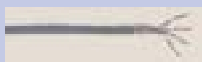

Switchgear Cable


FCC 68 Flat Modular Cable

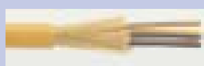

Unscreened Multi core Cable


Screened Multi core Cable


Unscreened Twisted Pair


Screened Twisted Pair


Coaxial Cable


Fibre Optic Cable

Stripping Tools

Knives

Dangerous - don't strip wires or cables with them.

Side cutters

This is probably the worlds most popular stripping tool - we don't recommend it! They can cause accidents when used for stripping and success depends on feel/operator dexterity.

Adjustable V blade pliers

Very popular but success depends upon the operator setting the tool properly, furthermore the tool must be adjusted each time a different type of wire has to be stripped.

Adjustable Rotary Action Strippers

As above these require correct setting of the blade depth to achieve a good strip. However they are one of the best types to use on heavy duty cables. The cable hook can be pushed open to accommodate a large range of sizes and the blade can be turned to produce rotary cuts around the cable, spiral cuts about the cable and longitudinal cuts along the cable.

Die Strippers

These tools feature ground nests into which wires can be placed for stripping. Whilst useful as service tools they can be easily misused. Success relies on the operator putting the right wire into the right nest. All too often in production this does not happen. Furthermore a large range of tools are required to cover a reasonable wire size range.

Self Adjusting Cut & Strip Tools

These tools use mechanical feedback to sense the outer diameter of the wire to be stripped and therefore a large number of different sized wires can be successfully stripped without user adjustment of the tool reducing the risk of nicked conductors. Additionally most models feature a wire cutter which is especially useful for cabinet and service use. These tools are ideal as general purpose PVC insulated wire stripping tools but are not effective when used on rubber or PTFE type insulations.

Precision Stripping Tools

These tools feature precision ground die blades against which the wire insulation is further supported and guided. The tools at right are each individually specified to specific wire size and insulation width. The tools below right can strip a number of wire sizes but each die nest is also designed for a specific wire size and insulation width. These tools are especially suitable for fibre optic and aerospace wires and cables.

Machines

For volume applications no hand tool can compete with a machine, the best of which feature digital control over cut depth and stripping length. Some are even able to cut multiple layers of coaxial cables. Numerous types are available from semi to fully automatic. Stripping blades can be supplied to suit any wire configuration.

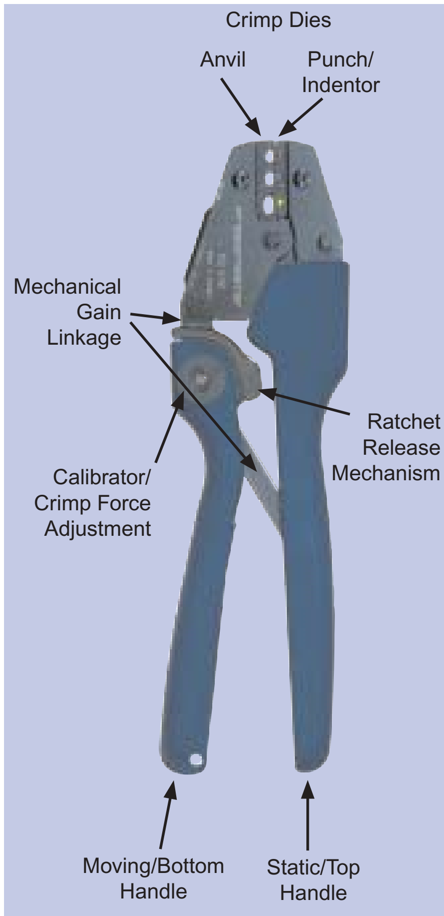
Crimp Tools

It can require a force of over 1 tonne to crimp even the smallest of connectors to within an accuracy of ± 0.001 mm.

By and large the precision and ease of use of crimp tools is directly related to their cost, with more features being added as you move up the scale.

The reason why there is such a large range of crimp tools is that manufacturers try to design out the possibility of human error in the crimp process. At the lowest level a good or bad crimp corresponds to the force that a human hand can impart to the crimp pliers, the positioning of the connector in the crimp dies and the quality of the crimp die profiles. At the top level mechanical linkages are employed to increase mechanical gain, locators are employed to correctly position the connector, ratchets to ensure a complete crimp cycle and dies are ground and matched to the tool frame to guarantee the precision required.

