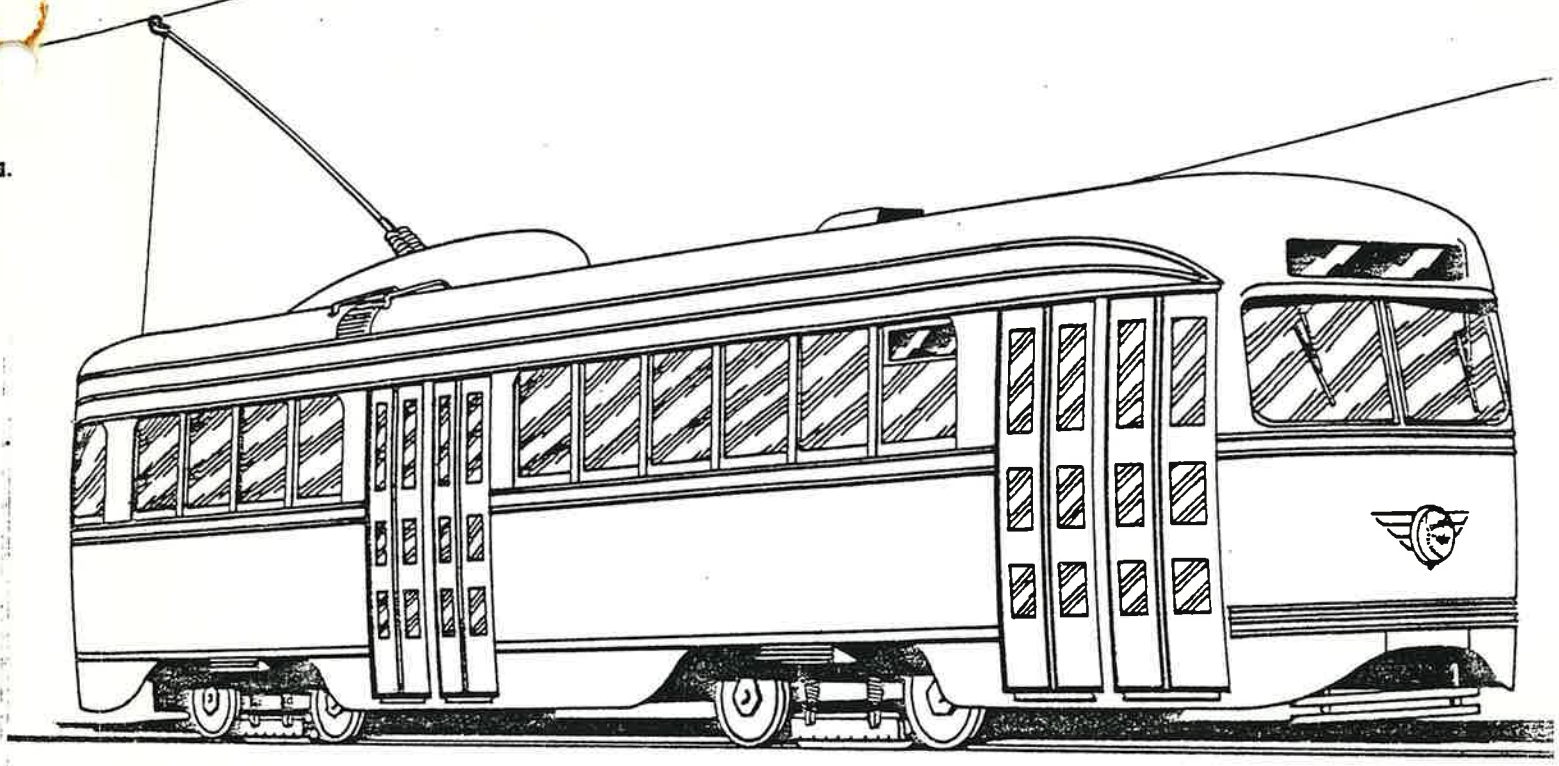


The PCC car—still a good idea

by Harre Demoro

The PCC car was the first successful standardized streetcar design, developed by the Electric Railway Presidents' Conference Committee during the early 1930s. The first type of surface rail car built in the U.S. and Canada, 4,918 were constructed and used in 25 U.S. and Canadian cities between 1936 and 1952. Artist: Barry G. Smith

The current generation of transit engineers and experts who suddenly have discovered the benefits of "light rail" transit typically ignore the development of the PCC—Presidents' Conference Committee—car and the lessons that may be learned from it.

