Electricity, Cables and Cable Joints

Basic electricity

The measurement of electrical 'pressure' (think of water pressure) is in Volts, usually abbreviated as 'V'. e.g. 30V is thirty volts.

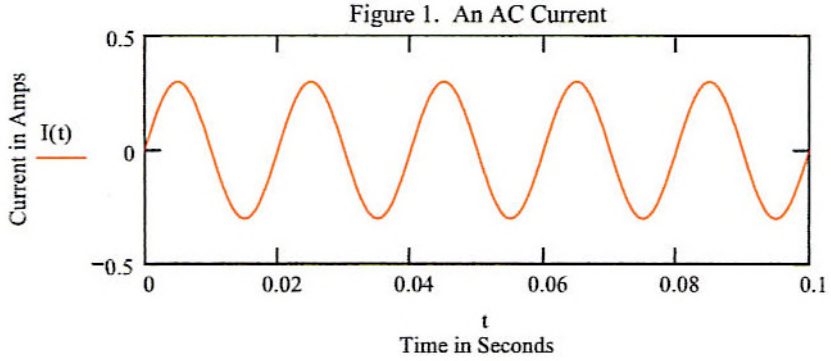
The measurement of electrical current (think of water flow) is in Amps or sometimes milliamps (1/1000Amp), usually abbreviated to 'A' or 'mA'. e.g. 100mA is one hundred milliamps (=100/1000 Amps) = 0.1A, which is nought point one of an Amp.

The measurement of the resistance to current (flow) for a given voltage (pressure) is in ohms. Think of a narrow bore pipe resisting water flow at a given pressure compared to a wide bore pipe with the same pressure behind it. That is the narrow bore pipe has a higher resistance. Ohms are abbreviated to the Greek letter Omega and written Ω e.g. 100Ω is one hundred ohms.

There are two main types of voltage which produce correspondingly two types of current. A DC or Direct Current is one which is steady, remaining at one value all the time. An AC or Alternating Current on the other hand fluctuates regularly from positive to negative and back again, in our case 50 times a second or 50Hz pronounced fifty hertz. The wave shape of the alternating current is called a sine wave and has the shape drawn in figure 1.

$f := 50 \cdot Hz \qquad I_{pk} := 300 \cdot 10^{-3} \cdot amp \qquad t := 0, 0.1 \cdot 10^{-3} .. 100 \cdot 10^{-3} \qquad I(t) := I_{pk} \cdot \sin(2 \cdot \pi \cdot f \cdot t)$

Figure 1. An AC Current



Common usage is to refer to a DC voltage or an AC voltage. The AC voltage will have the same shape as the current just illustrated but will of course have the units of Volts.

The AC voltage measured corresponds to the heating power of the voltage. For example, your kettle would boil in the same time whether you connected it to the mains (240V AC) or to 20 series-connected 12V car batteries (20 X 12 = 240V DC). The peak value of the 240V AC mains is as high as plus or minus 340V; however it just doesn't stay there for long.

The flow of current is limited by the resistance of the circuit (i.e. cable). The higher the resistance the lower the flow of current for a particular voltage impressed. A simple law called Ohm's Law relates the entities.

V = I x R (V equals I times R)
Where: V is volts, I is current in amps and R is resistance in Ohms

Using Algebra, also I = V / R and R = V / I (I equals V divided by R etc.)

e.g. Putting 30V across 10Ω results in a current of 30 / 10 = 3A.

Ohm's Law applies for both DC and AC voltages and currents. However some components like solenoid coils have both a DC and an AC resistance which add up, so making the current through the coil smaller than the measured DC resistance would first suggest.

Safety Issues:
Voltage AC or DC can be dangerous, even to kill.

To avoid injury, all voltages on the field wiring are less than 48V, called Extra Low Voltage (ELV). This is internationally recognized as been low enough not to cause harm in any circumstances.

Inside the controller however there will be 115V or 240V which can kill. Avoid opening the insides of a controller with the line (mains) power on. Obey the warning notices placarded. Be extra careful around pumping systems as voltages can be as high as 440V ac.

