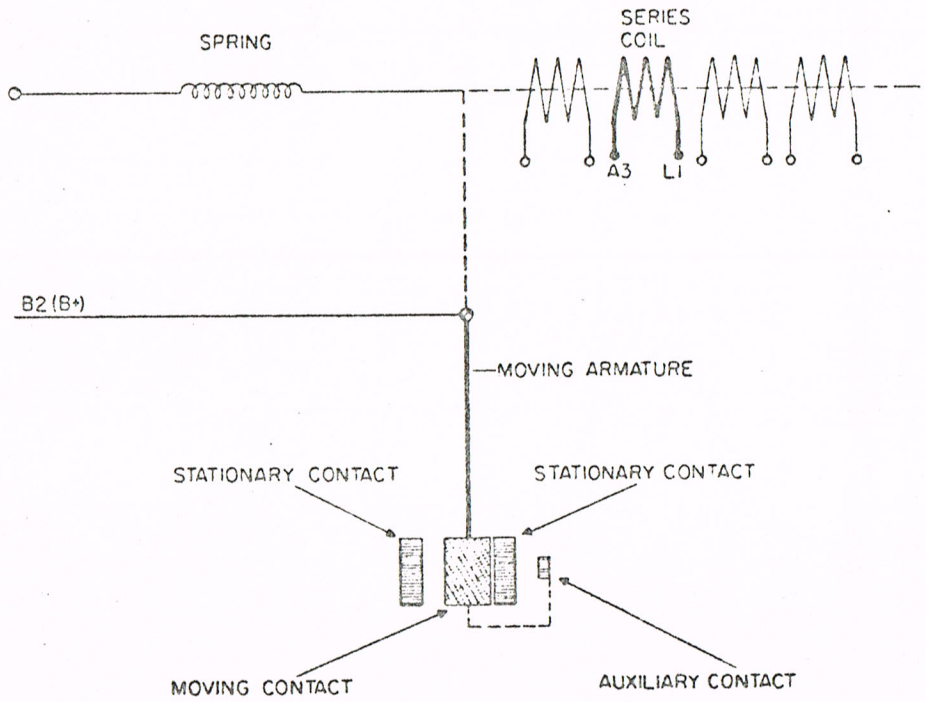
CURRENT LIMIT RELAY AND PILOT MOTOR OPERATION

A-7 P.C.C. CARS.

In order to obtain smooth control of a P.C.C. car, an accelerator having 99 resistance steps in series with the four traction motors was devised. In acceleration, 79 of these steps are used; in dynamic braking all 99 steps are in circuit. With so many resistance steps available, a hand operated drum-type controller would be unreasonable. The accelerator is, therefore, driven by a pilot motor.

The pilot motor which drives the accelerator to cut out or cut in resistance is controlled by the current limit relay, usually shortened to limit relay. The limit relay is essentially a current regulator for the four traction motors, during both acceleration and dynamic braking. It may be considered as the electric brain of the P.C.C. car.

Traction motor current flows through a heavy copper strap coil on the limit relay. This is called the series coil. The magnetic field so established moves a contact-carrying armature against the constant tension of a spring. The armature contacts determine whether the



