Electricity (from ήλεκτρον [electron], "amber") is a general term for a variety of phenomena resulting from the presence and flow of charge. This includes many well-known physical phenomena such as lightning, electromagnetic fields and electric currents, and is put to use in industrial applications such as electronics and electric power. These related, but distinct, concepts are better identified by more precise terms:

- Electric field — an effect produced by an electric charge that exerts a force on charged objects in its vicinity.
- Electric potential — the capacity of an electric field to do work, typically measured in volts (V).
- Electric current — a movement or flow of electrically charged particles, typically measured in amperes (A).
- Electrical energy — the energy made available by the flow of electric charge through an electrical conductor.
- Electric power — the rate at which electric energy is converted to or from another energy form, such as light, heat, or mechanical energy.
- Electric charge — a connection conserved property of some subatomic particles, which determines their electromagnetic interactions. Electrically charged matter is influenced by, and produces, electromagnetic fields.
- Electromagnetism — a fundamental interaction

History of electricity

Static electricity produced by rubbing objects against fur was known to the ancient Greeks, Phoenicians, Parthians and Mesopotamians. The Parthians and Mesopotamians may have had some knowledge of electroplating, based on the discovery of the Baghdad Battery, which resembles a Galvanic cell.

Benjamin Franklin conducted extensive research in electricity. He had theories on the relationship between lightning and static electricity, including his famous kite-flying experiment, which was a key attached to a wet string and kite. During a lightning storm a small spark struck his finger showing that lightning is electricity. It sparked the interest of later scientists whose work provided the basis for modern electrical technology. Most notably these include Luigi Galvani (1737–1798), Alessandro Volta (1745-1827), Michael Faraday (1791–1867), André-Marie Ampère (1775–1836), and Georg Simon Ohm (1789-1854). The late 19th and early 20th century produced such giants of electrical engineering as Nikola Tesla, Antonio Meucci, Thomas Edison, George Westinghouse, Werner von Siemens, Charles Steinmetz, Alexander Graham Bell and William Thomson, 1st Baron Kelvin.

Electric potential

The electric potential difference between two points is defined as the work done (against electrical forces) per unit of charge in moving a positive point charge slowly between two points. If one of the points is taken to be a reference point with zero potential, then the electric potential at any point can be defined in terms of the work done per unit charge in moving a positive point charge from that reference point to the point at which the potential is to be determined. For isolated charges, the reference point is usually taken to be infinity. The potential is measured in volts. (1 volt = 1 joule/coulomb) The electric potential is analogous to temperature: there is a different temperature at every point in space, and the temperature gradient indicates the direction and magnitude of the driving force behind heat flow. Similarly, there is an electric potential at every point in space, and its gradient indicates the direction and magnitude of the driving force behind charge movement.

Electric current

An electric current is a flow of electric charge, and its intensity is measured in amperes. Examples of electric currents include metallic conduction, where electrons flow through a conductor or conductors such as a metal wire, and electrolysis, where ions (charged atoms) flow through liquids. The particles themselves often move quite slowly, while the electric field that drives them propagates at close to the speed of light. See electrical conduction for more information.

Devices that use charge flow principles in materials are called electronic devices.
A direct current (DC) is a unidirectional flow, while an alternating current (AC) reverses direction repeatedly. The time average of an alternating current is zero, but its energy capability (RMS value) is not zero.

Ohm's law is an important relationship describing the behavior of electric currents, relating them to voltage.
For historical reasons, electric current is said to flow from the most positive part of a circuit to the most negative part. The electric current thus defined is called conventional current. It is now known that, depending on the conditions, an electric current can consist of a flow of charged particles in either direction, or even in both directions at once. The positive-to-negative convention is widely used to simplify this situation. If another definition is used - for example, "electron current" - it should be explicitly stated.