Around 5,000 Presidents' Conference Committee streetcars and about 1,000 PCC rapid transit cars were built in the United States between 1936 and the mid-1950s. Only about 1,000 streetcars of this design remain in operation although most of the rapid transit units continue in use.

Despite what some historians have stated, the PCC design effort was one of the most comprehensive in any American industry. It was, to be sure, an attempt to "rescue" the investment many companies had in street railways. But its design went far beyond that and the components and concepts perfected by the program continue to be refined in western and eastern Europe, where "light rail" development remains a high priority.

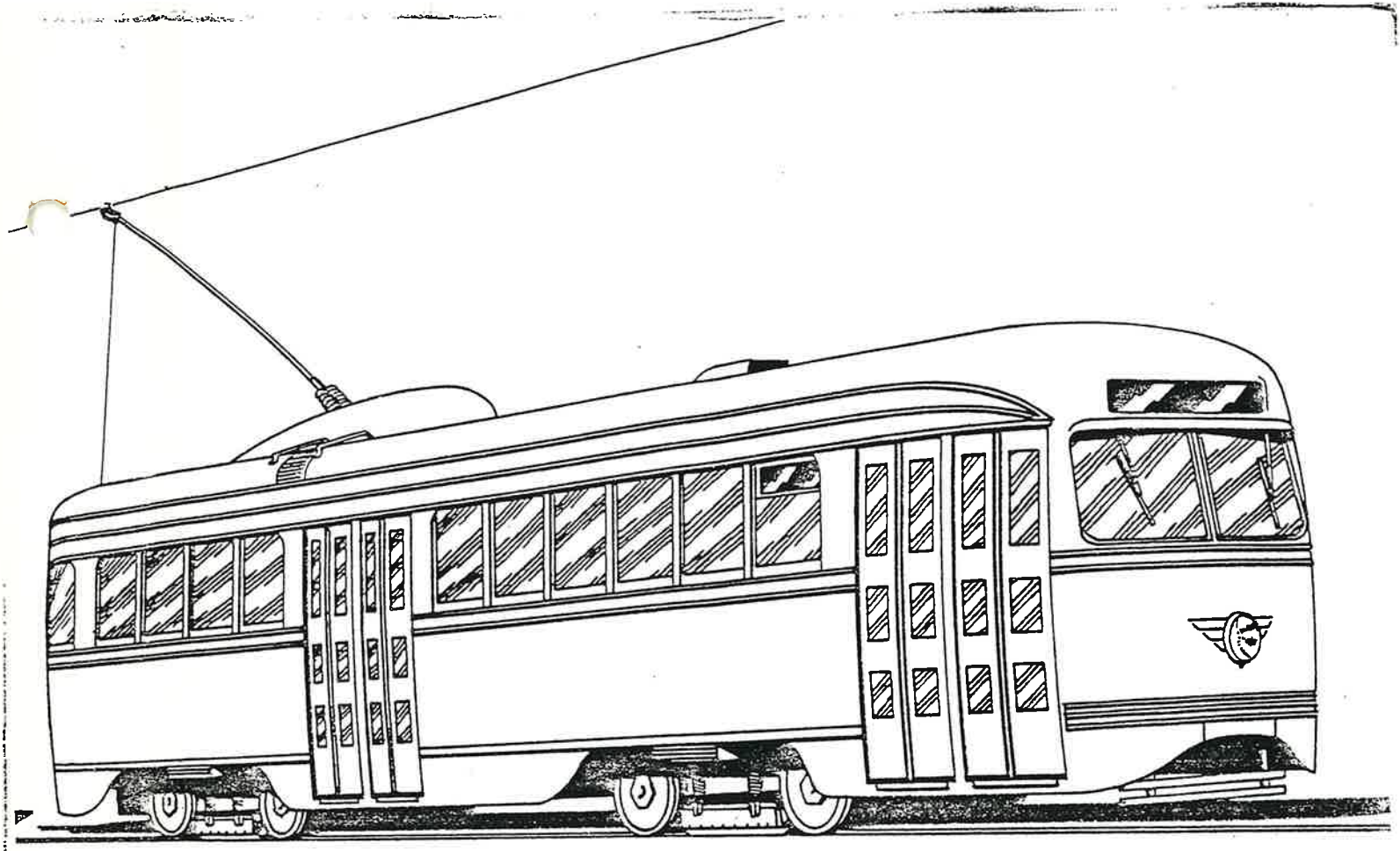
Quite unlike the present effort to develop the so-called "Standard Light Rail Vehicle" (SLRV), the PCC process was long-range and quite methodical. This is even more remarkable when it is realized the program was financed totally by operating companies during the most dismal years of the Great Depression.