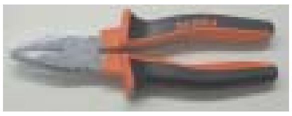
It would clearly be unacceptable for an end user to have to purchase a professional military specification crimp tool (costing as much as a new kitchen) to perform a once in a lifetime repair on a car. Similarly it would be inappropriate for a pair of pliers to be used by an electrician completing crimps every day of the week. Therefore we have categorised the following selection of crimp tools according to their intended usage.



Crimp Tools

Never Use

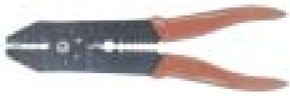
Pliers



It could be done. We definitely don't recommend it! Producing an acceptable crimp is down to pure chance.

Incidental Use

Combination Pliers



An acceptable crimp using even the best made (most aren't) crimp/strip pliers is totally dependant upon the feel of the operators' hand. These tools are best left to be used in emergency tool kits, for example replacing a critical connector on your car in the middle of the Sahara desert.

Occasional Use

Crimp pliers with mechanical gain

These tools employ a compound plier action to increase leverage and therefore increase the force that can be applied at the dies. However the crimp result is still directly related to the hand force applied.
Over Centre/Toggle Action Crimp tools

As well as employing a mechanical gain linkage these tools try to give an indication of when a crimp has been completed (the handle force reduces after a given point, centre). Nevertheless it is still possible to release the handle without having completed a crimp cycle.

With all of the above tools note that the crimp dies are integrated into the frame of the tool to reduce cost. Inevitably this compromises the precision of the die profiles.

Moderate Use

Scissor Action Ratchet Release

At last we come to a type of tool that offers: mechanical gain, a ratchet that ensures that the crimp cycle must be completed before handle release (for emergencies a ratchet release mechanism is normally incorporated), the opportunity for tool calibration via an offset screw adjuster, the possibility of interchangeable dies (this is not always desirable as for precision crimps the tool frame is calibrated to the die), locators and wire stops can be incorporated into the tool/die design.
Dies are available for this level of tool manufactured to extremely fine tolerances and can produce acceptable crimps for all but the most demanding of applications.
A major benefit of scissor action tools is that they can be manufactured to a relatively compact size and the face of the tool is small enough to give easy access in restricted spaces.
Some designs, especially for end splice terminals allow the connector to be inserted into the dies from the front of the tool.
At this level the opportunity for human error has been reduced to a minimum, although it must be stressed that there are many different quality levels of this type of tool available.

Frequent Use

Ergonomic Crimp Tools

A relatively recent innovation developed with the knowledge that has been acquired from research into repetitive strain injuries, these have all the benefits of the previous tool but particular attention has been given to the mechanical gain mechanism, handle form and material usage to significantly reduce the hand pressures required to crimp.
One unfortunate side effect of such tools is that greater leverage is always achieved with longer levers, therefore the size of the tools tend to be bigger than others.
The best designs allow the tool to be closed one handed and then two hands can be used for the crimp itself

Precision User

Parallel Action Tools


One of the principal drawbacks of scissor action crimp tools is that the connector is always to some degree squeezed towards the front of the tool. Tool manufacturers design dies to allow for this effect, yet there will always be some kinds of connector which will not crimp with a scissor action tool.
Sharing all of the features of scissor action ratchet tools parallel action tools are available in two types: "closed head" (as above left) which gives the strongest, most rigid die platform but has restricted access for connector entry; and "open head" which has better die accessibility but the tool frame must be significantly enlarged/strengthened to ensure a stable die platform.
These tools are inherently the most precise but same application to application a parallel action tool will always be bigger than its' scissor action counterpart.

For heavy duty, high power connectors long handled tools are available to provide the required crimp force.

High Volume/Production

Portable

Until recently portable crimp machines had been bulky and the crimp heads in particular extremely heavy. Furthermore they relied on compressed air as a power source which assumes that the end user has a compressor at hand. The unit shown above is powered by rechargeable battery or mains, is microprocessor controlled and has a lightweight crimp head the hose of which extends to 2 metres to enable use at arms length if necessary. The unit is part of a system which includes accessories to convert it for foot pedal operated bench mount applications if so desired. Extremely versatile and precise, this tool could be described as the ultimate hand crimp tool.

Bench Top & Fully Automated

For volume production crimp presses are available from the simplest toggle lever action type to fully automated workstations that can cut, strip, terminate and then bundle wires and connectors into complete wire harnesses.
Connectors are supplied in reel (strip) form with applicators (die sets and bolster with feeds) being supplied directly by the connector manufacturers.