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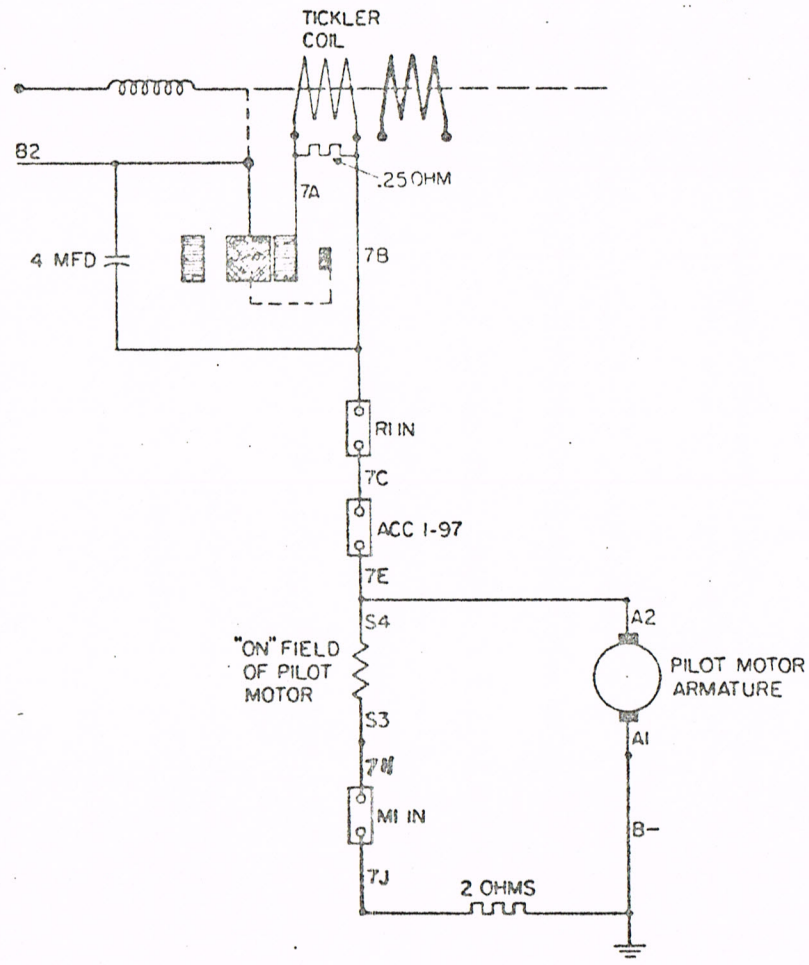
pilot motor will "Run up" -- cut out resistance in the traction motor circuit, or "Run down" -- insert resistance.

At the beginning of the acceleration cycle the tension spring will hold the limit relay contacts in the "Normal" position. The pilot motor will commence to run the accelerator up, cutting resistance out of the traction motor circuit. Soon a point will be reached where the traction motor current exceeds the limit relay setting. At this point the relay armature will move against the tension of the spring, the contacts will open and the pilot motor will stop.

Operation of the limit relay by a single coil would result in erratic traction motor performance. The pilot motor would over-run in each direction and car performance would be far from ideal. To provide more accurate control a second coil is added, the "Tickler" coil.

Line B2 is fed from the 36.0 volt D.C. supply and will be alive at all times when the M-G switch on the Gang switch assembly is closed. Line B2 is connected to the moving contact of the limit relay. In the normal position of the relay armature, current will pass to the tickler coil on lead 7A and leave on lead 7B.



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When the car operator depresses the power pedal and the R-1 contactor picks up, the circuit will continue through the R-1 interlock to 7C. The accelerator interlock 1-97 carries the circuit to 7E, which feeds the pilot motor.

The pilot motor is set up at this time as a shunt motor. Current will pass to the pilot motor armature A2 - A1 to B-. Current also flows through the "on" field coil to 7H, through an interlock on the M-1 contactor (which is now closed) to 7J and through a resistor to B-. The pilot motor is thus energized and commences to run in the forward or accelerating direction. Resistance is cut out of the traction motor circuit and the load current builds up.

The pilot motor current flowing through the tickler coil induces magnetic flux in the core of the limit relay. The increasing traction motor load current flowing through the series coil adds to the flux in the core and the limit relay contacts will open. The current to the pilot motor, through the tickler coil, is interrupted, the relay flux is reduced and the contacts will close again.

