AUTO ELECTRICALS

TECH TOPICS

It would be possible to produce and run a motor car without any electrical system at all, and in fact, the earliest of cars had, at best, only a rudimentary electrical layout.

Ignition of the fuel/air mixture in the combustion chamber can be achieved via a rod or tube which is heated by an external flame, lighting can use acetylene or other combustible fuel on the lamps, and starting - well what are sloping streets and strong and willing friends for? As for air-conditioning, open a side-curtain if you have one (!), and radio - those early roads would have jiggled the catswhisker off the crystal in your crystal-set anyway !

What is clear is that many of the comfort-generating and safety features of even the classic cars in which we are interested could not be achieved as conveniently, efficiently or effectively by other than electrical means.

In this series, it is intended to take the reader through the rudiments of electricity, making him "comfortable" with it by relating it to more common and easily understood phenomena where possible and appropriate, and then to deal systematically with the features, operation and service/repair of the components of the automotive electrical systems which club members might encounter in classic and earlier Citroëns. Main emphasis will be given to the Traction Avant models however.

CONCEPTS AND ANALOGIES:

Because electricity is not a "visible" or "perceptible" form of energy like heat, light, sound, hydraulic energy etc, many people seemed to shy away from it, perhaps dabble a bit, and then have to fall back on "experts". However, electricity is simply that - another form of energy which can be understood, mastered and applied to your use and benefit.

Thanks to Lord Rumford who concluded that friction converts mechanical energy into heat energy (he observed that a cannon becomes hot when the barrel is being bored out), we now know that all energy forms, including electricity, can be transformed from one form to another e.g. chemical energy (petrol and air) into heat and motion in an engine, light into electricity in a photo-voltaic cell, electricity into light in a light bulb etc, etc.

Electricity in cars, as distinct from that in power mains, is "safe", at worst giving you a harmless "jolt" if you handle the "high-tension" ignition circuit carelessly. We've come a long way since Benjamin Franklin flirted with death by flying a kite into the middle of thunder clouds and watching sparks jump to his hand from the cord !

Electrical circuitry can be much more readily understood by relating it to hydraulic circuitry with which there are close parallels.

Hydraulic circuits and electrical circuits in their fundamental forms consist of "currents" or "flows" of matter of some kind moving under the influence of a "pressure" along or through a "conductor" or "conduit". The movement is from

Fig. 1: Simple hydraulic circuit.

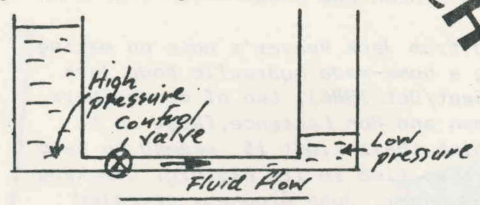


Fig. 2: Simple electrical circuit

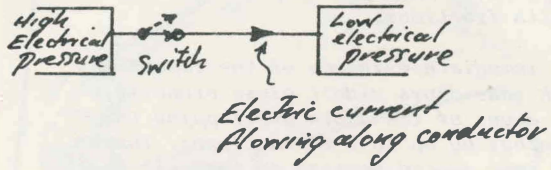
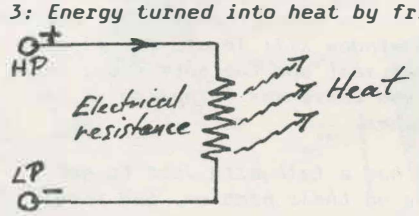


Fig. 3: Energy turned into heat by friction.

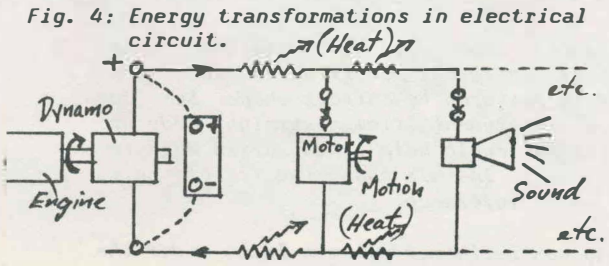


a point of high pressure to one of low pressure. Frequently, the electrical conductor is in the form of a wire, while the hydraulic conduit is usually in the form of a pipe (Figs. 1, 2).

Since the current/flow is going from an area of high pressure to an area of low pressure, pressure must be being dissipated along the way. This pressure loss is due to the energy contained in the flow/current being converted to another form. If the energy loss is due to "friction" in the pipe or wire, the energy "lost" will appear as heat which will then be radiated away to the air or elsewhere. (Fig. 3). In an electrical circuit, this friction is called "electrical resistence" or simply "resistence".