Street railway executives met in 1929 to discuss the financial and technical problems plaguing their industry. There had been considerable effort in the late 1920s to improve car design. But generally this was done by the car builders and electrical suppliers on a piecemeal basis. It was decided to take a bold step to try to preserve the great investment the companies had in track, yards and power distribution facilities by designing a surface rail car capable of meeting, headon, competition from buses and automobiles.

Committee established

In 1930, under the sponsorship of the American Electric Railway Association, the Electric Railway Presidents' Conference Committee was established.

This group comprised about 25 operating companies and eventually about $750,000 was raised, an incredible amount when the end product is considered in light of today's costs. The ERPCC decided an expert with little or no experience in street railways should head the project. C.F. Hirshfeld, a longtime Detroit Edison engineer and well qualified researcher, was hired to direct the work.



The researchers examined and tested most of the then modern street railway cars. Trucks, motors, control apparatus, sound level, interior lighting and body fabrication methods were among the items receiving close attention.

Hirshfeld insisted that rather than selecting the best components then available and refining them, it was necessary to advance the state of the art by a considerable distance. Hirshfeld did take many modern items the industry already had developed, such as the concept of lightweight, high speed motors, magnetic brakes and accelerator control. But his main effort was to produce a car that would meet high standards for speed, comfort and economy.

A variety of tests were done, including experiments using women standing on cars while wearing high heel shoes. The researchers found that such a passenger could comfortably tolerate rapid acceleration and braking if it were done smoothly. Tests were made to find a comfortable level of light for a standing passenger reading a newspaper. Considerable effort was spent to trace sources of noise and vibration evident in even the most modern cars.

Whatever was to be developed had to be capable of mass production at economical cost. And the final product had to consistently result in a standard of performance no matter where it operated.

The Hirshfeld team spent much effort working with rubber. The industry had experimented with rubber in wheels to deaden noise, but with mixed results. The researchers succeeded in developing a resilient wheel, a sandwich of steel and rubber that effectively dampened much of the noise and vibration. In addition, a combined rubber and steel spring was developed that smoothed out the ride and all but eliminated noise and vibration from being transmitted to the car body. Hypoid gears of the automotive type, bathed in oil, replaced the old and noisy spur gears used on conventional cars. Four 55 horsepower, 300 volt motors, powered the car.

Braking improved

Multi-notch controllers that provided smooth acceleration and braking were built by Westinghouse Electric & Manufacturing Co., and General Electric. They were so precise, the jerking motion characteristic of the older cars was eliminated.

Three braking systems, blended into one process, were used. Dynamic brakes were the primary stopping force, assisted by magnetic track brakes. As dynamic braking faded at slow speeds, an air-actuated wheel brake completed the stopping and held the car.

Considerable attention was paid to the car body. While it was not as light as would have been possible then, major structural members were arranged to also act as air ducts and channels for wiring and piping.

Four sample cars were unveiled in 1934, almost four years after the work began. Three were all new and one was an experimental unit Hirshfeld developed using an older Brooklyn & Queens car. None was considered the production car. All cars proved the Hirshfeld effort was a success, but none of the manufacturers was willing to risk building the car on a production line.

Finally, Brooklyn & Queens agreed to order 100 cars and St. Louis Car Co. decided to tool up and mass produce the PCC streetcar. Much credit is due the St. Louis firm for carrying to practical fruition the work of the researchers. The first car, with many hand-built parts, was completed in 1936 and after testing, the balance of the order was delivered to Brooklyn in 1937. Soon the St. Louis order books were filled; PCC streetcars appeared in Pittsburgh, Philadelphia, Los Angeles, San Diego, Twin Cities and

(Continued on p. 29)

(Continued from p. 15)
a host of other cities.

By 1946, 10 years after the first Brooklyn car was delivered, there were 2,864 PCC streetcars on 19 transit systems in North America, including those built under license in Canada. The committee kept detailed records of the performance of the cars and found in almost every case revenue and schedule speeds increased and costs went down. Pullman-Standard Car Manufacturing Co. began PCC streetcar production in 1939, supplying a sample car to Cincinnati and 11 to Baltimore.

The PCC design was not static. It not only was refined, it also could be applied in a variety of configurations.