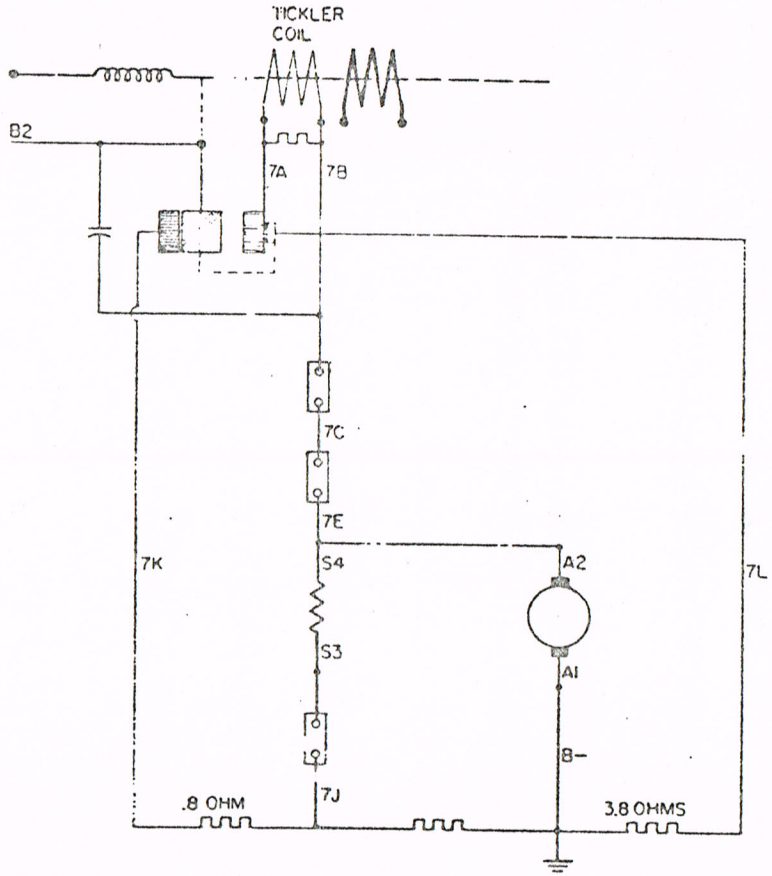
Now the pilot motor is energized through the tickler coil once more, the relay flux increases and contacts open. A fluttering action is thus established which will persist as long as the current in the series coil is above

the value for which the relay has been set. This flutter is essential for the proper regulation of the pilot motor.

Whenever the limit relay interrupts the pilot motor circuit, the motor armature will tend to become a generator and pass current through its field in the normal direction. This will apply a braking or plugging action to the motor and it will stop promptly.

With the afore-mentioned fluttering action of the limit relay, the pilot motor rotation becomes a rapid series of power and braking impulses which vary in length according to the traction motor current. For a given relay setting, if the traction motor current tends to rise the plugging impulses will become longer; if the motor current tends to fall, the power impulses become longer. Traction motor current is thus maintained at a constant value by this regulation of pilot motor speed.

If the operator calls for less acceleration or braking by releasing some foot pressure on the pedal, the traction motor current may momentarily be greater than the relay setting. When this occurs, the relay armature will respond to the flux which now exerts more force than the spring and the relay will "Back Contact".