The energy "lost" from the flow need not all appear as "useless heat" however. Sometimes of course, we want the flow energy to appear as heat e.g. in an electric radiator, but generally, we make the conductor sufficiently large that friction losses are negligible, and we then choose to pick the energy of the flow off in some more useful form such as light, sound, motion etc. We do this by passing the flow through devices such as lamps, horns, motors etc (Fig. 4). In a hydraulic circuit, the flow can be turned into motion by passing it through a hydraulic motor, into sound by passing the flow (in the case where the fluid is a gas) through an air-horn, and so on.

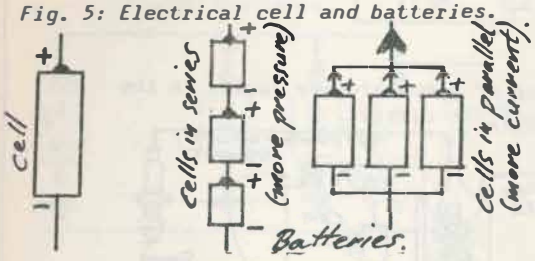
Fig. 4: Energy transformations in electrical circuit.



Of course, if the flow in the circuit is to be kept going for any appreciable period of time, there must be some device in the circuit to maintain the pressure difference between the high pressure and low pressure sides. In a hydraulic circuit, pressure would typically be maintained by a hydraulic pump, driven by a motor operating off some other energy form such as oil, coal etc. The electrical equivalent of this hydraulic pump in the circuit is the electrical generator or dynamo, which in a motor car is driven via the fan-belt by the vehicle's internal combustion engine.

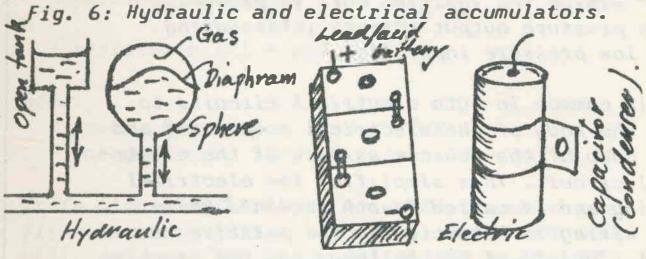
Electrical pressure and flow can also be maintained by chemical reactions occuring in appropriate devices e.g. when metallic zinc dissolves inside a carbon/zinc torch cell. Such cells can be joined up to form a battery, in series to produce a greater total electrical pressure, or in parallel to achieve greater capacity to provide current (Fig. 5).

Fig. 5: Electrical cell and batteries.



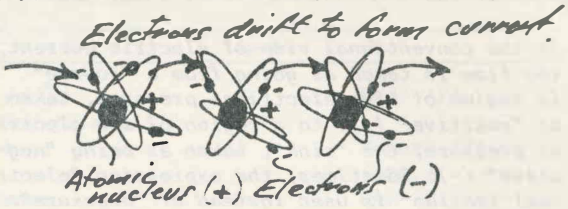
As well, hydraulic and electrical flows can be maintained by drawing on pressure energy previously stored in a "reservoir" or "accumulator". The common storage device for electrical energy is the lead/acid accumulator used in the motor car and elsewhere. Much use is also made of non-chemical storages of electricity in "condensers or capacitors" e.g. to prevent destructive arcing of current across the contact breaker points in the low-pressure ("low tension") part of the ignition circuit, or to provide the rapid release of electrical energy to fire a photographic flash-gun. Storage devices in hydraulic circuits include pressure spheres (as in the suspension of D-series Citroëns), and elevated water tanks and open storages in water supply networks (Fig. 6). The fundamental use of accumulators is to "smooth out" the operation of the system, enabling it to cope with great differences between instantaneous supplies and demands.

Fig. 6: Hydraulic and electrical accumulators.



The "flowing medium" in the case of hydraulics is a liquid such as water, oil etc, or a gas such as air or nitrogen (in the latter cases, the systems are usually called "pneumatic"). With electricity, the flowing medium is electrons (usually). Electrons are minute negatively-charged particles which orbit the positively-charged "nucleus" of each atom of matter (Fig. 7).

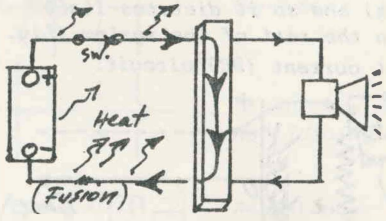
Fig. 7: The basis of an electrical current.