It is not just the voltage on its own that is dangerous, it is this with the current available. You know that an electric fence can produce 5,000V, but it is not lethal. This is because the current is limited to a very small value. Contrast this with the execution method by electric chair. Only 2,000V is used but with many amps.

An old adage: “It’s the volts that jolts, but the mills* that kills”.

*milliamps

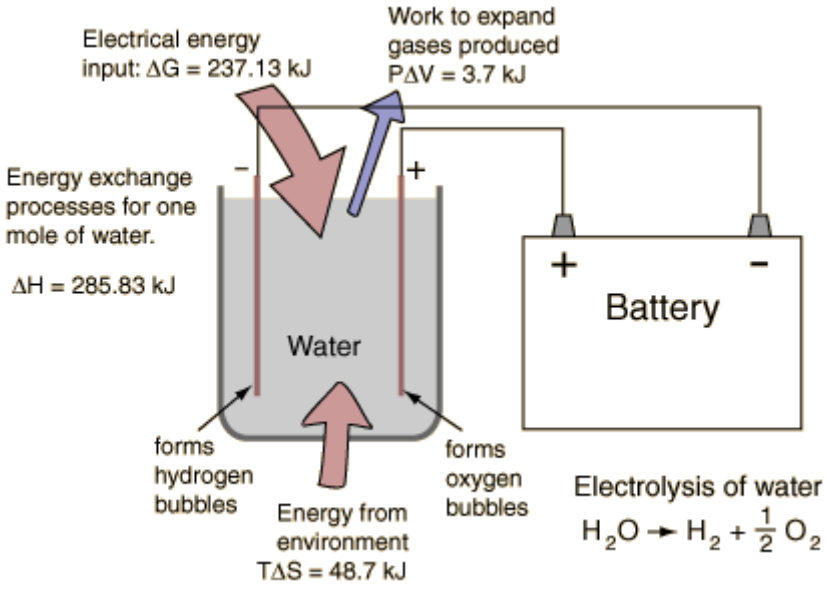
The other factor in the lethality of electric shock is the current path. The worst case is one that passes near the heart. From one arm to another is potentially far more lethal than from a finger to the back of the same hand. Electrical engineers are taught to work on live equipment with one hand in their pocket! (honest!)

In all cases, the manipulation or wiring of more than 48V should be undertaken by a certified electrician. Don’t risk it!

AC or DC, Which is Best?

The Destruction of Field Cables by DC

Perhaps you remember from your school days, the experiment to demonstrate how water can be electrolysed into its component Hydrogen and Oxygen gases. Passing a current through 2 electrodes in water will cause bubbles of Hydrogen to form on the negative electrode and Oxygen on the positive. What you probably do not remember is that the material of the electrodes had been carefully chosen. If you try and repeat the experiment using copper wires, **the copper will dissolve over time** leaving a green sludge in the bottom of the beaker.



This does not happen with AC because the polarity of the voltage changes 50 times a second and the bubbles don't have time to form.

Because of this, irrigation systems which use DC anywhere on the field cables have to have very well insulated wires and cable joints; the copper conductors cannot be allowed to come into contact with water.

To tell whether an irrigation system uses DC anywhere in the field, review the manufacturer's claims for the number of solenoids active at the same time on the same cable. If this exceeds 6, it is likely that DC is being used for what is called solenoid Current Reduction (please refer to the Solenoid section for a discussion on this).

To be fair, providing the cabling and jointing are first class and maintained so, there is no problem with this technique. Irrigation systems which use DC often have detector circuits that will sense imperfect insulation, stop the watering and warn the operator.

If poorly insulated cables or joints are present, only a pure AC system can be used. The down side of this is that only between 2 - 6 solenoids may be active at any one time on the same cable.

Measuring Voltages, Currents and Resistance
Unlike water, electricity cannot be seen. No progress will be made fixing problems without a measuring instrument. The best of these is a **Digital Multimeter.**

A measuring meter that reads AC volts and resistance is a valuable tool in diagnosing faults. When the readout is a sensitive digital display rather than a pointer, it can be used to even better effect. If a sensitive current measuring capability without breaking the wire is available too, the multimeter becomes almost indispensable.

AC volts are used to detect the location of high resistance joints and open circuits.