Good or bad crimp?

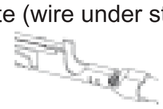
The key elements to achieving a good crimp are:
- select the right wire
- strip it correctly
- select the right connector
- select the right crimp tool
- crimp according to the manufacturers instructions.

There are many techniques available today to test for a good crimp, some involving laboratory equipment which require destroying the crimp itself. This would clearly be unacceptable for use out in the field or for small volume crimping where it would become uneconomical.

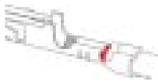
At a bare minimum the crimp should be visually inspected to ensure that:
- there are no loose conductor strands lying outside of the connector.

- there isn't an excess of exposed conductor showing out the back or front of the crimp area (wire over stripped).


- the crimp area fully encapsulates the conductors and insulation when appropriate (wire under stripped).



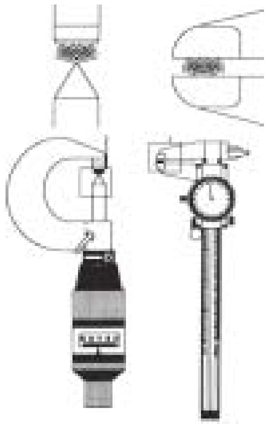
- there is no insulation in the conductor crimp area.



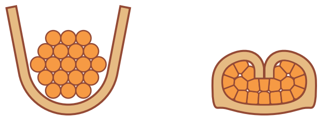
- where the tool manufacturer has incorporated a mark of some kind into the crimp dies, the mark produced in the crimp correlates to the wire size of the connector/wire.

For higher volume requirements it becomes economical to use a pull-off tester.

These are bench mount machines which literally pull the connector off the wire and display the maximum force required for doing so. The forces can then be compared to readily available international standards and recommendations from the connector manufacturer. Once a norm has been established the crimp height can be measured and used in production to give a non-destructive means of indicating any significant variation from the norm.



For high precision applications it may be necessary to produce a cross-section of the crimp area to further assess its' efficacy.



Before After

This process requires that the middle of the conductor barrel is sectioned with a precision wet saw, mounted in a mould or fixture, ground and then polished. The section may further be chemically etched to enhance detail.

The section can then be viewed in a microscope and inspected for any imperfections. Particularly:
- correct crimp height and width?
- does the crimp barrel fully enclose the conductors and has it been damaged in any way (flashing or cracks)?
- is there a generally uniform polygonal shape to the conductor strands. Circular conductors would indicate an under crimp?
- are there any excessive gaps/voids between the conductors (under crimp)?
- have any parts of the crimp barrel pierced entirely through the wire (over crimp)?
- are all the wire strands accounted for?

Furthermore the image can be digitally captured allowing for very accurate calculation of crimp compression.

Electrical testing can also be required which not only measures the volt drop across the terminal (which must be less than that across an equivalent length of wire) but also the heating effects of on-off loads and repeated short circuit tests (again the heating effect must be less than that across an equivalent length of wire).

Other tests that can be performed which are more closely related to the application are: vibration, bending and corrosion resistance.

International standards

International
IEC 352-2: Solderless crimped connections - General requirements, test methods and practical guidance

USA
UL 486: mechanical and electrical testing of all connectors

Germany
VDE 0220: Copper and aluminium connectors
DIN 46 249: Mechanical and electrical testing of push-on terminals and flat tabs

France
NF C 63-061: Aluminium terminations, electrical cycle and short circuit testing
NF C 20-130: Copper tests with measures for terminals/connectors

British
BS 4579/1,3: Electrical and mechanical testing of copper and aluminium connectors
BS 5057: Mechanical and electrical testing of push-on terminals and flat tabs

Swedish
SEN 24 50 10: Pull-out force and short circuit testing of copper terminations
SEN 24 50 12: Short circuit and temperature cycle testing of aluminium terminations

Summary

With all of the variables involved, the perfect crimp probably doesn't exist, but satisfactory crimps should be achievable 100% of the time provided that the right wire is correctly prepared for the right connector and crimped with the right tool according to manufacturers instructions.