In certain materials, the electrons readily pass from atom to adjacent atom with very little energy loss due to "internal friction" or electrical resistance. These materials are called "electrical conductors" and include most metals (copper, aluminium, iron, lead etc). Some non-metals, notably carbon, can be good conductors also. Solutions of salts in water ("electrolytes") are often good conductors of electricity as well. In electrolytes, the current is carried by the passage of charged "ions" (positive and negative) rather than by electron movement. Materials which are poor conductors of electricity are called "insulators".

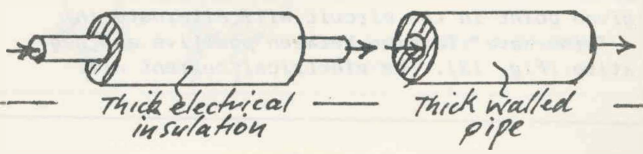
If a piece of conducting material were to be in electrical contact with both the high pressure and low pressure sides of an electrical circuit, then it would be possible for a flow of electricity or "leakage" to pass through this alternative electrical path (Fig. 8). This condition is called a "short circuit" and is usually very undesireable. Not only does the short circuit "rob" the "useful" parts of the circuit of energy, but the excessive current which may pass may overload the energy source (dynamo, battery etc) and the excessive heat produced may cause heat damage, even fusion, within the circuit. At this stage, the circuit or its components are said to have been "burnt out". The hydraulic equivalent of a short circuit is some form of internal leakage such as blown seal or an external leak such as the rupture of a high-pressure pipe.

Fig. 8: A short circuit.



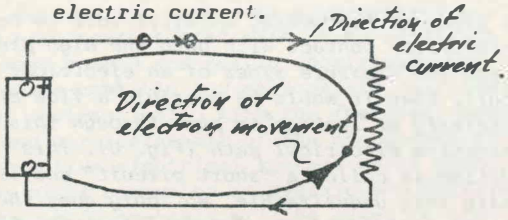
To prevent short circuits in electrical systems, any parts which might be contacted by other conductors are usually coated with a layer or sleeve of insulating material (rubber, plastic, ceramic etc). The use of effective insulation is particularly important where there are very high electrical pressures (the high tension ignition circuit, electric mains) or where there is a risk of fatal electric shock (mains operated electric appliances etc). One might compare the heavy insulation of high-tension ignition wires with the thick walls of high pressure hydraulic lines (Fig. 9). Both are adopted for the same basic reason.

Fig. 9: Preventing leakage from "high pressure" conductors.



In the conventional view of electric current, the flow is taken as going from a "source" (a region of high electrical pressure, taken as "positive" (+)) to a region of low electrical pressure, the "sink", taken as being "negative" (-). Sometimes, the expression "electrical tension" is used instead of "pressure". Electrons, are conventionally considered to be negatively charged as we have seen, and hence since "unlike charges attract", the electrons will tend to move away from the negative (low tension) side of the circuit towards the positive (high tension) side of the circuit. Thus, we have the paradox that conventional electric current flows from positive to negative, but the electrons which normally constituate that current move from negative to positive in the circuit i.e. "the electrons move against the current". This is a historically derived situation which you will have to live with and shouldn't cause you much bother (see Fig. 10).

Fig. 10: Directions of electron movement and electric current.



For most of the circuits we will be considering, one side of the circuit is always positive and the other side is always negative. The electrical pressure and the circuit are then said to be "direct current" (DC), since the current flows in one direction only. This is most convenient in vehicle systems since the on-board electrical storage unit (the lead/acid accumulator) accepts and delivers DC only. The accumulator performs vital functions (especially engine starting) and so it dictates its DC requirements on the rest of the system (Fig. 11).

Fig. 11: Direct current (DC) circuit.

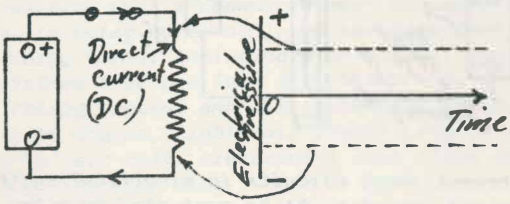
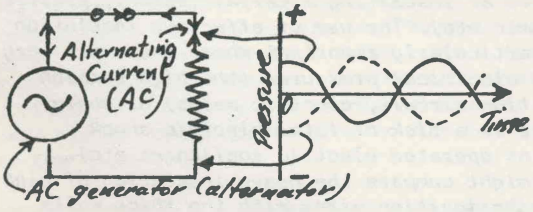


Fig. 12: Alternating current (AC) circuit.



However, parts of the vehicle electrical system do not run on DC. The generator or alternator (dynamo) produces electric pressures which "alternate" in a smooth fashion over time i.e. a given point in the circuit will alternate in a "sine-wave" fashion between positive and negative (Fig. 12). The electrical current will then alternate its direction in response to these cyclic pressures. Before this "alternating current" (AC) can be fed into the rest of the system, especially the accumulator, it must be turned into DC ("rectified"). This rectification is done by a bank of "diodes" (really one-way electrical "valves") in the case of an alternator, or by a rotating contact set ("commutator") in the case of a generator (Fig. 13).