In 1940, after testing in Brooklyn, St. Louis Public Service received 100 "all-electric" cars that had no air brakes or air door operating machinery. A spring brake on motor driveshafts acted as a parking brake as the dynamic brakes faded. After tests in Boston, Washington, D.C. and Chicago, a better ventilation system using a roof duct containing fans, was developed. An improved truck more suitable for open track (which is typical today for "light rail") was perfected.

From the beginning, the design allowed a single-ended car, and what today is called bi-directional capability. Most cars for surface operation were of the single-ended design, but both Pullman and St. Louis offered double-enders that appeared in Dallas, San Francisco, Los Angeles and on the Illinois Terminal service in St. Louis.

Also from the beginning, a rapid transit specification was developed. PCC rapid transit cars were built for the BMT division in New York, Chicago Transit Authority, Cleveland Transit System and Boston's MTA.

The last streetcars of the PCC pattern were 25 delivered by St. Louis to the San Francisco Municipal Railway in 1951-52. They are still in service. The PCC design effort, which was financed after 1936 by royalties collected for use of patented items, faded away in the mid-1950s.

The new SLRV has a higher top speed than the PCC's maximum 41.5 mph. But the PCC could and does accelerate and brake faster, making it more agile in urban traffic. And the Europeans have built articulated PCC streetcars with excellent results.

Sometimes a good idea passes only once. Perhaps it is not too late to watch a PCC streetcar pass by on a street in one of the few U.S. cities where they still operate, and ponder the significance of Hirshfeld's $750,000 effort. □

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THE P.C.C. STREET CAR

Through the depression years, 1929 - 34, public transit revenues fell off sharply. Maintenance of all rolling stock was cut back sharply and the equipment deteriorated.

When it became evident that conditions were slowly improving, surveys indicated that huge expenditures would be necessary to reclaim and modernize existing equipment. It was realized that the travelling public would not tolerate riding on antique vehicles. The gasoline-driven bus had made great inroads on electric transit and passengers were demanding smooth, comfortable rides.

The old type of street car was noisy, rough and slow. It lacked eye-appeal. It did not accelerate fast enough to keep its place in traffic, or stop fast enough to be safe.

The electric transit industry, both manufacturers and operators, realized that new vehicles must be designed and built. These cars would have to offer all the comfort and convenience found in motor coaches. To facilitate the design of new equipment, a large committee representing many transit operators in the United States and Canada was set up. This group became known as the Presidents' Conference Committee (P.C.C.), since it was nominally established by the presidents of the transit companies.

The Committee was divided into a number of individual groups to establish specifications for such things as electric traction and control, braking, trucks, body design, heating, lighting and passenger seating. The designs and specifications produced by the Committee were made available to all interested manufacturers. The general design became known as the P.C.C. car.

Two body designs were approved, one by the Pullman Car Company and one by the St. Louis Car Company (the T.T.C. adopted the St. Louis Car Co. style). Two

systems of electric traction control were adopted by the Committee, General Electric and Westinghouse (the T.T.C. decided upon Westinghouse).

Electric Traction Equipment

(The equipment to be described is the Westinghouse version of P.C.C. control equipment.)

Four traction motors are used on the P.C.C. street car. These are each rated at 55 H.P., 300 volts, D.C., and are permanently connected electrically in pairs. The armature and field leads for each motor are brought out separately.

Replacing the old hand-operated drum controller with its eight or nine positions and cumbersome rheostat boxes is an electric motor-driven accelerator which has 75 operating positions in acceleration and 99 for braking. When the driver pushes down on the accelerator pedal, the accelerator is driven to cut resistance out of the traction motor circuit. Since there are 75 resistance steps available, acceleration is smooth and positive.

Power to the traction motor circuit is controlled by an electro-magnetically operated lineswitch. The overload portion of the unit is set to operate at 750 amperes. When this occurs, an electro-magnetic holding device maintains the contacts in an open position until the driver's accelerator pedal is returned to the "off" position. Magnetic arc blow-out extinguishes the arc when the main contacts open the motor circuit.

Nine electro-magnetically operated contactors set up circuits for acceleration, traction motor field shunting and dynamic braking. Auxiliary contacts on the contactors provide for interlocking between various control circuits.

A current limit relay is used to provide control

of the rates of acceleration and dynamic braking. This is accomplished by passing the traction motor current through one coil of the relay and arranging for the relay contacts to determine the accelerator position. Limit relays for use on cars designed for single-car operation have three operating or control coils and variable spring tension; for M-U (multiple unit) control, four coils are used and the spring tension is constant.