Glossary

Barrel - (1) Conductor Barrel - The section of the terminal, splice or contact that accommodates the stripped conductor (2) Insulation Barrel - The section of the terminal, splice or contact that accommodates the conductor insulation
Bayonet coupling, rotary - A quick coupling device for mating connectors utilizing pins on a connector and ramps on the mating connector. Mating and unmating is accomplished by rotating the coupling ring
Body, connector - The main portion of a connector to which contacts and other components are attached. This term is not used with connectors incorporating non integral shells in their construction
Boot - A form placed around the wire terminations of a multiple contact connector as a protective housing or as a container for potting compound
Braid - Flexible conductor made of a woven or braided assembly of fine wires
Busing - The joining of two or more circuits
Butting dies - Crimping dies so designed that the nest and indenter touch at the end of the crimping cycle. (Also called bottoming dies
Cable clamp - A mechanical clamp attached to the cable side of the connector to support the cable or wire bundle, provide strain relief, and absorb vibration and shock otherwise transmitted by the cable to the contact/wire connection
Cable shielding clamp - A device consisting of a sealing member and cable support designed to terminate the screen (shield) of an electrical cable
Circumferential crimp - The type of crimp where the crimping dies completely surround a barrel resulting in symmetrical indentations in the barrel
Closed entry - A contact or contact cavity design in the insert or body of the connector which limits the size or position of the mating contact or printed circuit board to a predetermined dimension
Coaxial contact - A contact having two conducting surfaces, a centre contact and a coaxially placed sleeve
Colour coding - A system of identification of terminals and related devices
Conductor stop - A device on a terminal, splice, contact or tool used to prevent excessive extension of the conductor barrel
Connector, electrical - A device, either a plug or receptacle, used to terminate or connect the conductors of individual wires or cables and provide a means to continue the conductors to a mating connector or printed circuit board
Contact - The conductive element in a connector which makes actual contact, for the purpose of transferring electrical energy
Contact area - The area in contact between two conductors, two contacts, or a conductor and a contact permitting the flow of electricity
Contact arrangement - The number, spacing and arrangement of contacts in a connector
Contact engaging and separating force - Force needed to either engage or separate mating contacts
Contact resistance - Electrical resistance of a pair of engaged contacts
Contact retainer - A device either on the contact or in the insert to retain the contact in an insert or body
Contact retention - The axial load in either direction which a contact can withstand without being dislodged from its normal position within an insert or body
Contact size - An assigned number denoting the size of the contact engaging end
Contact shoulder - The flanged portion of a contact which limits its travel into the insert
Coupling ring - That portion of a plug which aids in the mating or unmating of a plug and receptacle and holds the plug to the receptacle
Crimp - The physical compression (deformation) of a contact barrel around a conductor in order to make an electrical connection
Crimping - A pressure method of mechanically securing a terminal, splice or contact to a conductor
Crimping dies - Portion of the crimping tool that shapes the crimp
Crimping tool - Mechanism used for crimping
Depth of crimp - The distance the indenter penetrates into the barrel
Die Closure - The gap between indenter dies at full handle closure. Usually defined by Go/No-Go dimensions
Dielectric - A material having electrical insulating properties
Environmentally sealed - A device that is provided with gaskets, seals, grommets, potting or other means to keep out moisture, dirt, air or dust which might reduce its performance
Extraction tool - A device used to remove a contact from a connector
Ferrule - A short tube used to make connections to shielded or coaxial cables
Flange, connector - A projection extending from or around the periphery of a connector with provisions to permit mounting the connector to a panel
Front mounted - A connector mounted on the outside of a panel or box with its mounting flange outside the equipment
Full cycle control - Controls placed on the crimping cycle of crimping tools forcing the tool to be closed to its fullest extent completing the crimping cycle before the tool can be opened
Grommet, connector - An elastomeric seal used on the cable side of a connector to seal the connector against moisture, air and dirt
Grounding fingers - A set of spring fingers provided in the connector to allow shell to shell grounding, before contacts mate and after they separate
Guide pin - A pin or rod extending beyond the mating faces of a connector designed to guide the closing or mating of the connector to ensure proper engagement of contacts
Head assembly - A positioner or turret designed to attach to a crimping tool
Hermaphroditic connector - A connector design which utilizes pin and socket contacts in a balanced arrangement such that both mating connectors are identical
Hermaphroditic contact - A contact design which is neither pin nor socket and which mates with other contact of the same design