Resistance (Ohms) allows testing of solenoid coils. It can also be used for the measurement of end-to-end resistance of the cable.

Current measuring capability is used with great effect to detect the point of short circuits, high currents in decoders and the whereabouts of earth leakage.

Current Clamp Meter
Hint: Use a ‘Leakage Clamp Meter’ and not an ordinary clamp meter as they do not have the current resolution to be of much use.

Examples:

Type	Part Number/Distributor
AVO DCM300E	247-0142, RS Components
Clamp Meter	CLMPMTR, TWL Irrigation

When a current flows, it produces a magnetic field. This is how the solenoid can lift its plunger. If a ring of magnetic material is placed around a wire carrying a current, it can be used to detect and measure that current. If the ring can open like the jaws of a crab's claw, be placed around the wire, then closed, there is no need to break the wire to measure the current. Such a device is called a Current Clamp Meter.

This feature is normally included in the features of a multimeter, however most clamp meters have been designed to measure hundreds of amps so are not sensitive enough to measure the current taken by an individual decoder. A ‘leakage clamp meter’ can easily measure to one tenth of a milliamp and can be used to check a decoder's standby current which is often a reliable indication of its goodness.

Also knowing the standby currents of decoders allows an estimate of the number on a branch of the cable!

Cables for Field Wiring

Field wiring must be made with the correct type of cable. This typically conforms to the following description:

- Designed for direct burial
- Solid, single conductor, not stranded
- Insulated with PVC, polypropylene or polyethylene
- Rated for at least 48V ac
- Un-armoured
- If multicore (2 or 3 conductor), the overall insulating sheath & packing to make a round profile.

Like water pipe, the more current that has to flow, the thicker the copper conductors have to be to avoid too much volt drop when solenoids are on. Resistances of popular conductor sizes are given in the table below. The resistance tabled is for out and back e.g. 'Ohms per 1000ft, 2 way', is the resistance for 2000ft of cable.

Size mm.sq.	Ohms/Km 2 way	AWG	Ohms/1000ft 2 way
0.5	78	18	14.5
0.75	52	16	9.2
1	39	14	5.2
2.5	16	12	6
4	10	10	2.3
6	6.6		

As a rough rule of thumb, allow 250mA (0.25A) per solenoid. The normal minimum voltage to operate a solenoid is 19V ac. Most controllers put out around 32V ac. The maximum voltage drop allowed in the cable will then be 32V-19V= 13V.

Using Ohms Law V = I x R

Say we have 4 solenoids, 4 x 0.25A = 1A

At the end of 1000m (1Km), 2.5mm.sq cable will have a resistance of 16 Ohms (=R)
So V = 1A x 16 Ohms = 16 volts… more than 13V; too much

Won't work.
Need fewer solenoids, less distance, higher voltage output from the controller or a thicker cable.

SPREADSHEET

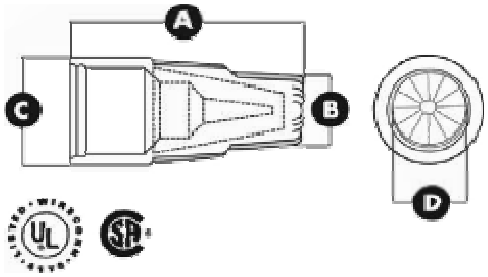
An Excel spreadsheet is available from TWL, called MaxWireRunsStudent.xls. It can help you get more accurate results.

Joining Cables in the Field
Cable joints must be waterproof and afford strain relief. There are many types on the market. Here are a few examples.

Product Specifications

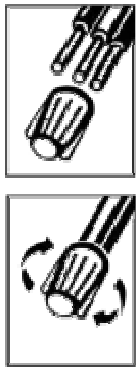
- **Max. Voltage:** 600V (1,000V in fixtures and signs)
- **Size:** 13/16" x 2"
- **Wire Combinations:** Copper/Copper
- **Wire Range:** Min. #22 / Max. #8
- **Temperature Rating:** 75°C (167°F)
- **Silicone Sealant:** -45°F to 400°F
- **Performance Testing:**
  For direct burial according to UL 486D test standard.