A small split-field D.C. motor is used to drive the accelerator under control of the current limit relay. This unit is called the pilot motor.

The master power and braking controller is operated by means of the driver's foot pedals. It consists of two cam rolls with associated cam-operated switches. One cam roll controls acceleration of the car and one controls braking. A reversing device is also included. This may be an additional cam roll which sets up circuits for an electro-magnetic reverser or may be a more conventional wooden-drum type reverse roll. The reverse section is operated by a hand lever at the driving position.

The electro-magnetic reverser is a device used on some M-U cars to obtain reversal of the traction motors. It consists of two large electro-magnets which act upon a common armature or yoke. Only one coil is energized at a time. The yoke is mechanically coupled to a reverse drum, which allows reversal of the traction motor fields.

Braking Systems

Three methods of braking are used to stop and hold an all-electric P.C.C. car, dynamic, drum or friction brake, and track brakes.

Dynamic braking is achieved by making the four traction motors act as generators during the braking cycle. A series motor is inherently unstable when

acting as a generator, and this characteristic is overcome by cross-connecting armatures and fields for braking. The armatures of traction motors #1 and #2 energize the field coils of motors #3 and #4. Armatures #3 and #4 energize fields #1 and #2.

The multi-step accelerator is now connected as a load for the four generators. The potential energy of the car's motion is converted into electrical energy by the generators and this is dissipated in the accelerator as heat. The current limit relay connections are such that it will now control the rate of dynamic braking, ensuring a smooth stop.

The drum or friction brake is used to provide a final stop when the dynamic brake fades. It also prevents the car from rolling when parked. The brake acts on a drum fastened directly to each traction motor armature shaft. In the Westinghouse system of control, the brake is spring applied and electrically released.

The third braking method, track brakes, involves the use of large electro-magnets slung between each pair of traction wheels and hanging directly over the running rail. When energized, the track brake shoes are attracted to the rail and act as friction drag brakes. The electro-magnet coils in the shoes are energized from the 32-volt auxiliary electrical system.

The Auxiliary or Low Voltage Supply

The P.C.C. car has a low voltage power system similar to that found on an automobile or motor coach. A direct current generator supplies the electrical power. It is directly coupled to the shaft of a high voltage D.C. motor. In actual practice, the motor and generator armatures are mounted on a single shaft and contained in a single housing. The unit is called the motor-generator set. Large multi-vane fans are mounted on both ends of the armature shaft. Air from the fans is blown through the traction motors and through the accelerator compartment.

The D.C. drive motor of the M-G set is connected directly to the 600 volt trolley supply by means of a contactor. The motor is energized at all times when the car is in service.

Since the generator armature is mounted on the motor shaft, it also operates continuously. The D.C. output is maintained at 36.0 volts by means of a voltage regulator. The generator supplies power to almost all of the control and auxiliary circuits and maintains the car battery in a fully-charged state.

The voltage regulator is a vibrating type with a carbon moving contact and two stationary silver contacts. The regulated voltage is adjustable by varying the spring tension on the armature.

The battery carried on the car is of the lead-acid variety and has a nominal potential of 32 volts. The 36-volt generator output therefore maintains a small "trickle" charging current through the cells at all times. The battery is used to operate all emergency devices such as gong, stop lights, sander, track brakes etc., in the event of a generator output failure.

Heating

Heating of the P.C.C. car is by means of "waste" heat. Air from one of the multi-vane fans on the M-G set is blown continuously through the accelerator compartment. During acceleration of the car, and particularly during dynamic braking, the accelerator resistor ribbons become quite hot. The air passing over the ribbons is heated and is directed up into the car body.

When a pre-determined temperature is reached, a thermostat acts to operate two dampers in the air ducts and the hot air is discharged to atmosphere under the car. As the car body temperature falls, the thermostat causes the dampers to operate back to the "heat" position.

The Driver's Controls

The controls located at the driver's position consist of:

(a) Three foot pedals --- accelerator, brake and foot interlock.

(b) The reverse lever.

(c) The "gang" or control switch assembly.

Three foot pedals permit complete control of car movement. The accelerator pedal is the large one located at the right-hand side of the pedal-plate assembly. When it is depressed, one cam roll in the master controller is rotated and power is applied to the traction motors. The farther the pedal is pushed down the greater will be the rate of acceleration. However, whether the pedal is depressed only a short distance or travels all the way down, the car will eventually reach its top speed. No provision is made for obtaining intermediate speeds.

