HEADLAMPS

The Rest of the System

by Lee Carroll

We recently completed a series on headlight lenses (SK May 2014 - July 2014). The lenses are but one of the components in the lighting system. It is important that we look at, and restore, several of the other parts of the systems.

Essentially, the headlight lens merely protects the headlight and focuses the beam. But what goes on behind the lens is just as - if not more so - important.

Very simply, the lighting system consists of a switch, wiring, fuses, sockets, reflectors and bulbs. And, of course, electricity. Remove any one of these elements from the system and our light is gone.

We love hearing from you, our readers. Certain questions, or classes of questions, seem to keep re-appearing. Top of the list? Electricity. Maybe it is because we cannot 'see' electricity. We know that it is there because of its results: a motor runs, a light is illuminated, a radio plays, but we cannot see it or hold it. And wires all look pretty much the same. It is not always easy to tell the difference between a 16 gauge wire and a 14 gauge wire and a 12 gauge wire, especially if they are in a harness or if they are old, dirty, cloth-wrapped wires. An analogous subject is light bulbs. What type bulb, what size, and most confusingly, what is the light output?

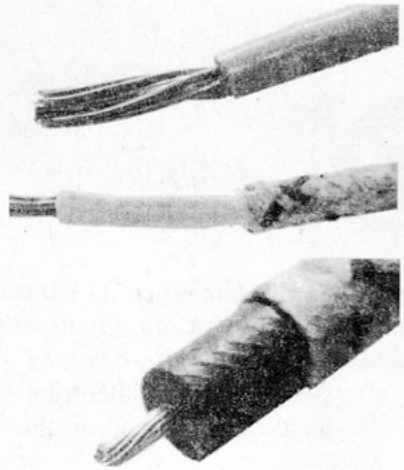
Let's review some basics about wire. I know, you know all this stuff. Bear with me, please. There are folks who do not, or maybe they should and they don't, or maybe, frankly, like me, they've forgotten.

A wire is nothing more than a conduit for electricity. It is merely a conductor for electricity to move from point A to point B. The conductor is the only part that all wires must have. Before you start to jump up and down and start to scream, "what about insulation?" think a moment. The frame of your car is steel. It is not covered with a 'traditional' insulator, but it is a conductor of electricity nevertheless.

A car or truck's electrical system is direct current (D.C.). That means that the electricity leaves one side of the battery, flows through a cable (a large wire) to the ground (frame of the car or the engine). The frame and engine and all of the connected parts are potentially charged with electricity. But at this point the electricity has nothing to do and no place to go. Now comes that insulation.

The other side of the battery cannot touch the frame or engine directly. The result, if it does, will look like the Fourth of July! Since there is no load - no motor, no light, no radio or anything else in between, there will be massive sparking. So in order to keep the other side of the battery from touching the ground, the electricity must be contained in a conduit that is insulated from everything outside the wire.

Simply speaking, that wire is nothing more than an electrical conductor covered by a non-conductive material. Newer wires have a coating of plastic, older wires might have a rubber or other non-conductive material. If it is a cloth-covered wire, the cloth covering is merely dressing which goes over the insulation. So a plastic wire, the kind that you buy at a hardware store or Home Depot, is a two-part wire - an inner conductor and an outer plastic insulator, and maybe a clear protective sheath over the colored plastic. A cloth covered



Top left: plastic-insulated wire. Stranded conductors and insulation.

Center left: fabric-covered wire. Stranded conductors, insulation and fabric wrap.

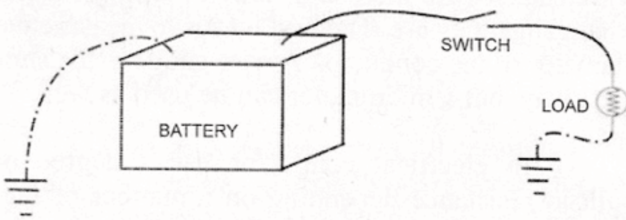
Lower left: sparkplug wire. High voltage requires more insulation. Stranded conductor, insulation and fabric wrap.

wire is a three part wire - an inner conductor, an insulator and a fabric wrapping on top of the insulator. That doesn't mean that the cloth wrapping doesn't serve a purpose. It does. It is identification. The plain plastic wire is red or blue or yellow. The cloth wrapping does the same thing; it can be red or orange or black or a combination of colors. Sometimes a thread of a second color, or a third color, or fourth, can be woven into the fabric wrap. These colored threads are known as tracers. The tracer might have two or three threads of one color making that the primary tracer color. Then there are secondary colors. The cloth covered wire is identified by the color of the covering with the tracers identifying the color of the wire even further. For example, the wiring schematic might call out a yellow wire with a red tracer, or a black wire with a blue and orange tracer. The schematic will often abbreviate the colors as Yel/red or Black/blu/orng.