Electric field

The concept of electric fields was introduced by Michael Faraday. The electrical field force acts between two charges, in the same way that the gravitational force acts between two masses. However, the electric field is a little bit different. Gravitational force depends on the masses of two bodies, whereas electric force depends on the electric charges of two bodies. While gravity can only pull masses together, the electric force can be an attractive or repulsive force. If both charges are of same sign (e.g. both positive), there will be a repulsive force between the two. If the charges are opposite, there will be an attractive force between the two bodies. The magnitude of the force varies inversely with the square of the distance between the two bodies, and is also proportional to the product of the unsigned magnitudes of the two charges.

Electric charge

Electric charge is a property of certain subatomic particles (e.g., electrons and protons) which interacts with electromagnetic fields and causes attractive and repulsive forces between them. Electric charge gives rise to one of the four fundamental forces of nature, and is a conserved property of matter that can be quantified. In this sense, the phrase "quantity of electricity" is used interchangeably with the phrases "charge of electricity" and "quantity of charge". There are two types of charge: we call one kind of charge positive and the other negative. Through experimentation, we find that like-charged objects repel and opposite-charged objects attract one another. The magnitude of the force of attraction or repulsion is given by Coulomb's law.

DC Voltage

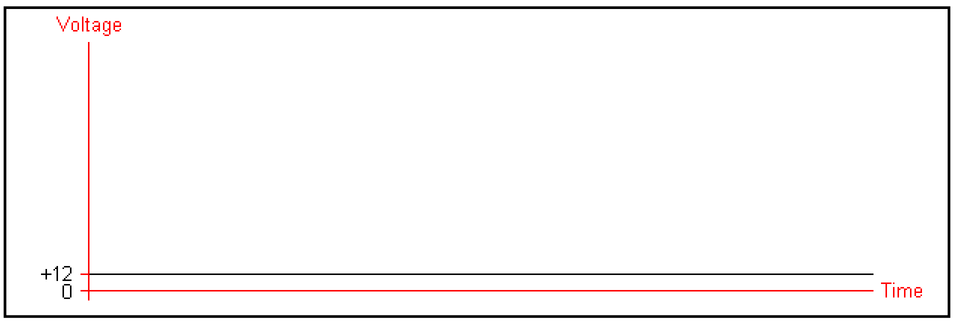
There are two different ways that electricity is produced, and they are used in most cases for very different purposes. They can also be converted from one form to another using transformers, inverters, and rectifiers.
The first and simpler type of electricity is called direct current, abbreviated "DC". This is the type of electricity that is produced by batteries, static, and lightning. A voltage is created, and possibly stored, until a circuit is completed. When the circuit is complete, the current flows directly, in one direction. In the circuit, the current flows at a specific, constant voltage (this is oversimplified somewhat but good enough for our needs.) When you use a flashlight, pocket radio, portable CD player or virtually any other type of portable or battery-powered device, you are using direct current. Most DC circuits are relatively low in voltage; for example, your car's battery is approximately 12 V, and that's about as high a DC voltage as most people ever use. In industrial plants, it is common place to see entire control systems running on +24VDC.

Another less common use of DC is in the transmission of power over great distances. The advantages are numerous, and include more stable power, and much higher transmission efficiency. The disadvantages are higher initial equipment costs, complexity, and the need for constant monitoring.

AC Voltage

The other type of electricity is called alternating current, or "AC". This is the electricity that you get from your house's wall and that you use to power most of your electrical appliances. Alternating current is harder to explain than direct current. The electricity is not provided as a single, constant voltage, but rather as a sinusoidal (sine) wave that over time starts at zero, increases to a maximum value, then decreases to a minimum value, and repeats. A representation of an alternating current's voltage over time is shown in the diagram below.