The brake pedal is the centre one of the assembly. When it is depressed, the brake cam roll in the master controller is rotated. When pedal travel is to the service brake position, dynamic braking is obtained which slows the car to about 5 M.P.H. As the dynamic brake fades the drum or friction brakes are automatically applied to stop and hold the car.

When the brake pedal is pushed down beyond the service brake position, the track brakes are also energized and a considerably higher rate of deceleration is obtained.

If the brake pedal is pushed all the way down to the floor, emergency braking is obtained, and the pedal latches in this position. In the emergency position two braking systems, dynamic and track brakes, are applied and the car stops very rapidly. Drum brakes are applied only near the end of the braking cycle, as the dynamic brake fades. In addition, the gong will sound continuously, sand will be dropped on the rail from two hoppers and all pas-

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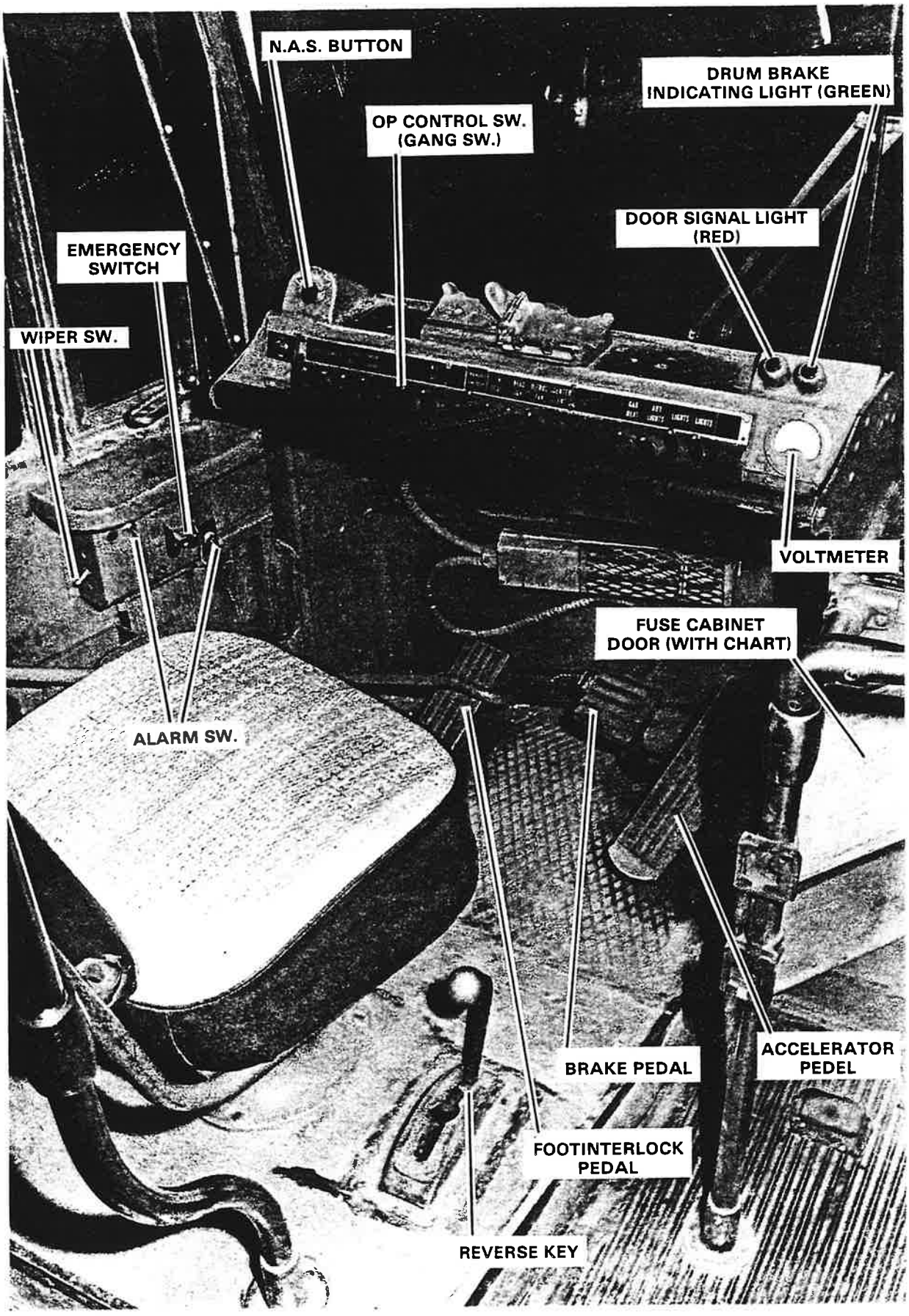
senger doors "balance" so that they may be pushed open by hand.