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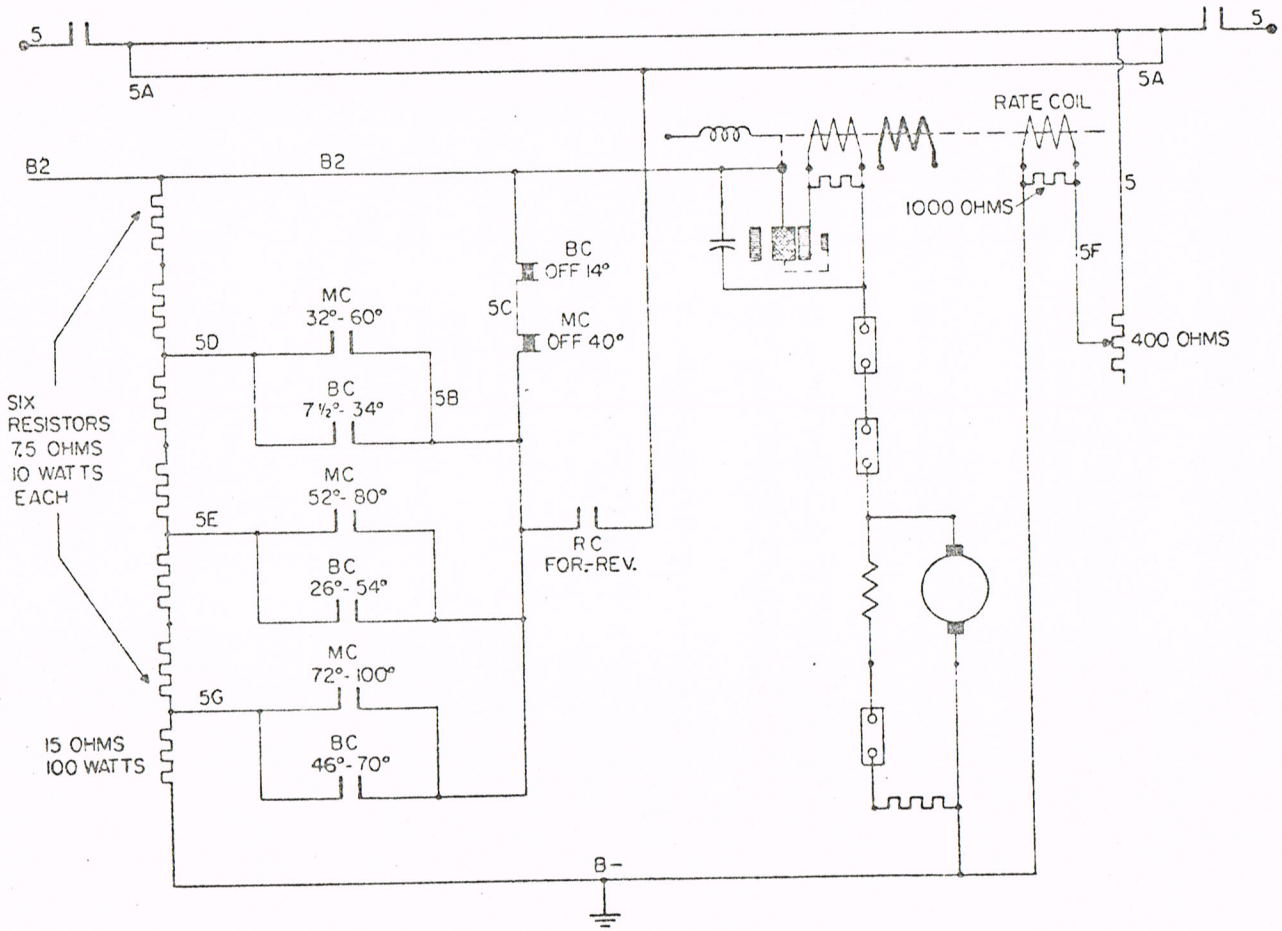
When back-contacting occurs, the pilot motor circuit is re-arranged. Current from B2 now flows to the left-hand contact of the relay, through a 0.8 ohm resistor, the M.1 "In" interlock and the "On" field of the motor in the reverse direction. The circuit is completed through the armature A2 - A1 to B-. The pilot motor is now series - connected operating in the reverse direction to run the accelerator down slightly, thus increasing resistance in the traction motor circuit.

Back-contacting of the relay also results in the auxiliary contact touching the right hand stationary contact. This establishes a circuit from the junction of the pilot motor field and armature 7E through the accelerator interlock 1-97, the R-1 "in" interlock to the tickler coil. Current now flows through the coil in a reversed direction, through a 3.8 ohm resistor to B-. This decreases the relay core flux and causes the necessary fluttering action of the armature. In practice, back-contacting is an extremely brief action.

It is desirable that increasing amounts of depression of the power pedal will result in higher rates of acceleration. This is achieved by adding a "Rate" coil to the limit relay assembly.



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The rate coil is energized from the B.2 line, and 36.0 volt D.C. power is applied through a series of cam-operated switches in the master controller and a group of fixed resistors. This coil furnishes a part of the magnetic flux tending to open the relay contacts. Its lessening effect as the master controller is advanced permits a greater traction motor current to flow through the series coil before the relay contacts open. This increases the length of the "Run" impulses to the pilot motor and so increases the rate of acceleration.

The circuit for the rate coil at low rates is from B.2 through a cam switch on the brake controller closed in the off position to 5C; through a cam switch on the master controller closed to 40° to 5B; through a cam switch on the reverse controller to train line 5-A which is directly connected to train line 5; through a 400 ohm calibrating resistor to 5F and through the rate coil and its 1000 ohm resistor to B- .