Indenter - That part of a crimping die, usually the moving part, which indents or compresses the contact barrel
Insert, electrical connector - An insulating element with or without contact(s), designed to position and support contacts in a connector
Inspection hole - A hole placed at the bottom end of a contact wire barrel to permit visual inspection to see that the conductor has been inserted to the proper depth in the barrel prior to crimping
Installing tool - A device used to install contacts into a connector
Insulation displacement connector (IDC) - An assembly process wherein an insulation piercing edge of the contact is pushed through the insulation and into contact with the wire by the assembly press
Insulation support - The portion of a barrel similar to an insulation grip except that it is not compressed around the conductor insulation
Interface - The two surfaces on the contact side of mating connectors or plug-in component and receptacle, which face each other when mated
Interfacial seal - A sealing of mated connectors over the whole area of the interface to provide sealing around each contact
Jacket - The outermost layer of insulating material of a cable or wire
Key - A short pin or other projection which slides in a mating slot, hole, groove or keyway to guide two parts being assembled
Locator - Device for positioning terminals, splices, or contacts into crimping dies, positioner, or turret heads
Millivolt drop test - A test designed to determine the voltage loss due to resistance of a crimped joint
Nest - The portion of a crimping die which supports the barrel during crimping
Nick (notch) - A cut or notch in conductor strands or insulation
Pigtail - A short wire extending from an electric or electronic device to serve as a jumper or ground connection
Pin contact - A contact having an engagement end that enters the socket contact
Plating - The overlaying of a thin coating of metal on metallic components to improve conductivity, provide for easy soldering or prevent rusting or corrosion
Plug connector - An electrical fitting with pin, socket, or pin and socket contacts, constructed to be affixed to the end of a cable, conduit, coaxial line, cord or wire for convenience in joining with another electrical connector(s), and not designed to be mounted on a bulkhead, chassis or panel
Polarize - The arrangement of mating connectors such that the connector can be mated in only one way
Polarizing pin, key or keyway - A device incorporated in a connector to accomplish polarization
Positioner - A device when attached to a crimping tool locates the contact in the correct position
Potting - The permanent sealing of the cable end of a connector with a compound or material to exclude moisture and/or to provide a strain relief
Power contact - Type of contact used in multi-contact connectors to support the flow of rated current
Pull-out force - Force necessary to separate a conductor from a contact or terminal, or a contact from a connector, by exerting a tensile pull
Rack and panel - The type of connector that is attached to a panel or side of equipment so that when these members are brought together, the connector is engaged
Radio frequency contact (RF contact) - An impedance matched shielded contact
Range, wire - The sizes of conductors accommodated by a particular barrel
Ratchet control - A device to ensure the full crimping cycle of a crimping tool
Receptacle, connector - An electrical fitting with contacts constructed to be electrically connected to a cable, coaxial line, cord, or wire to join with another electrical connector(s), and is designed to be mounted on a bulkhead, wall, chassis, or panel
Sealing plug - A plug which is inserted to fill an unoccupied contact aperture in a connector insert
Seamless terminal or splice - Terminal or splice conductor barrel made without an open seam
Selective plating - The application of plating material to a limited portion of a connector contact, especially those areas susceptible to wear
Service rating - The maximum voltage or current with a connector is designed to carry continuously
Shell, electrical connector - The outside case of a connector into which the dielectric material and contacts are assembled
Shielded contact - A contact which carries alternating current and is shielded from unwanted signals (RFI and EMI)
Socket contact - A contact having an engagement end that will accept entry of a pin contact
Solderless connection - The joining of two metals by pressure means without the use of solder, braze, or any method requiring heat
Splice - Device used to join two or more conductors to each other
Stop plate (see locator) - A device attached to a crimping tool to properly locate a terminal, splice or contact in the tool prior to crimping
Strip - To remove insulation from a conductor
Taper pin - A pin type contact having a tapered end designed to be impacted into a taper hole
Tensile testing - A controlled pull test on the crimp joint to determine its mechanical strength
Threaded coupling - A means of coupling mating connectors by engaging threads in a coupling ring with threads on a receptacle shell
Thermocouple contact - Contact of special material used in connectors employed in thermocouple applications
Turret Head - A device that contains more than one locator which can be indexed by rotating a circular barrel, and when attached to a crimping tool, positions the contact
Zero-force connector - A connector in which the contact surfaces do not mechanically touch until it is completely mated thus requiring no insertion force