The control system is so arranged that braking will predominate over power. If for any reason the accelerator pedal should stick in the "on" position, movement of the brake pedal will cause the lineswitch to drop out, disconnecting traction power.

The pedal at the left side of the assembly is the foot interlock or "deadman's" pedal. This is so arranged that constant pressure of the driver's left foot is required to maintain car operation. If the foot interlock is released, traction power is cut off, track brakes are applied, sand is dropped, the gong sounds and the doors balance.

The reverse lever is located to the right of the operator's seat, resembling somewhat a floor-mounted "stick-shift" in an automobile. It has three positions, forward, reverse, and emergency. In the emergency position the lever may be removed from its socket.

The gang or control switch assembly consists of a number of switches mounted on the dash directly in front of the driver. Some are toggle-type switches and remain in the position to which they are moved; others are of the spring-return type. Such functions as gong, sander, front doors, M-G set, defrosting fan, and car lighting are controlled by these switches.


N.A.S. BUTTON
DRUM BRAKE INDICATING LIGHT (GREEN)
OP CONTROL SW. (GANG SW.)
DOOR SIGNAL LIGHT (RED)
EMERGENCY SWITCH
WIPER SW.
VOLTMETER
FUSE CABINET DOOR (WITH CHART)
ALARM SW.
ACCELERATOR PEDEL
BRAKE PEDAL
FOOTINTERLOCK PEDAL
REVERSE KEY

TORONTO TRANSIT COMMISSION

MULTIPLE UNIT P.C.C. CARS
4400-4499

Principle of Operation

(See Schematic Diagram A-5008)

The principle pieces of control apparatus are:-

The combined master and brake controller
The reverser
The accelerator
The limit relay
The contactor panel
The line switch
The inductive shunt
The brake relay panel
The motor cutout switch
The M.G. set regulator panel
The motor and control resistors.

Referring to the schematic wiring diagram, it will be noted that the four motors are permanently connected so that the two motors on each truck are in series. These pairs are connected in parallel. During dynamic braking the armatures and field are re-combined; the motors, now operating as generators, supply power to a common resistance. By allowing one pair of armatures to excite the fields of the other pair, a balance of dynamic braking current is maintained.

Starting

In order to start the car it is first necessary to close the M.G. set control switch at the operator's position to start the motor generator set which provides control and brake circuit power. If the emergency relay is open, it must be closed by momentarily closing the emergency relay reset switch at the operator's position. The relay will then hold itself closed as long as battery voltage is available and the various safety stops

remain closed.

Advancing the master controller to a power rate position (14^{o} or higher), contactor M1, the line switch, and contactor R1 will close in sequence. The circuit for the line switch is from battery positive B2, through a switch on the brake controller to 6A, through the emergency relay to 6, through the door interlock relay to 6C, through switches 6C-3 and 3-3A on the master controller, through the master reverser to 1, through pilot contacts on the reverser to 3B, through the overload relay to 3C, through the emergency relay to 3E, through the L.S. coil to 3F, through an interlock on B1 contactor to B-. The use of a switch on the brake controller is to ensure that braking takes precedence over power; the use of a switch on the master reverser is to ensure the line switch being opened if the reverser should be thrown during car operation (If the reverser were in reverse position the circuit would be 3A to 2) and the use of the pilot contact on the reverser is to ensure that it is in an operating position.

The circuit to 3 on the master controller passes through the coil of M1 to B- direct.

The circuit 6, through an interlock on M2 contactor to 6B through an interlock on R1 contactor to 4K and through the coil of F2 contactor to B- picks up this contactor briefly to weaken the fields of motors 1 & 2 until R1 closes and thus provides smooth starting.

Since contactors B1 and B2 are energized in the control off position, the B1 interlock in the line switch coil circuit prevents the latter from closing until M1 has closed and B1 has opened.

The circuit for R1 is from B2, through a switch on the master controller to 4, through the trolley relay to 4A, through an interlock on the line switch (after it has closed) to 4B and through the R1 contactor coil to B-.