At higher rates of acceleration (beyond 40° of rotation of the master controller cam shaft) circuits are set up through a group of resistors and cam switches. The resistors form a voltage dividing network connected from B.2 to B- and the over-lapping cam switches apply increments

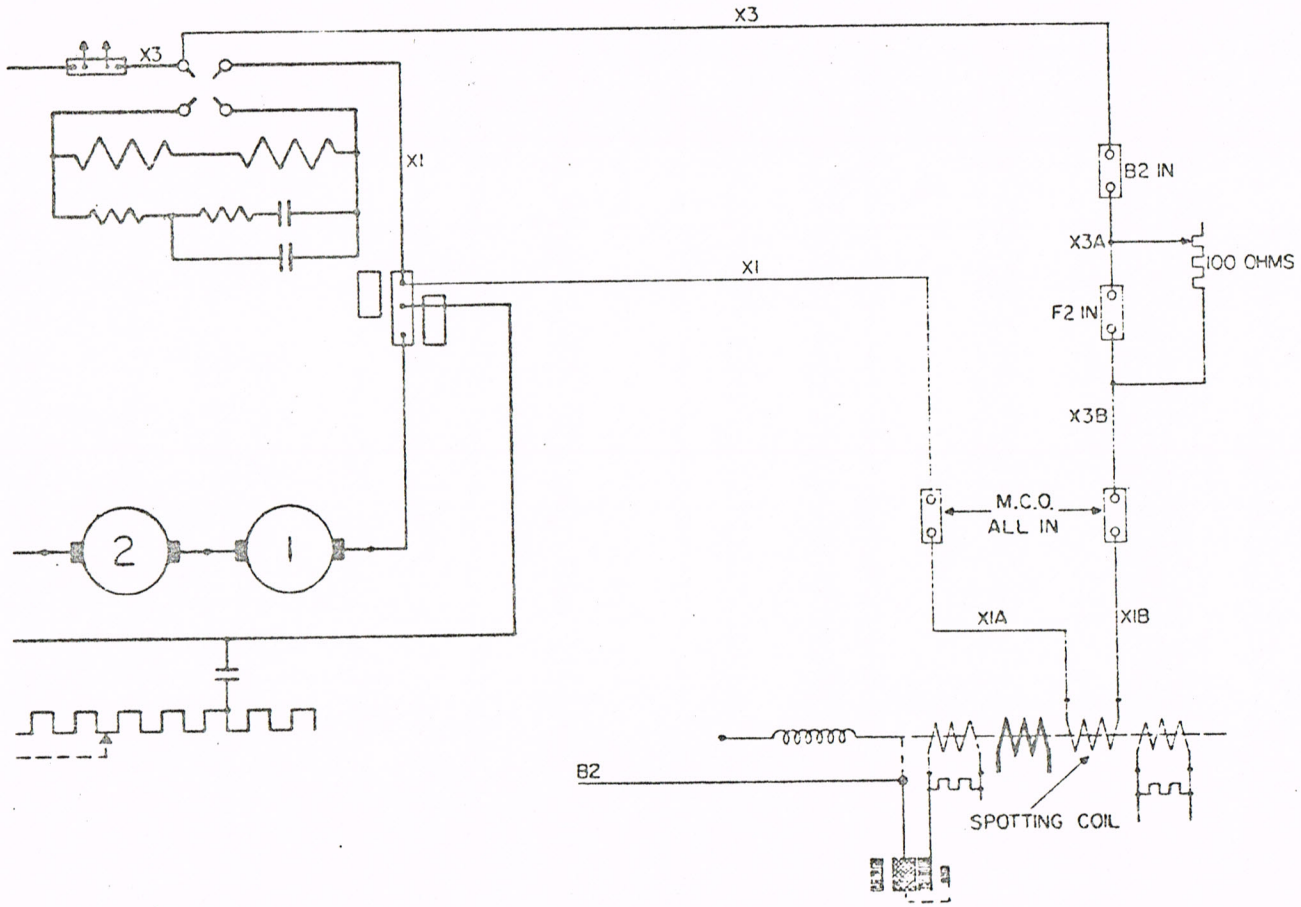
of the full 36 volts to the rate coil. Beyond 100° of rotation of the master controller cam shaft the rate coil circuit is de-energized and maximum rates are obtained.