Conversion Tables

AWG American Wire Gage to mm^2

AWG	Stranding*	Outside diameter** Inches	mm	Wire Area Circular mils***	mm^2
44	1	0.00198	0.050	3.92	0.002
42	1	0.00249	0.063	6.20	0.003
40	1	0.00314	0.080	9.86	0.005
38	1	0.00396	0.101	15.68	0.008
36	1	0.00500	0.127	25.00	0.013
36	7/44	0.00600	0.153	27.44	0.014
34	1	0.00630	0.160	39.69	0.020
34	7/42	0.00750	0.191	43.40	0.022
32	1	0.00795	0.202	63.20	0.032
32	7/40	0.00930	0.203	69.02	0.035
32	19/44	0.01000	0.229	74.49	0.038
30	1	0.0100	0.254	100.0	0.051
30	7/38	0.0120	0.305	109.8	0.056
30	19/42	0.0120	0.305	117.80	0.060
29	1	0.0113	0.287	127.7	0.065
28	1	0.0126	0.320	158.8	0.080
28	7/36	0.0150	0.381	175.0	0.089
28	19/40	0.0160	0.406	187.3	0.095
27	1	0.0142	0.361	201.6	0.102
26	1	0.0159	0.404	252.8	0.128
26	7/34	0.0190	0.483	277.8	0.141
26	10/36	0.0210	0.553	250.0	0.127
26	19/38	0.0200	0.508	297.9	0.151
25	1	0.0179	0.455	320.4	0.162
24	1	0.0201	0.511	404.0	0.205
24	7/32	0.0240	0.610	442.4	0.224
24	10/34	0.0240	0.610	396.9	0.201
24	19/36	0.0240	0.610	475.0	0.241
24	42/40	0.0230	0.584	414.1	0.210
22	1	0.0253	0.643	640.1	0.324
22	7/30	0.0300	0.762	700.0	0.355
22	19/34	0.0310	0.787	754.1	0.382
20	1	0.0320	0.813	1024	0.519
20	7/28	0.0370	0.890	1111	0.563
20	10/30	0.0370	0.890	1000	0.507
20	19/32	0.0370	0.940	1201	0.608
20	42/36	0.0360	0.914	1050	0.532
18	1	0.0403	1.024	1624	0.823
18	7/26	0.0480	1.220	1770	0.897
18	16/30	0.0470	1.200	1600	0.811
18	19/30	0.0490	1.240	1900	0.963
18	42/34	0.0470	1.200	1667	0.845
18	65/36	0.0470	1.200	1625	0.823
16	1	0.0508	1.290	2581	1.308
16	7/24	0.0600	1.520	2828	1.433
16	19/29	0.0580	1.470	2426	1.229
16	26/30	0.0590	1.500	2600	1.317
16	65/34	0.0590	1.500	2580	1.307
16	105/36	0.0580	1.470	2625	1.330
14	1	0.0641	1.628	4109	2.082
14	7/22	0.0760	1.930	4481	2.270
14	19/26	0.0710	1.800	4803	2.434
14	42/30	0.0750	1.900	4200	2.128
14	105/34	0.0750	1.900	4167	2.112
12	1	0.0808	2.052	6529	3.308
12	7/20	0.0960	2.440	7168	3.632
12	19/25	0.0930	2.360	6088	3.085
12	65/30	0.0950	2.410	6500	3.294
12	165/34	0.0950	2.410	6549	3.318
10	1	0.1019	2.588	10384	5.261
10	37/26	0.1150	2.920	9354	4.740
10	49/27	0.1160	2.950	9880	5.006
10	65/28	0.1200	2.950	10319	5.229
10	105/30	0.1180	2.950	10500	5.320

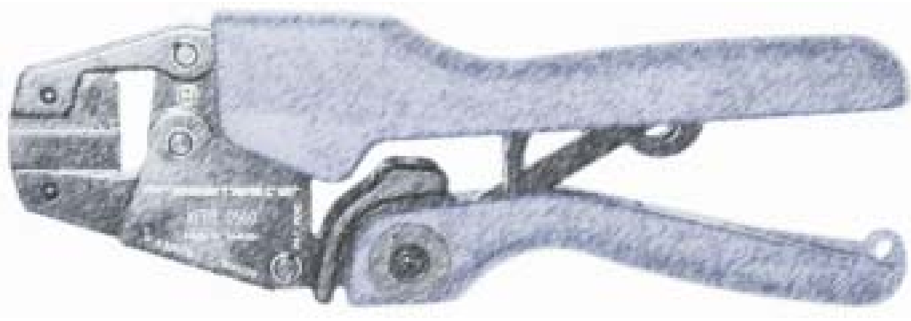
* 7/36 means 7 strands of nominal 36 AWG wire.