Sparkplug wire is essentially the same as regular wire, but because of the extremely high voltage that it carries, the insulation must be much greater than a wire with a similar conductor size.

Back to the electrical system. Generally the cable coming off the 'hot' side of the battery goes to a solenoid or to a switch and then to the starter motor. The solenoid is a switch. The starter button operates a switch. When the switch is closed, the circuit allows a flow of electricity from the battery to the starter motor. The starter motor is bolted to the engine - the ground. The circuit is completed and the starter motor runs. That's it. That's the whole story about a direct current circuit. What I discussed is the high-amperage starting circuit. Another wire is tapped into that high amperage circuit and goes to the low amperage circuit.

The low amperage circuit powers everything else in the car or truck: the ignition, the coil, the gauges, the headlights, the radio, the blower motor, the instrument lights, the taillights, the stop lights and everything else. Each one of those named items is a 'load.' Essentially they work like that starter motor. One side is connected to ground and the other side is awaiting a complete circuit from the 'hot' side of the battery. Each of those 'loads' has a switch which opens or closes the electrical circuit. Maybe it is the headlight switch, or the on/off knob of the radio or blower motor. Or maybe it is the ignition switch - a key, or a lever, or a knob - that closes the circuit and powers the distributor, the coil and the dash gauges. If those switches were not in the circuit, the loads would always be operating, and each morning you would find the battery drained.



In a direct current circuit the electricity must make a complete loop. One side passes through a switch and then to one terminal of the load. The other side goes to ground (generally the vehicle's frame) and the other terminal of the load is connected to ground to complete the circuit.

The starter motor requires a lot of amperage. When energized, the starter motor has to operate against a tremendous resistance: the car's engine. The torque of the starter motor has to overcome the inertia (a body in motion tends to stay in motion, while a body at rest tends to remain at rest) of the engine. The pinion gear on the starter motor has to spin the flywheel, and then the rest of the engine, fast enough to allow it to start. The starter motor works very hard for a short period of time.

The low amperage loads each require a varying amount of amperage, but still low compared to the starter motor. The highest consumers of amperage are the headlights and the horn. Those wires have to be larger in gauge (conductor diameter) than the taillight, brake light, gas gauge, interior lights, radio, etc. Generally speaking, the headlights and horn require a 12 gauge wire, and the lesser loads a 14 gauge or 16 gauge wire. The generator and ammeter gauge are heavy-amp carrying loads. It is recommended that at least an 8 gauge wire be used. This should handle up to about 40+ amps. Remember that the higher the gauge number, the smaller the wire diameter.

If you contact a wire supplier like Restoration Supply Company you can order cloth-covered wire by gauge (and color). But if you have a drawer filled with odd lengths of cloth covered wire, chances are there is no way of telling exactly what gauge they are. The best way is to measure the diameter of the conductor. A wire gauge is the simplest way, but a micrometer can be used as well.

An electrical conductor has a degree of built-in resistance depending on a number of factors. The type of conductor - aluminum, copper, etc. is one factor. The resistance causes a heating of the wire. If the heat is not able to dissipate, the resistance is increased even further. A bare (free-air) wire is more able to cool and will provide higher amperage transmission. The heavier the insulation the less heat dissipation and the higher the resistance. A wire wrapped within a harness has even less heat-dissipation ability. Since we are discussing insulated and bundled wires, we will use the lower of the amperage ratings known as 'power transmission' or enclosed amperage.