Fig. 13: Rectifying AC into DC.

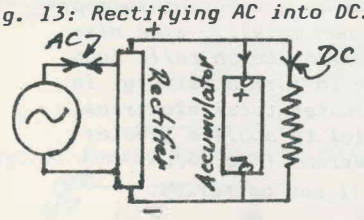
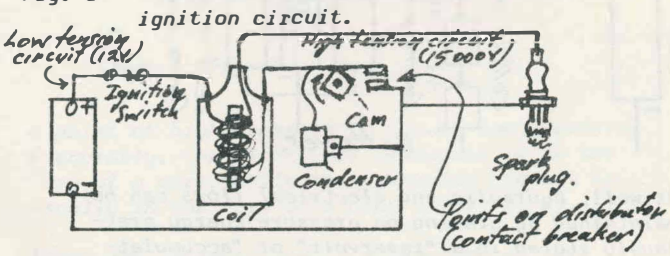


Fig. 14: Use of a transformer (coil) in the ignition circuit.

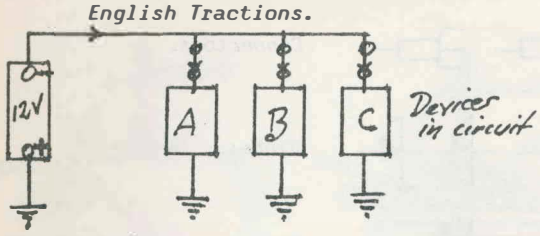


One of the useful characteristics of AC is that its pressure can be readily altered, up or down, by feeding it into an "electrical transformer". The common example of an electrical transformer in a motor car is the ignition coil (Fig. 14). A kind of AC (actually DC interrupted by the contact points (contact breaker (CB)) in the distributor in sympathy with the engine rotation) is fed into the input ("primary winding") of the ignition coil and stepped up in pressure over 1000-fold at the output ("secondary") so that it can jump as a spark across the highly insulating "air gap" at the spark plug points in the combustion chamber, and so ignite the fuel/air mixture. Pursuing the hydraulic parallel, it is interesting to see how the simple "hydraulic ram" mimics the ignition coil in producing a high pressure output through interrupting the low pressure input flow.

It is common in auto electrical circuits to use the body of the electrical components and the body of the vehicle as part of the electrical circuit. This simplifies the electrical wiring and is called "earth return". Where the wiring is connected to the positive terminal ("pole") of the battery, and the negative pole of the battery is connected direct to the body ("earth"), this system is called "negative earth".* *[See also "The good earth" - FD Jan/Feb 1986].

However, English cars in particular, from the mid-1930s on, adopted a "positive earth" system for certain technical reasons, and thus all

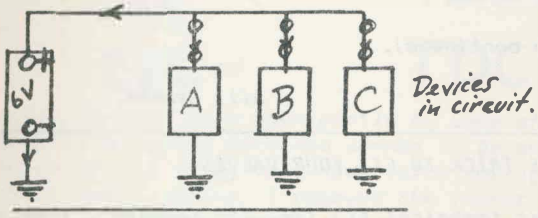
Fig. 15: Positive earth system (12V) as in English Tractions.



Slough (UK)-built Tractions have a positive earth system, running at a pressure of 12 volts (12V) - the British were early in recognising the advantages of going from 6V up to 12V systems).(Fig. 15). French-built Tractions are 6V negative earth.* To my knowledge, the Americans did not adopt the positive earth system, but they did eventually swing to 12V. The 12V negative earth is now virtually universal.

*See Fig. 16.

Fig. 16: Negative earth system (6V) as in French Tractions.



UNITS AND SYMBOLS

Certain special units and symbols are used to describe electrical systems, and it is worth knowing a few. The common units are listed in Table 1.

Certain relationships exist between these quantities, and these are also worth remembering.

Most relationships are based on Ohm's Law, from which we have fairly "obvious" outcomes:

- current (I) is proportional to the pressure drop (V) which is driving it, and is inversely proportional to the resistence (R) of the component which is "resisting" the current (Fig. 17). i.e.

$$I = V/R \quad \text{and hence;}$$

- voltage drop (V) = IxR

- resistence (R) = V/I

Also:
- power (P) = VxI = I^2xR = V^2/R
- energy (work) (E) = Px time (t) = VxIxt etc.