While simple direct current circuits are generally described only by their voltage, alternating current circuits require more detail. First of all, if the voltage goes from a positive value to a negative value and back again, what do we say is the voltage? Is it zero, because it averages

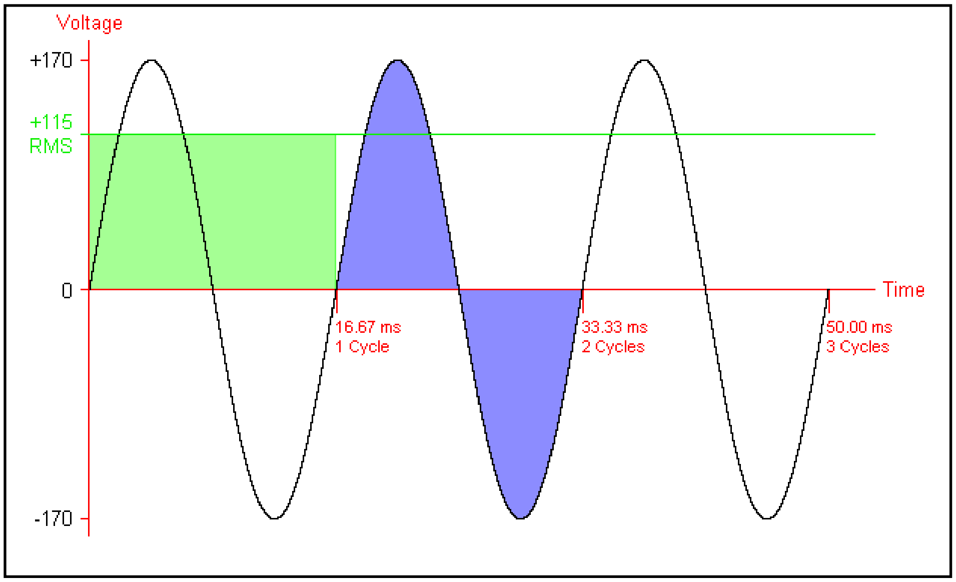


An idealized 12 V DC current. The voltage is considered positive because its potential is measured relative to ground or the zero-potential default state of the earth.
(This diagram drawn to the same scale as the AC diagram, next page.)

out to zero? That would seem to imply that there is no energy there at all. But imagine, if you will, a wave of water flowing across the surface of the sea. The peaks and troughs of the wave seem to "cancel each other out", but the wave clearly exists and has energy. The same is true of alternating current.

The way the science world measures the energy in an AC signal is to compute what is called the root mean square (RMS) average of the voltage. In simple terms, the RMS value of an electrical current is the number which represents the same energy that a DC current at that voltage would produce; it is in essence an average of the alternating current waveform.

Whenever you see an AC voltage specification, they are giving you the RMS number unless they say otherwise specifically. So for example, in North America, most homes have 115 VAC electricity. This is AC electricity equivalent in energy to a 115 V DC circuit. (This is an approximate number, and standard household electricity in North America is also sometimes called 110VAC or 120VAC; it's the same thing.) Other parts of the world use different voltages ranging from 100VAC to 240VAC, and of course, heavy equipment anywhere can use much higher voltages.



Three cycles of an idealized North American 115 VAC, 60 Hz alternating current signal (black curve). Note that each cycle represents 16.67 milliseconds of time, because that is 1/60th of a second. The curve actually goes from -170 V to +170 V in order to provide the average (RMS) value of 115 V. The RMS equivalent is shown as a green horizontal line. To demonstrate what RMS means, look at the blue shaded area, which shows the total energy in the signal for one cycle. The green shading is the area between the RMS line and the zero line for one cycle, and represents the energy in an equivalent 115 V DC signal. The definition of the RMS value is that which makes the green and blue areas equal.
(This diagram drawn to the same scale as the DC diagram above.)

The other key characteristic of AC is its frequency, measured in cycles per second (cps) or, more commonly, Hertz (Hz). This number describes how many times in a second the voltage alternates from positive to negative and back again, completing one cycle. In North America, the standard is 60 Hz, meaning 60 cycles from positive to negative and back again in one second. In other parts of the world the standard is 50 Hz. Please see this "World Electric Guide" to determine the frequency for a given country: http://kropla.com/electric2.htm Note: Always ask the frequency, as there are exceptions.