Wire gauge	Diameter (inches)	Enclosed Amperage Rating (approximations)
2/0 (00)	0.365"	175
8	0.129"	46
10	0.102"	33
12	0.081"	23
14	0.064"	17
16	0.051"	13

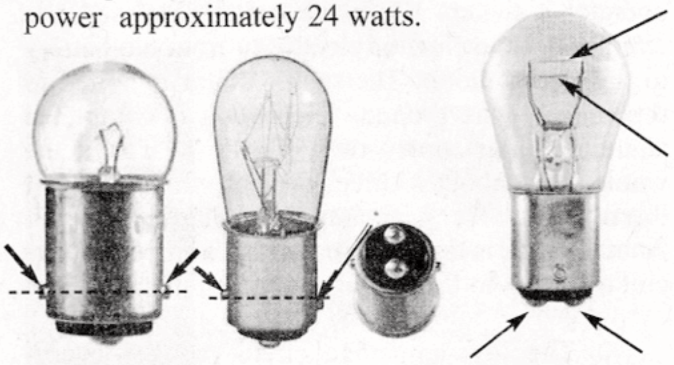
Another consideration is whether the insulated wire is a solid strand or a number of very fine wires twisted together and then enclosed within an insulating jacket. This is known as stranded wire. A single, solid strand of wire, especially when you get into the larger gauges - 10, 8, 6, etc. is quite stiff. It does not flex as easily as a stranded wire of the same gauge. Solid wire is often used in home-wiring applications, but it is not recommended for a car or truck.

A stranded wire is made up of a bundle of many flexible wires; together they all carry the electricity and equal gauge of a single strand. In a car or truck, not only do the wires have to snake through conduits, but they are often inadvertently moved when making repairs to or around the wires or their fittings.

The wires power a variety of appliances - starter, ignition, radio, horn, and on later cars windshield wipers, power seats, locks, etc. But by far the most common appliance within the car are the light bulbs. Individually most (with the exception of the headlights), consume very little electricity and require smaller (#16 or #18) wires.

Now let's look at some common light bulbs and their specifications. In the 1920s headlights were rated by an arbitrary standard called candlepower (cpw). Over the years the candle power rating was replaced by lumens or wattage. Unfortunately there is no direct conversion from candlepower to wattage to lumens.

Until mid-1920s most 6-volt systems used 15 cpw or 21 cpw bulbs. Some cars used series resistors to dim headlights. The most popular headlight bulbs were the #1110, a 6-volt double contact, double filament bulb rated at 21 candlepower for each filament. When restrictions against too-bright-bulbs were lifted, the 32 candlepower bulb became popular. The #1000 bulb was also a double contact. double filament bulb each rated at 32 candlepower. A third bulb used one filament of 32 candlepower and one of 21 candlepower. It was the #1116. Some internet research indicated that the 21 candlepower consumed 17 watts and the 32 candlepower approximately 24 watts.



Left to right: (a) bayonet base with even pins, single filament, single base contact; (b) bayonet base, uneven pins, double filament, double base contact; (3) bayonet base, dual filament, dual base contact. All three examples rely on the metal base to provide the ground contact.

Most automotive light bulbs are identified by: 1) base diameter, 2) position of locating pins, 3) number of filaments, 4) number of base contacts, and 5) envelope (glass enclosure) shape, as well as voltage and candlepower.

A watt is the number of volts times the amps. So a 24 watt bulb is 24 divided by the 6 volts equal approximately 4 amps. A 17 watt bulb is about 2.8 amps.

Watts = amps x volts
Amps = watts/volts
Volts = watts/amps

A headlight circuit requires two bulbs - one left and one right, with the low beam 32 candlepower filaments illuminated there are 8 amps; with both filaments illuminated there are 16 amps. That requires a 12 gauge wire which affords a slight safety margin. In addition it requires a safety valve - a fuse - that will blow when too much amperage attempts to pass through it. A 12 gauge wire requires a 20 amp fuse. A 14 gauge wire requires a 15 amp fuse, and a 16 gauge wire uses a 7 amp fuse.

A number 63 (6-v) miniature map-light, interior, license plate bulb is approx 0.63 amps; an #81 (6-v) - taillight, interior bulb is 1.02 amps; a #87 (6-v) courtesy light, dome light bulb is 1.91 amps

A rough reference chart of load description and wire size (for both 6-volt and 12-volt) is below. This is to be used merely as a guide and not as a firm determination of wire size. That has to be determined by actual load requirements.