It is also advisable to know the standard prefixes to these units: micro (μ) = 1/1 000 000, milli (m) = 1/1000, kilo (k) = 1000, mega (M) = 1 000 000 etc.

Fig. 17: Ohm's Law in a DC circuit.

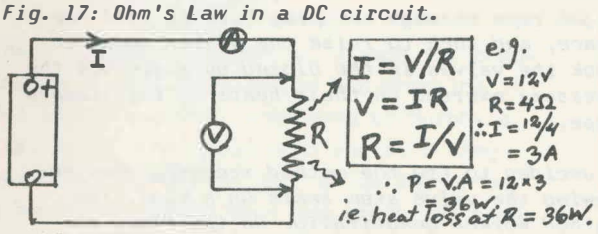


Table 1: Some electrical units.

Name	Symbol	Unit
Pressure * (tension, potential)	V	Volt (V)
Current	I	Ampere (A) (amp.)
Resistence	R	Ohm (Ω)
Power	P	Watt (W) (1 J/s)
Energy or work	E	Kilowatt,hour (kW.h)
Capacitance	(C)	Farad (F)

*Also commonly called "voltage" cf. "mileage".

Sometimes, one encounters old units e.g. 1 horsepower = 746 watts ≃ 3/4 kW.

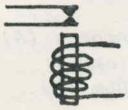
Lighting devices (lamps, bulbs etc) are now rated in watts, according to the power they consume. However, you may encounter old components and references where lights are rated according to their light output, usually expressed in candlepower, a now-obsolete unit. Fortunately, for incandescent bulbs, ≃1 candlepower (CP) is produced for each watt consumed (1 CP ≃ 1 W). However, this relation does not hold for more efficient lamps e.g. fluorescents (≃ 3CP/W) and probably not for quartz-iodine (QI or halogen) lamps either.

Certain symbols are used in the diagrams which describe how the wiring connections are made up.

Table 2: Some symbols used in wiring diagrams.

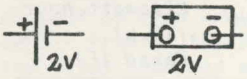
Symbol	Meaning
	Conductor, wire (usually insulated).
	Conductors joining.
	Conductors crossing but not joining.
	Resistence.
	Variable or tapped resistence.
	Earth (body) connection.
	Fuse.
	Switch.
	Multi-purpose switches (various).

Contacts.

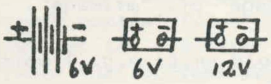


Relay.

Light bulbs.

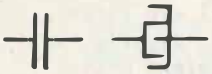


Electric cell (e.g. lead/acid, 2V).

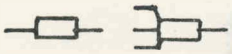


Batteries.

Simple coil (e.g. electric choke with iron core).



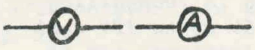
Capacitors (condensers).



Connectors.

Diodes.

Transformer (iron cored).



Meters (volt, amp.).

These symbols are a kind of convenient shorthand (Table 2). Often though, there is no "standard" symbol for a component, and it is then simply put in the circuit diagram as a "labelled box".

(To be continued).

Bill Graham.

AUTO ELECTRICALS

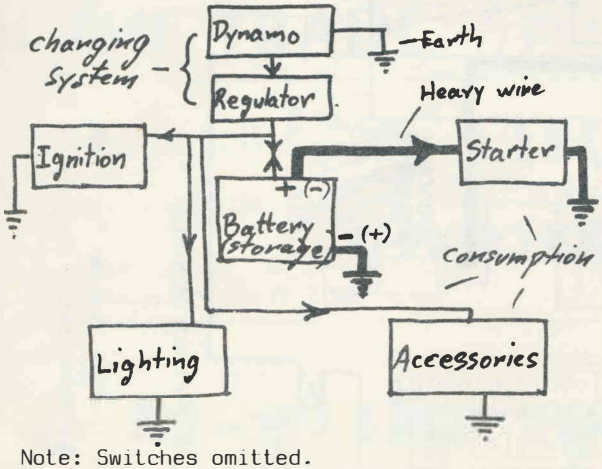
CONTINUED FROM FD 10 (5)

THE CIRCUIT DIAGRAM AND WIRING HARNESS

The modern auto electrical system consists essentially of perhaps a handful of kinds of bits and pieces:

- *a source of electrical energy (the generator or alternator* or dynamo)
- *a device for controlling the output of the generator/alternator* to suit the needs *of the energy-using and -storing devices (the regulator).*
- *an energy storage device to balance up supply and demands (the battery).*
- *energy consuming devices (starter, lights, radio, ignition etc, etc).*
- *conductors (insulated wires) to carry the electrical energy from the generator and battery to the starter. lights etc.*
- *switches and relays which open and close conductors so that electricity only flows to the places where we want it to go.*

Fig. 18: Basic auto electrical system



Note: Switches omitted.