Measurements



A	2.00"
B	0.540"
C	0.813"
D	0.547"

Installation Instructions



Important: Turn off power before installing or removing connector. Product to be used in accordance with local and national codes.

1. Strip wires 1/2".
2. Align frayed strands or conductors.
3. NO pre-twisting needed. Hold wires together with ends even. Note: Twist and lead stranded wires slightly.
4. Push wires firmly into connector when starting.
5. Twist connector onto wires pushing firmly until tight. Do not over-torque.
6. DO NOT REUSE.

King 6 Yellow (Gas) Wire Combinations

3-6 # 22	3 # 18 w/ 1-2 #10	2 # 14 w/ 1 # 8 or 10
2-6 # 18 or 20	4 # 18 w/ 1-2 # 12, 14 or 16	3 # 14 w/ 1 #10 or 12
1-6 # 14 or 16	4 # 18 w/ 1 # 10	3 # 14 w/ 2 # 12
1-3 # 10 or 12	5 # 18 w/ 1 # 14 or 16	4 # 14 w/ 1 # 12
4 # 12 solid	1 # 16 w/ 1-4 # 12 or 14	1 # 12 w/ 1 # 8 or 10
I # 22 w/ 2-5 # 20	1 # 16 w/ 1-2 # 10	2 # 12 w/ 1 # 10
1 # 22 w/ 1-5 # 16 or 18	2 # 16 w/ 1-4 # 14	1 # 22 w/ 1 # 16 & 18
2 # 22 w/ 1-4 # 16, 18 or 20	2 # 16 w/ 1-3 # 12	1 # 22 w/ 1-2 # 16 & I # 20
3 # 22 w/ 1-3 # 16, 18 or 20	2 # 16 w/ 1-2 # 10	1 # 16 w/ 1 # 10 or 12 & 1-2 # 14
4 # 22 w/ 1-2 # 16, 18 or 20	3 # 16 w/ 1-3 # 14	1-2 # 16 w/ 1# 10 & 12
1 # 20 w/ 1-4 # 14, 16 or 18	3 # 16 w/ 1-2 # 10 or 12	2 # 16 w/ 1-2 #12 & 1 # 14
2 # 20 w/ 1-3 # 14, 16 or 18	4 # 16 w/ 1-2 # 12 or 14	2 # 16 w/ 1 # 12 & 2 # 14
3 # 20 w/ 1-2 # 14, 16 or 18	4 # 16 w/ 1 # 10	3 # 16 w/ 1 # 10 or 12 & 1 #14
4 # 20 w/ 1-2 #14, 16 or 18	5 # 16 w/ 1 #14	4 # 16 w/ 1 # 10 & 12
1 # 18 w/ 1-4 #12 or 14	5 # 16 solid w/ 1 # 10 solid	2 # 14 w/ 1 # 10 & 1-2 # 12
1-2 # 18 w/ 1-2 # 10	1# 14 solid w/ 1-3 # 12	2 # 14 w/ 1 # 10 & 12
2 # 18 w/ 1-4 # 12, 14 or 16	1 # 14 w/ 1-2 # 10	
3 # 18 w/ 1-3 # 12, 14 or 16	2 #14 w/ 1-2 # 12	

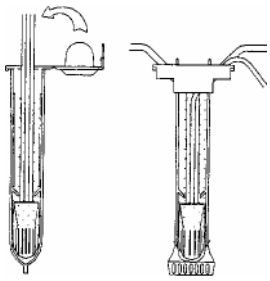
CONNECTOR KING GREASE-FILLED SLEEVES
Used extensively in the UK.