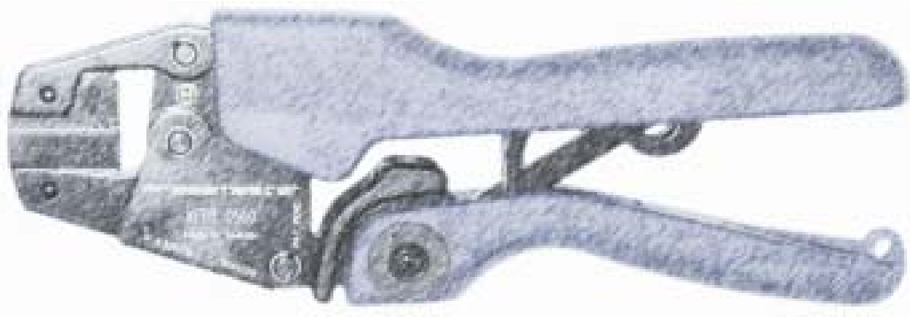
** the outside diameters and circular mil areas of stranded wires are approximate

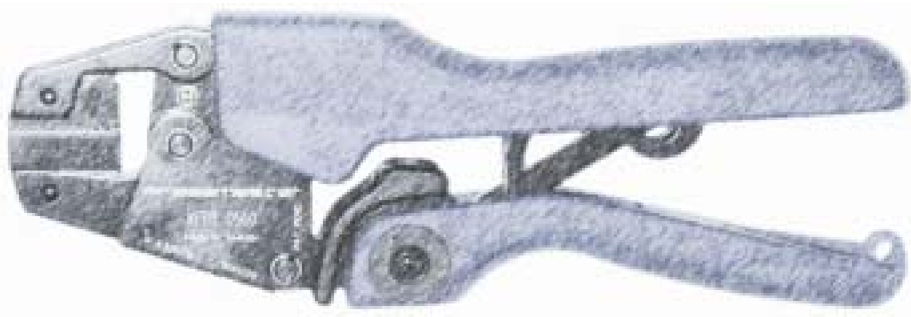
*** a circular mil is the area of a circle 0.001 inch in diameter.