Figure 18 shows a simple way of looking at this kind of set-up. The "return circuit" usually takes place through the metal body of the car in the form of an "earth return". Remembering the water plumbing analogy to electrical flow, Figure 19 shows how a similar hydraulic system might work. In this case, water is pumped into the overhead storage or cistern ("the battery") by a pump ("dynamo"). This stored energy can then be run down a pipe ("conductor") through a tap ("switch") and a turbine ("starter motor") for instance or some other energy using device. If the pump to the cistern was to be driven by an electric motor which in turn was controlled by a float-operated switch located in the cistern, then the pressure in the cistern would be kept essentially constant. The float switch could then be thought of as a "regulator". The sump from which the water is drawn and which receives the discharge from the turbine etc could be thought of the "earth return".

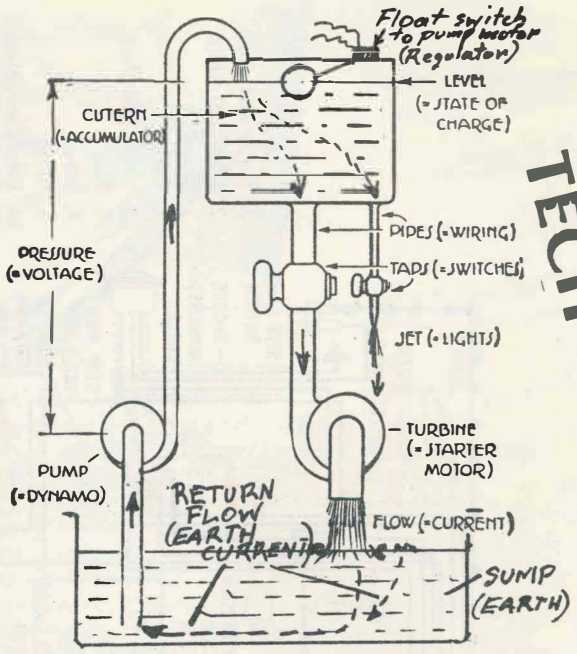


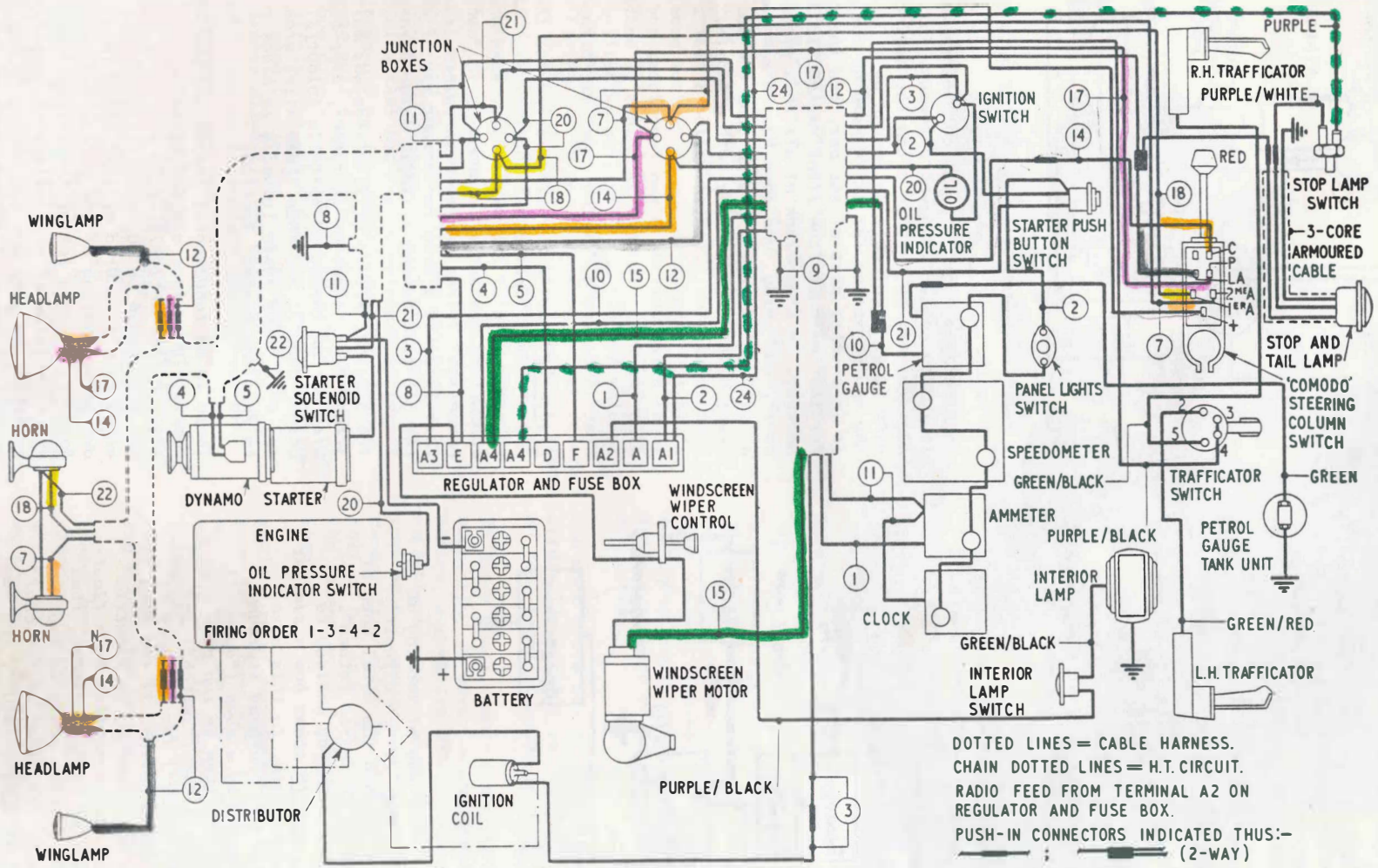
Fig. 19: Hydraulic equivalent of auto electrical circuit.