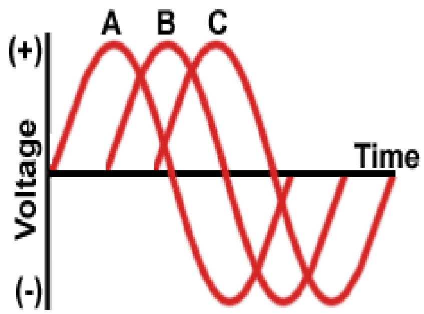
Why does standard electricity come only in the form of alternating current? There are a number of reasons, but one of the most important is that a characteristic of AC is that it is relatively easy to change voltages from one level to another using a transformer, while transformers do not work for DC. This capability allows the companies that generate and distribute electricity to do it in a more efficient manner, by transmitting it at high voltage for long lengths, which reduces energy loss due to the resistance in the transmission wires. Another reason is that it is easier to mechanically generate alternating current electricity than direct current.

3 Phase Electricity

3 phase electricity is referred to alternating current. It is best described as the timing of the electron movements. It is the most common delivery method worldwide because it is a cheaper and easier way to transmit power from one place to another. While this method of electrical transmission is popular in industrial, commercial and institutional power systems, most homes only use single-phase power.

What does it mean?
If wires are in "phase", it means that timing of the electron movement, back and forth, is the same. The electrons are "in step" or "in time".

To transmit and distribute alternating current, it is more efficient to use 3 circuits that are



out of sequence. This idea was discovered by Nikola Tesla (1856 -1943). Much of its efficiency is because there is always voltage (electrons moving) in at least one wire.

He found that it is an arrangement that fits in very nicely with generator design. The 120° phasing separation allows close to the optimum spacing and size of the copper conductors around the stator bore. The compatible generator is the cheapest form to make. This type of power is designed especially for large electrical loads where the total electrical load is divided among the three separate phasing sequences. As a result, the wire and transformers will be less expensive than if these large loads were carried on a single system.

Generators usually have three separate windings, each producing its own separate single-phase voltage. Since these windings are staggered around the generator circumference, each of the voltages is "out of phase" with one another. That is, each of the three reaches the maximum and minimum points in the AC cycle at different times. Power is generated at electric utilities in this way. But, if this power is better than single phase, why not four, five or six phase? Theoretically, these would be even better, but equipment manufacturers would have to build motors to use it, and that just wouldn't be cost effective given the installed base of equipment that must continue to be powered.

The word phase is often abbreviated using the Greek letter "phi" and is written as a zero with a slash mark through it. The most important class of load is the electric motor. An induction motor has a simple design, inherently high starting torque, and high efficiency. Such motors are applied in industry for pumps, fans, blowers, compressors, conveyor drives, and many other kinds of motor-driven equipment. A motor will be more compact and less costly than a motor of the same voltage class and rating; and AC motors above 10 HP (7.5 kW) are uncommon. Three phase motors will also vibrate less and hence last longer than motor of the same power used under the same conditions.

Large air conditioning, etc. equipment use motors for reasons of efficiency, economy and longevity.

Resistance heating loads such as electric boilers or space heating may be connected to systems. Electric lighting may also be similarly connected. These types of loads do not require the revolving magnetic field characteristic of motors but take advantage of the higher voltage and power level usually associated with distribution. Fluorescent lighting systems also benefit from reduced flicker if adjacent fixtures are powered from different.

Large rectifier systems may have inputs; the resulting DC current is easier to filter (smooth) than the output of a rectifier. Such rectifiers may be used for battery charging, electrolysis processes such as aluminum production, or for operation of DC motors. An interesting example of a load is the electric arc furnace used in steelmaking and in refining of ores.

In much of Europe stoves are designed to allow for a feed. Usually the individual heating units are connected between phase and neutral to allow for connection to a supply where this is all that is available.