LOAD	6-volt Wire Size	12-volt Wire Size
Starter Motor	#00	#1
Ammeter gauge	#8	#10
Generator main terminals	#8	#10
Headlights	#12	#14
Generator secondary terminals	#12	#14
Turn signals, radio, parking lights	#14	#16
Instrument gauges (other than ammeter)	#14	#16
Coil, ignition system	#14	#16

Ironically, despite the many components, attachments and connections, the electrical system gives very little trouble, but when it does, it's frustrating; probably because we cannot see electricity. We can only see its results. Unquestionably though, the biggest problems with an electrical circuit (any electrical circuit) are two: poor connections or a bad ground. We constantly hear of the need to 'improve' a six-volt electrical system by upping the voltage from 6 volts to 8 volts, or even to 12 volts. And in most cases, it is not necessary. The need is caused by poor maintenance. (Come on. Man up and accept the blame.) Corrosion is often the biggest problem, and it is the easiest to correct. It takes time and patience. I wouldn't even guess how many times we've written this before: every connection must be shiny clean! That includes, but is by no means limited to, the battery terminals, the battery ground connections, the grounds at the load (radio mounting bolts, lamp sockets, etc.), and each and every wire connection. The tools for doing the job are simple: a brass-bristle wire 'toothbrush' and a piece of fine sandpaper. A continuity meter, or an ohm meter, is also handy for checking connections for resistance, but clean the connections to 'shiny' nevertheless.

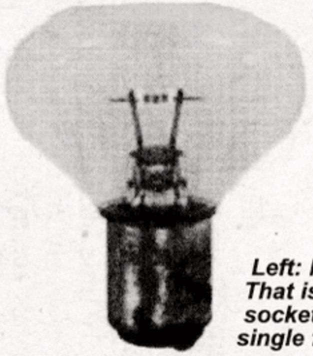
Disconnect the battery (to prevent shorting and to clean both the battery terminals and the cable contacts). Start at the battery and work through every single electrical load. That includes the battery shut-off switch, the starter switch or solenoid, and every place a wire is connected (both 'hot' and ground). Disconnect the wire, clean both the wire end and the terminal stud with the wire toothbrush and sandpaper. Roll the sandpaper into a tube to clean the inside of a light socket. Use the ohm meter to confirm that there is 'zero' resistance between the ground connection and a good, clean known ground. (I recently added Trippe lights to a car but one bulb just barely glowed. It turned out that the bracket was mounted to a powder-coated body part. The powder-coating prevented a good ground connection.) While you are cleaning, don't forget to clean both the fuses and the fuse holders.

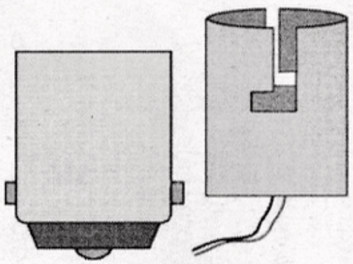
Many older cars use a rotary switch at the base of the steering column for the headlights. Often it is difficult to reach this switch, but it is imperative that each wire be removed and the wire connection and the terminal post be cleaned. Remove, clean and replace the wires one by one so that they don't get mixed up.

Reconnect the battery and check each and every electrical load. If you have done the job properly, all of the light bulbs will be brighter and will not flicker from a loose wire or bad connection.

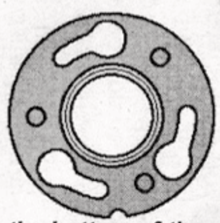
SIX VOLT BULBS (most popular sizes)