In electrical systems, the conductors may have to follow rather involved pathways. This is particularly so because often the device being used (e.g. headlight) is in one part of the car, the energy source for it (dynamo or battery) is in another part of the car, and the control for that circuit (the light switch) is in yet another. To keep track of all this electrical coming-and-going, one soon has to make use of a "circuit diagram", and to stop the multitudinous wires degenerating into a hopeless and time-wasting mess (often called a "rat's nest"), it is the usual practice to "colour code" individual wires serving given functions, and to bind the wires in neat groupings of appropriate lengths and current-carrying capacities in what is called a "wiring loom" or "harness".

Figure 20 shows a circuit diagram for the wiring of Light 15s of 1950s together with the colour-coding of the wires used. Note how the conductors are actually bound up in "subsiduary harnesses" (wires enclosed in dashed lines). This is often a more convenient way of doing the job than having a single large harness.

The original wiring of Tractions was multi-strand wire, sheathed in rubber, over-bound with cotton thread of suitable colour(s) (the "colour code"), and then these wires grouped and over-bound again (usually in black cotton) to form the harness sections.

There is no fundamental reason why you can't completely replace old and rotted wiring yourself, either entirely or in sections, and this you may choose to do, especially if only a few wires have fractured or lost their insulation due to weathering of the cotton and/or rubber. However, where a lot of the wiring looks dodgy and especially if originality of appearance is important to you, you may choose to buy a "reproduction harness" already made up for your car, complete with proper colour coding, cotton binding, labelling of where each wire end goes and so on. This is what I did.



1950 LIGHT FIFTEEN MODELS.

KEY

1. Purple and white
2. Black and white
3. White
4. Yellow
5. Green and black
7. Purple
8. Black
9. Black
10. Purple and black
11. Black and yellow
12. Red
14. Blue
15. Green and yellow
17. Red and black
18. Purple and yellow
20. Green
21. Yellow
22. Black
23. Black and white
24. Black and yellow

Fig. 20: Circuit diagram for 1950s Citroen Light 15 (Should be essentially the same on Big 15, Family 9 and Big 6).

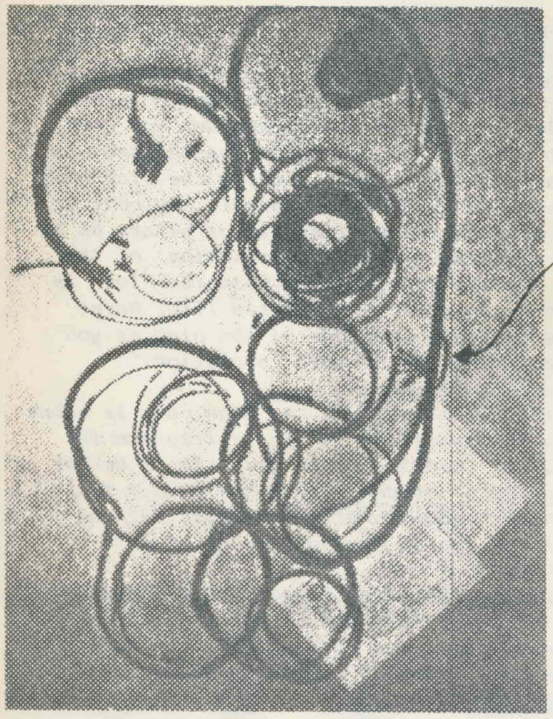
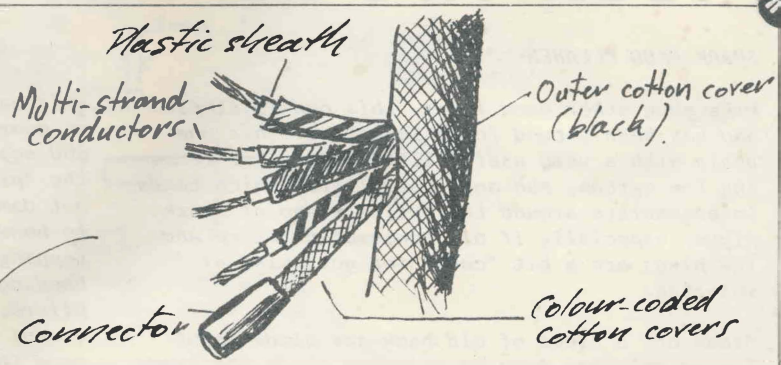