FULL LOAD CURRENTS FOR THREE PHASE AC INDUCTION TYPE SQUIRREL CAGE AND WOUND ROTOR MOTORS

HP	115V	200V	230V	460V	575V	2300V	4000V
1/2	4	2.3	2	1	0.8		
3/4	5.6	3.2	2.8	1.4	1.1		
1	7.2	4.15	3.6	1.8	1.4		
1 1/2	10.4	6	5.2	2.6	2.1		
2	13.6	7.8	6.8	3.4	2.7		
3		11	9.6	4.8	3.9		
5		17.5	15.2	7.6	6.1		
7 1/2		25	22	11	9		
10		32	28	14	11		
15		48	42	21	17		
20		62	54	27	22		
25		78	68	34	27		
30		92	80	40	32		
40		120	104	52	41		
50		150	130	65	52		
60		177	154	77	62	16	8.8
75		221	192	96	77	20	11
100		285	248	124	99	26	14.3
125		358	312	156	125	31	18
150		415	360	180	144	37	20.7
200		550	480	240	192	49	27.6
Over 200							
Approx Amps/ HP		2.75	2.4	1.2	0.96	0.24	0.14

Relationship of Voltage to Current

Current and voltage are inversely proportional. This means at any given voltage and current, raising the voltage will cause the current to drop.

In this example using a 100 watt light bulb in a house that supplies 110 VAC, we would use the following formula to find the amperes I(amps or current)= W(watts) / V(volts) or 100W / 110V=.909 amps. Moving across town to a house that supplies 120 VAC would result in an amp draw of .833 amps for the same light bulb.

Although we don't sell many light bulbs, the relationship remains the same. The following chart can also be used to get a ballpark idea of what a given motor horsepower equates to in amperes at a given voltage.

Please be aware of the motor type prior to chart use.

FULL LOAD CURRENTS FOR THREE PHASE SYNCHRONOUS MOTORS UNITY POWER FACTOR

HP	460V	575V	2300V	4000V
100	100	80	20	11.5
125	125	100	25	14.4
150	150	120	30	17.2
200	200	160	40	23
250	250	200	50	28.7
300	300	240	60	34.5
350	353	282	70.5	40.5
400	403	322	80.5	46.3
500	500	400	100	57.5
600	600	480	120	69
700	705	564	141	81
800	805	644	161	92.6
900	905	724	181	104
1000	960	768	192	110

This website contains another chart that also covers DC motor loads: http://www.hvacwebtech.com/motoramps.htm

Basic Calculations

Abbreviations used:
W = Watts
V or E = Voltage
I or A = Amps
R = Resistance

Watts to calculate circuit power
W = V x I

Amps to calculate circuit load
I = W / V

Voltage Calculation
V = W / I

Resistance to calculate Ohms
R = W / (I squared)

A somewhat handy ballpark rule of thumb is that a motor will draw about 746 watts per horsepower can be used to estimate horsepower when Voltage and Amperage are known. The actual number that 1 Horsepower = 745.699872 Watts.

This can be useful when the motor has lost its spec plate, or when it has been painted, and the customer has no records. By having the supply voltage measured and the current usage measured with a meter.
Let us assume the readings showed 460VAC supply voltage, and the motor was drawing 40 Amps. With this information we can solve for Watts by multiplying the voltage by the amperage as follows 460V X 40A= 18,400 Watts.
Dividing 18,400 Watts by 746 = 24.66 Horsepower. The specs for this example came off a 30 HP motor, and not a 25 as might be assumed

This is not very accurate for small motors, and is based upon this definition:

Horsepower

Common unit of power, the rate at which work is done. In the English system, one horsepower equals 33,000 foot-pounds of work per minute — that is, the power necessary to lift a total of 33,000 lbs a distance of one foot in one minute. This value was adopted by James Watt in the late 18th century after experiments with strong dray horses and is actually about 50% more than the rate an average horse can sustain for a working day. The electrical equivalent of one horsepower is 746 watts in the International System of Units; the heat equivalent is 2,545 BTU per hour. The metric horsepower (see metric system) equals 4,500 kg-m per minute (32,549 foot-pounds per minute), or 0.9863 horsepower.
The problem is that motors vary greatly in efficiency, and that the amp reading only represents the current being used and not the full load current rating of the motor.

On a typical dust collection system, the fan will draw more amps as the damper is opened and the least amps when the fans airflow is restricted.