When the car operator depresses the brake pedal to obtain dynamic braking similar circuits for the rate coil are set up using cam switches in the brake controller.

When two cars are coupled together, train line 5 is used to send rate information to the limit relay on the second car. This is essential if the vehicles are to operate satisfactorily when trained.

When the power pedal is released circuits are set up for coasting. This is actually preparation for either re-application of motive power or for dynamic braking. In order that the accelerator will be correctly positioned for either operation a fourth coil is added to the limit relay. This is the "spotting" coil. The spotting coil is connected across the field coils of traction motors #3 and #4. It is only energized when the B.2 contactor is closed.

Spotting is essentially dynamic braking at such a low rate that its effect on car retardation is not perceptible. Due to the unbalanced traction motor field conditions existing during coasting only a small circulating cur-



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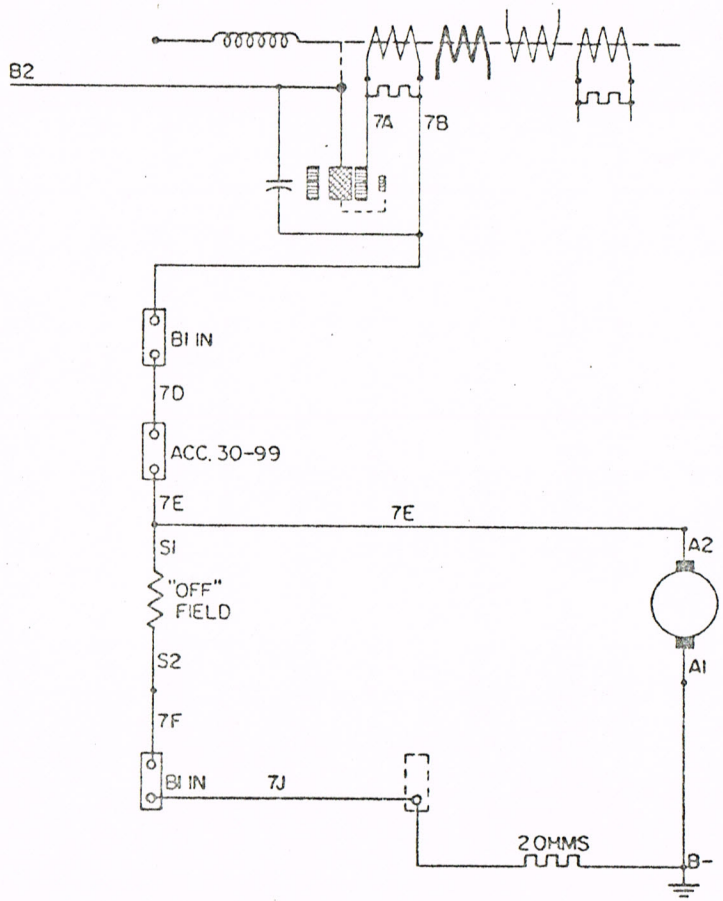
rent will flow in the traction motor (generator) circuits. This small current will, however, be sufficient to produce a voltage drop across the fields of traction motors #3 and #4.

The voltage drop across fields #3 and #4 is used to energize the spotting coil through the B.2 "In" interlock, the F.2 "In" interlock and the auxiliary contacts on the motor cut-out switch. Sufficient flux will be set up in the limit relay to cause it to operate and the accelerator rollers will be "spotted" in a position corresponding to car speed. The accelerator resistance in the traction motor circuit will thus be maintained at the correct value to permit the car to respond smoothly to either a re-application of power or to a demand for dynamic braking.