SA101 Connector King grease filled direct burial cable joints SMALL (50 per bag) - Orange **£37.00**
SA102 Connector King grease filled direct burial cable joints MEDIUM (50 per bag) - Yellow **£43.50**
SA103 Connector King grease filled direct burial cable joints LARGE (price per each) **£2.73**
CKGREASE Replacement Grease for Connector Kings **£20.00**

3M DBY/DBR
Direct Bury Splice Kits

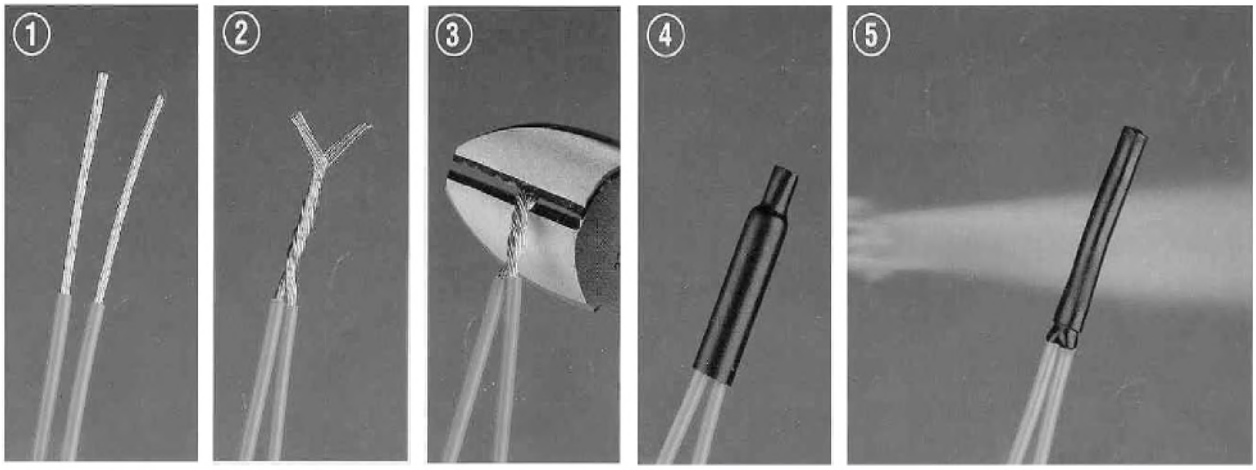
3M DBY/DBR Direct Bury Splice Kits are real time savers when installing underground electrical systems. Every component for the splice is included in the kit. The insulator tube is pre-filled, eliminating the chance of the installer using too much, or too little sealant. No crimping tool, no waste, no mess. Just quick, reliable underground splices for irrigation and sprinkler systems, landscape lighting and other 30-volt underground projects. The splice may be re-entered without cutting the wire (new tube required). These 3M under-ground electrical wire connectors splice and effectively moisture-seal two or more conductors.

Type	No. of Cables	Cable Diameter mm_2	Minimum Cross Section Capacity mm_2	Maximum Cross Section Capacity mm_2
DBY	2-6	1.0	2.0	7.5
	2-4	1.5		
	2-3	2.5		
DBR	5-6	1.0	8.0	24.0
	4-6	1.5		
	2-5	2.5		
	2-4	4.0		
	2	6.0		



Heat Shrinkable Cap

- A heat shrink cap for simple, fast sealing of multiple wire connection without the need for soldering.
- Strip wires to 25mm, twist bare wire ends together. Trim to 12mm. Put on cap and apply heat until cap achieves uniform length and the mastic sealant is visible at the end.



Cap Type	No. of Cables	Cable Diam mm_2
Cap 48	2	0.5 - 1.0
	3	0.5
Cap 64	2	2.5
	3	1.0 - 1.5
Cap 95	2	4.0 - 6.0
	3	2.5 - 4.0
Cap 125	6	4.0
	4	6.0

Code	Description
1012589	Scotchlok® Gel-Filled Connector for 0.5 mm_2 Cable
1012591	Snap-Sure™ Wire Connector
1012592	Sealant Tune 90 ml, to suit Snap-Sure™ Wire Connectors
1012590	Twist Lock Gel Filled Connector, 1.0 mm_2 – 2.5 mm_2 Cable
PA-270325	3M DBY Splice Kits Yellow
PA-270327	3M DBR Splice Kits Red
PA-270217	3M 314 2/3 0.5 – 1.0 mm_2 Cable Connector
PA-270228R	3M 31 6IR 2/3 0.5 – 1.5 mm_2 Cable Connector
PA-CAP48	Size “48” Cap
PA-CAP64	Size “64” Cap
PA-CAP95	Size “95” Cap
PA-CAP 125	Size “125” Cap