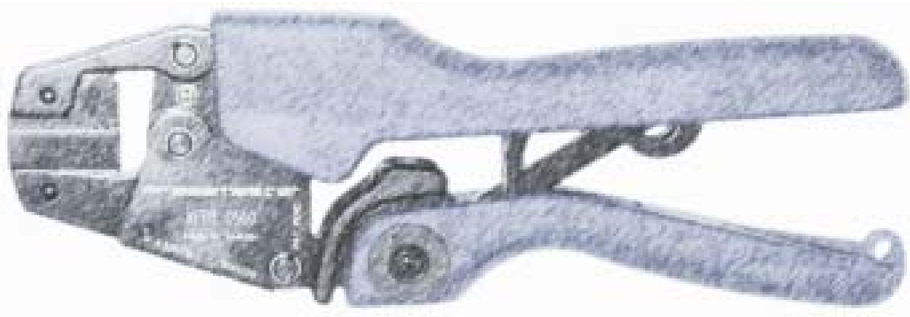
Unit Conversion Factors

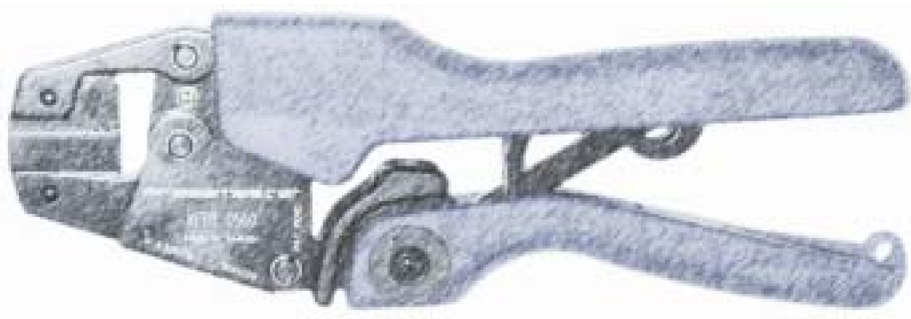
Unit x	Constant =	Unit
BTU	778.0	foot-pound (ft-ib)
BTU	1054.8	joules
BTU	0.293	watt-hours (w-hr)
centimetres (cm)	0.032808	feet (ft)
centimetres (cm)	0.3937	inches (in)
centimetres (cm)	0.00001	kilometres (km)
centimetres (cm)	0.010	meters (m)
centimetres (cm)	10.0	millimetres (mm)
circular mils	0.00064516	circular millimetres
circular mils	0.0000007854	$inches^2$ (in^2)
circular mils	0.000506671	square millimetres (mm^2)
circular mils	0.7854	$mils^2$
cubic centimetre (cm^3)	0.000035314	cubic foot (ft^3)
cubic centimetre (cm^3)	0.061023	cubic inch (in^3)
cubic centimetre (cm^3)	0.000001	cubic meter (m^3)
cubic centimetre (cm^3)	0.0026417	gallons
cubic foot (ft^3)	17280.	cubic inch (in^3)
cubic foot (ft^3)	28317.016	cubic centimetre (cm^3)
cubic inch (in^3)	0.00057870	cubic feet (ft^3)
cubic inch (in^3)	0.000016387	cubic meter (m^3)
cubic inch (in^3)	16.387162	cubic centimetre (cm^3)
cubic meter (m^3)	1000000.0	centimetre (cm)
cubic meter (m^3)	35.314456	cubic foot (ft^3)
cubic meter (m^3)	264.17	gallons
feet (ft)	0.00018939	miles
feet (ft)	0.33333	yards (yd)
feet (ft)	12	inches (in)
feet (ft)	0.00030480	kilometres (km)
feet (ft)	0.30480	meters (m)
feet (ft)	30.480	centimetres (cm)
feet (ft)	304.80	millimetres (mm)
feet/pound (ft/lb)	0.00067197	meters/grams (m/g)
foot/pound (ft-lb)	0.001285	BTU
foot/pound (ft-lb)	1.356	joules
foot/pound (ft-lb)	0.1383	kilogram/meter (kg/m)
gallons	3.785332	litres (1)
gallons	0.13368	cubic foot (ft^3)
gallons	231.0	cubic inch (in^3)
gallons	3785.332	cubic centimetre (cm^3)
grams (g)	15.432	grains
gram/centimeter^3 (gm/cm^3)	0.0361275	pounds/in^3 (lb/m^3)
horsepower (hp)	33000.0	ft-lb/min
horsepower (hp)	550.0	ft-lb/sec
horsepower (hp)	745.7	watts (w)
inch (in)	0.027178	yards (yd)
inch (in)	0.083333	feet (ft)
inch (in)	0.00002540	kilometre (km)
inch (in)	0.025400	meter (m)
inch (in)	2.54000514	centimetre (cm)
inch (in)	25.4000514	millimetre (mm)
inch (in)	1000.0	mils
joules	0.000948	BTU
joules	107	ergs
litres (1)	61.0250	cubic inch (in^3)
meters (m)	1.093611	yard (yd)
meters (m)	3.2808333	feet (ft)
meters (m)	39.37	inch (in)
meters (m)	100.0	centimetre (cm)
miles	1760.0	yards (yd)
miles	5280.0	feet (ft)
miles	1.6093	kilometre (km)
millimetres (mm)	0.0032808	feet (ft)
millimetres (mm)	0.03937	inch (in)
millimetres (mm)	0.001	meters (m)
millimetres (mm)	0.01	centimetres (cm)
millimetres (mm)	39.3701	mils
millimetres. (mm)	1000.0	microns (p)
watts (w)	44.25	ft-lb/minute
watts (w)	0.737562	ft-lb/sec
watts (w)	0.001341	horsepower (hp)
watt-hours (w-hr)	3.41266	BTU

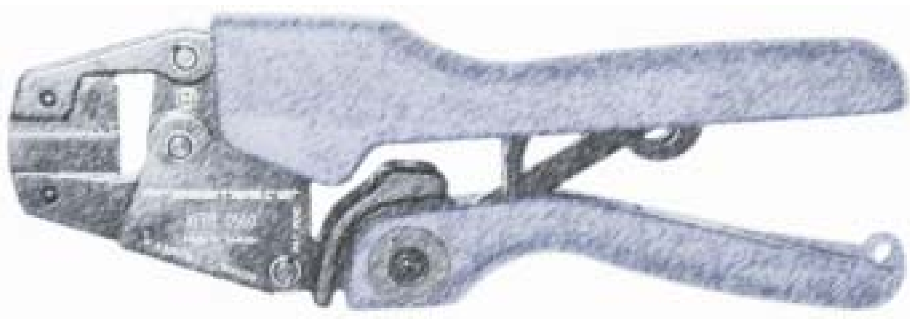












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