Fig. 21: Wiring kit for Big 15 as received from Electra-Loom.



I bought the replacement loom for my 1953 Big 15 from Electro-Loom Pty Ltd (Alan and Heather Taylor) in Sydney. It really is a beautiful and authentic looking job. It came with end connectors, instruction sheet, circuit diagram, and even (I was most impressed) metal-armoured wire for protection against abrasion by goods carried in the boot! Electra-Loom used wire which is plastic sheathed (not rubber) under the cotton, so it should last much better than the original, especially if the cotton is further protected by ultra-violet resistent clear lacquer -see note in FD 10 (5). A photo of the harness as received from Electra-loom appears as Figure 21. The cost was $150 (may be slightly more now).

(To be continued)

Bill Graham.

IN THE TRADE

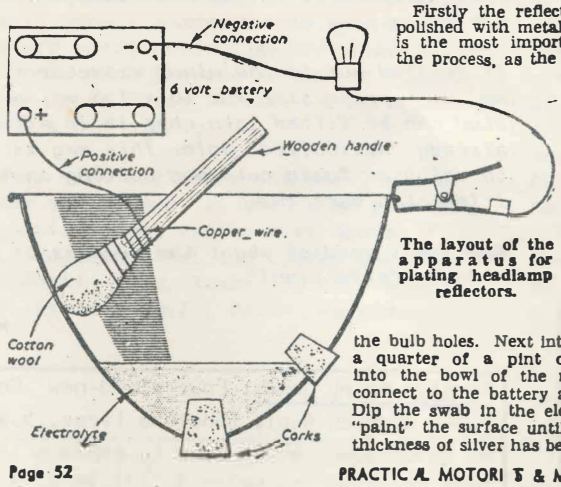
TECH TIPS

RE-SILVER YOUR HEADLAMPS

IN the method described the bowl of the reflector is made the cathode by connecting to the negative terminal of a six-volt battery. The anode is in the form of a cotton-wool swab soaked in the electrolyte and held by a wire connected to the positive terminal of the battery. The swab is used like a paint brush and by dipping in electrolyte a film of pure silver can be painted on the reflector.

SILVER PLATING

Firstly the reflector should be polished with metal polish. This is the most important stage of the process, as the initial degree of polish determines the final result. Obtain a mirror finish and remove any traces of lacquer from the surface. Wash the reflector free from metal polish and cork the bulb holes. Next introduce about a quarter of a pint of electrolyte into the bowl of the reflector and connect to the battery as illustrated. Dip the swab in the electrolyte and "paint" the surface until a sufficient thickness of silver has been deposited.



The layout of the apparatus for plating headlamp reflectors.

Do not allow the wire connection of the swab to touch the reflector. Wash the reflector and polish with metal polish until a desired finish has been obtained. Finally finish with a coat of transparent lacquer which has been thinned to about a third of the usual consistency.

THE ELECTROLYTE

For silver plating the electrolyte is made as follows. Obtain from the chemist a quarter of an ounce each of silver nitrate and sodium cyanide. Sodium cyanide is, of course, poisonous, and utmost care should be exercised in disposing of spent solutions. The materials should be kept under lock and key and preferably disposed of after the reflectors have been plated. Dissolve each of the chemicals in a half pint of water and mix. This quantity is sufficient for about four average reflectors.

By using different electrolytes this method is also successful for cadmium and nickel plating. The procedure is similar and almost any shape of object can be electroplated using a small volume of solution. In all cases, however, the importance of obtaining a clean and highly polished surface at the beginning must be emphasised. On this point the success off all electroplating depends.