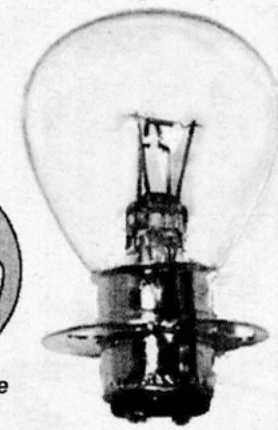
Bulb Designation	Volts (nominal)	Candlepower	Filament Number	Watts by filament	Amps (approx) by filament	Base	Contact	Pins straight or offset
HEADLIGHT BULBS								
50-50C	6	50/50	2			Bayonet	Double	St
1000	6.2	32/32	2	24/24	3.87/3.87	Bayonet	Double	St
1007	6.2	32	1	24.2	3.9	Flng PreFocus	Sngl	
1022	6.2		2	27.2/16.4	4.39/2.65	Flng PreFocus	Dbl	
1066	6	50/32	2			Bayonet	Double	St
1110	6	21/21	2	21/21	3.5/3.5	Bayonet	Double	St
1116	6	32/21	2	25/18	4.17/3	Bayonet	Double	St
2220	6.4	21/21	2	21/21	3.28/3.28	Flng PreFocus	Dbl	
2221	6	21/21	2	21/21	3.5/3.5	Flng PreFocus	Dbl	
2320	6.3	32/21	2	28.5/20.8	4.52/3.3	Flng PreFocus	Dbl	
2330	6.2	32/32	2	25.6/25.6	4.13/4.13	Flng PreFocus	Dbl	
2331	5.9	32/32	2	27.5/29	4.66/4.92	Flng PreFocus	Dbl	
2520	6	50/21	2	50/21	8.33/3.5	Flng PreFocus	Dbl	
4013	6.4			25	3.91	Sealed Beam	2 screw	
4020	6.4		2	30/30	4.69/4.69	Sealed Beam	3 prong	
4031	6.4		2	45/35	7.03/5/47	Sealed Beam	3 prong	





Below and right: Some bulbs have a flanged base. They are known as prefocused bulbs. They will not fit a regular socket.



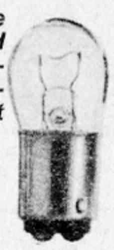


Left: Most headlight bulbs are of the bayonet base type. That is, they have two pins which engage with slots in the socket to give a positive contact. Headlight bulbs are available in single filament or dual filament.

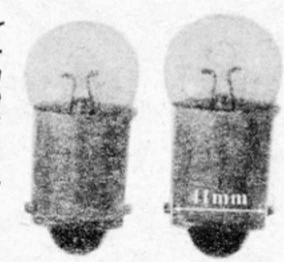
Above center: A bayonet base wtih straight pins. The pins are both the same distance from the bottom of the bulb. Some sockets have offset slots requiring a bulb to have one pin higher than the other. Those are most often found in bulbs with one filament offering more light than the other.

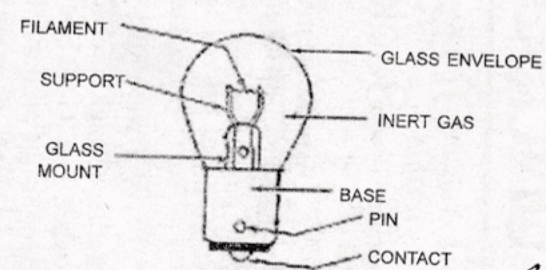
Bulb Designation	Volts (nominal)	Candlepower	Filament Number	Watts by filament	Amps (approx) by filament	Base	Contact	Pins straight or offset
ACCESSORY BULBS								
Standard Base 15mm diameter								
63	6-8	3		3.78-5.04	.63	Bayonet	Single	St
81	6.5			6.63	1.02	Bayonet	Single	St
82	6.5	6		6.63	1.02	Bayonet	Dual	St
87	6.8	15		13	1.91	Bayonet	Single	St
88	6.8	15		13	1.91	Bayonet	Dual	St
209	6.5	15		11.6	1.78	Bayonet	Single	St
210	6.5	15		11.6	1.78	Bayonet	Dual	St
1129	6.4	21		16.8	2.62	Bayonet	Single	St
1130	6.4	21		16.8	2.62	Bayonet	Dual	St
1133	6.2	32		24.2	3.9	Bayonet	Single	St
1134	6.2			24.2	3.91	Bayonet	Single	St
1154	6	21/3	2	18/6	3/1	Bayonet	Dual	Off
1158	6.4-7	21/3	2	16.8/5/25	2/63/.75	Bayonet	Dual	St
Miniature Base 11mm diameter								
44 min	6			1.6	.254	11mm Bay.	Single	St
51 min	7.5			1.65	.22	11mm Bay.	Single	St
55 min	6-8	2		2.4 - 3.2	.4	11mm Bay.	Single	St

Double filament and double contact bulbs are used where there are two separate circuits powering a single bulb, like a stop light and turn signal.



The smaller base diameter of a miniature bulb is 11mm, whereas a standard bulb base is 15mm.





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