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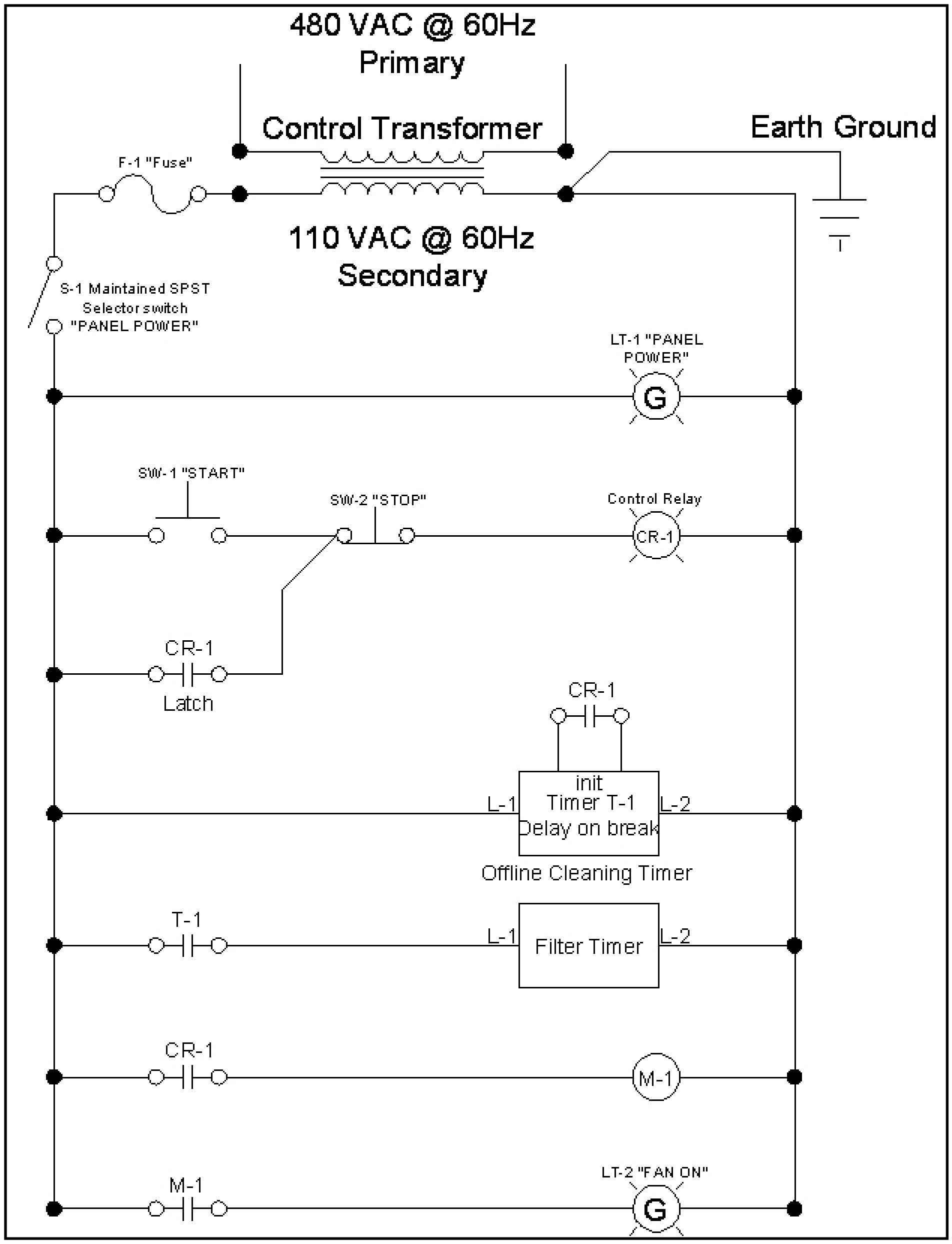

The above schematic could be used to control a dust collector without an airlock.
This setup gives the baghouse an opportunity to offline clean.