Operation of the pilot motor during spotting depends upon the physical position of the accelerator roller carrier. If all resistance was cut out of the traction motor circuit when the power pedal was released the accelerator would be in the 99th position. The pilot motor circuit would then be through the tickler coil from 7.A to 7.B; through the "In" interlock to 7.D; the accelerator interlock 30-99 to 7E; the "Off" field of the pilot motor to 7F; another B1 "In" interlock to 7J and through two ohms of resis-



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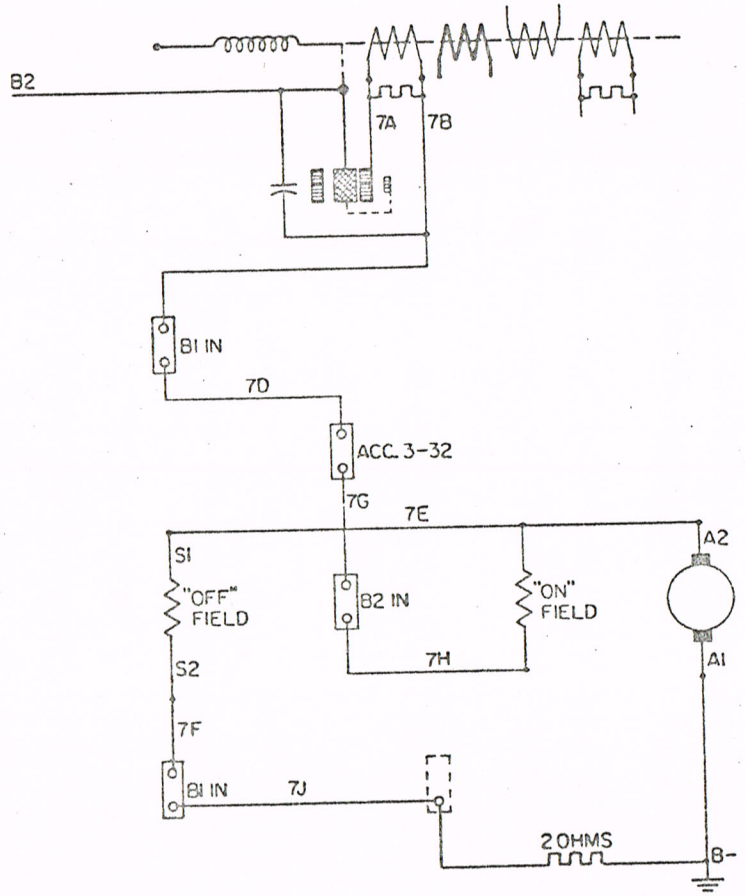
tance to B-. The motor now runs down shunt connected, cutting out the main resistance. This shunt motor connection is maintained down to the 30th position of the accelerator.

As the accelerator travels from position 32 to 30, a change in the pilot motor circuit is effected. The feed from 7.D transfers to the accelerator cam switch 3-32 and so to 7.G; through the B.2 "In" interlock to 7.H; the "On" field of the pilot motor in the reverse direction to 7.E and from this point through the "Off" field and the armature in parallel as previously set up. The pilot motor field strength is thus increased and its speed reduced. The motor now operates as a compound motor and more accurate spotting is obtained in the lower positions of the accelerator where it is of value in providing smooth braking.

Normally car speed will decrease during coasting, and the accelerator under control of the limit relay will slowly return to the Off position. However, under certain conditions such as down grade operation the car speed may increase. Such increasing speed will increase the circulating current, thereby increasing the spotting coil excitation. This will cause the relay to back contact briefly, reversing the pilot motor rotation. The accelerator will



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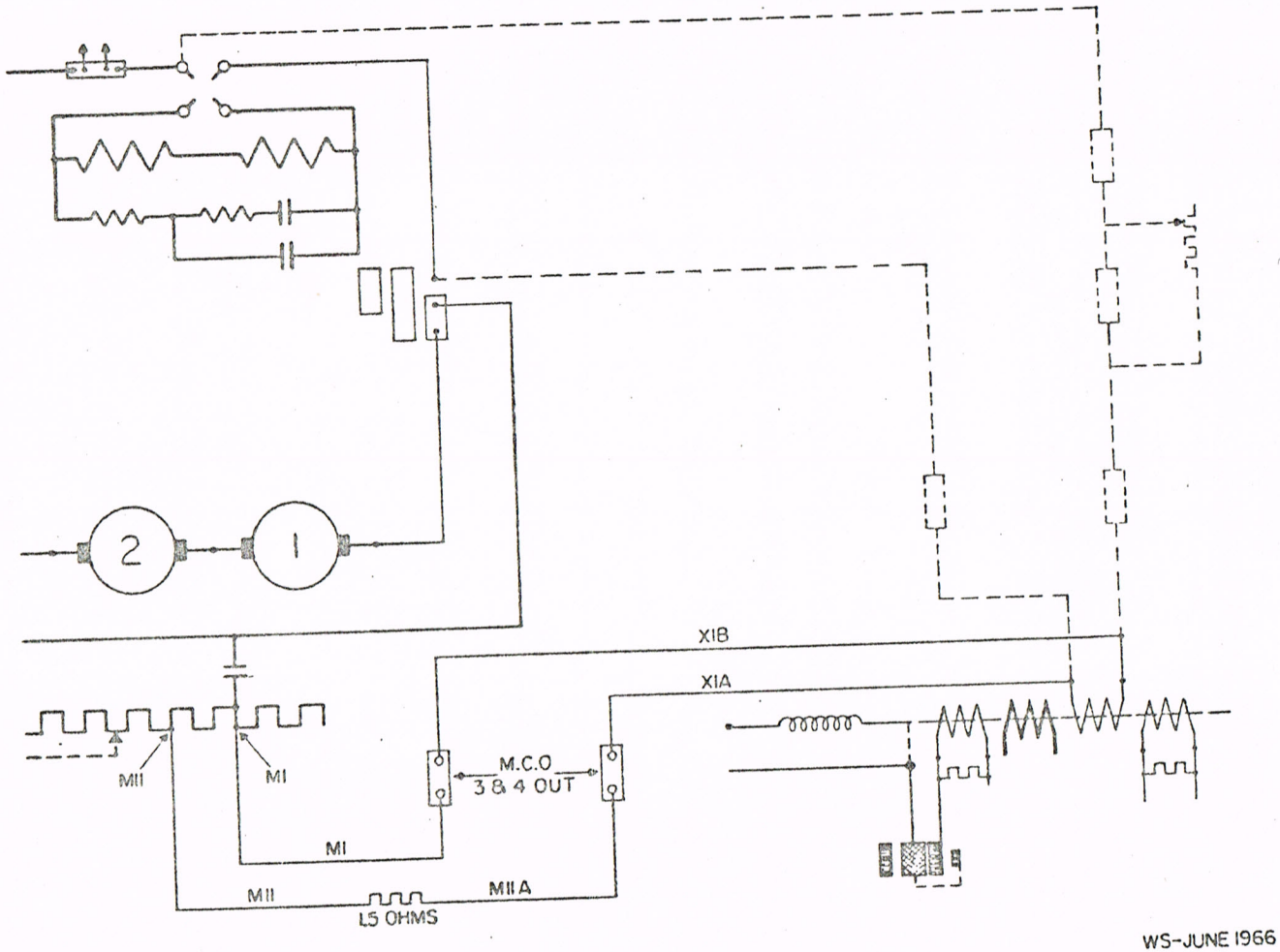
run up until the correct spotting is again obtained.

When the brake pedal is depressed and the F.2 contactor opens to permit the build-up of dynamic braking current, the opening of the F.2 "In" interlock places a resistor in series with the spotting coil. The limit relay is thus made more responsive to the action of the series, tickler and rate coils. Dynamic braking is thus more pronounced.

At 70° of rotation of the brake controller cam shaft the rate coil is de-energized and the tickler and series coils take over major control of accelerator position.

If traction motor trouble develops on a car and it is necessary to cut out motors #3 and #4, the limit relay circuit is changed somewhat. The series coil will be completely inoperative. The tickler coil and rate coil circuits will be unchanged. The spotting coil circuit will be energized during acceleration since it is now connected across part of the accelerator resistance. The limit relay will control the run-up of the accelerator.

When traction motors #1 and #2 are cut out the series coil will remain in the accelerating circuit and



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the limit relay will again control the run-up of the accelerator.

It should be noted that with a pair of traction motors cut out there can be no dynamic braking, since the generating circuit no longer exists. When the brake pedal is depressed the pilot motor will run the accelerator down ready for the next application of power.