The main circuit current passes through the line switch LS, and the OL relay, dividing the two pairs of motors and recombining to pass through switch M1 to finger 79 at the accelerator through the resistor ribbons to finger 1 which is pressed against the bus bar by one of the rollers, through the bus bar by the other roller, through the resistor ribbons to ground.

Moving the master controller back to the off position opens the switches in the sequence LS, R1, and M1.

Acceleration

Battery positive energy from B2 is at all times available at the moving contact of the limit relay. This energy, when the contacts are in the normally "closed" position, passes through circuit 7A and the tickler coil to 7B. When the power pedal is depressed and R1 closed, the circuit will continue through and interlock on R1 to 7C, through the accelerator cam switch 1-97 to 7E and through the pilot motor armature to B-. Another circuit from 7E, through the ON field to 7H, through an interlock on M1 to 7J, and through a resistor to B- energizes this field and causes the pilot motor to run in the forward or accelerating direction.

As the accelerator moves forward resistance in the main motor circuit is cut out and the main motor current builds up.

This increasing current, flowing through the limit relay series coil, adds to the current already flowing through the tickler coil and will soon reach a value which will cause the relay contacts to open , de-energizing the pilot motor and the tickler coil. As the tickler coil is de-energized, the pull on the relay is reduced, permitting the contacts to reclose and again energize the pilot motor and tickler coil which, in turn, will cause the relay to open again. A fluttering action is thus established which will persist as long as the current in the series coil is above full load and which is essential to the proper action and regulation of the pilot motor.

Whenever the pilot motor supply is interruped, the armature current will reverse and the pilot motor will act as a generator, passing current through the field in the usual direction. This will apply a considerable braking, or plugging action to the motor, and it will stop promptly in case of an interruption of any kind. With the aforementioned fluttering action, the pilot motor armature current becomes a quick succession of power and braking impulses, resulting in a reduction of motor speed. The effect is such as to always maintain at a constant value the main motor current as called for by the setting of the limit relay. For a given setting, if main motor current tends to rise the plugging impulses of the relay becomes longer; conversely, if main motor current tends to fall, the power impulses of the pilot motor becomes longer. The main motor current is thus maintained at a

constant value by this regulation of pilot speed.

As the car speeds up, the accelerator continues to advance, cutting out resistance to maintain the main motor current called for by the limit relay setting.. When the accelerator rollers attain position #75, energy from the 3 wire will pass through an accelerator interlock to 3G, through the M2 switch operating coil to ground. The closing of the M2 switch will cut out the remaining accelerator resistance.

The closing of R1 contactor sets up a circuit for the operation of the field shunting contactors after the accelerator reaches the proper position. The circuit is from battery positive B2 through an interlock on R1 to 4D. M2 being closed, at position 80 of the accelerator, a cam switch completes the circuit from 4L to 4K and through the coil of F2 to B-, closing this contactor. At position 85 a similar circuit from 4D to 4F and through the coil of F1 closes this contactor. At position 90 & 95 respectively, F3 & F4 are similarly closed. The motors now have full power applied to them.

The accelerator will continue to advance until it reaches the 97th position where the accelerator cam switch between the 7C and the 7E wire will open, interrupting the pilot motor supply. This stops the accelerator and the cycle for accelerating position is now complete.

The sequence of acceleration is the same for all master controller power positons after it has been initiated at the 14° position. Depressing the pedal beyond this point changes the rate of acceleration by varying the current in the rate coil

of the limit relay and the pull on the relay moving contact due to the effect of this coil in conjunction with that of the tickler and series coils.

The circuit for this coil is from B2 through a switch on the brake controller to 5C, through a switch on the master controller closed to 400 to 5B, through a switch on the master reverser to train line 5A, through any uncoupled coupler drum switch to 5, through a 400 ohm calibrating resistor to 5F and through the relay coil and its parallel 1,000 ohm resistor to B-. From 5B a parallel circuit to B- through the master controller rate resistors exists so that the operative portion of these resistors is parallel to the coil, its parallel resistor and its series calibrating resistor. Another parallel circuit to B- passes through the rate resistors on the brake controller. As the brake pedal is depressed the various rate cam switches on the brake controller increase the resistance in the limit relay rate coil circuit and weakens the strength of the coil.

As the accelerator pedal is depressed the various rate cam switches on the master controller increase the resistance in the limit relay rate coil circuit and weakens the strength of the coil.

The rate coil furnishes a part of the magnetic pull tending to open the limit relay contacts and its lessening effect as the master controller is advanced to higher rates permits a greater current to flow through the series coil before the contacts open increasing the lengths of running periods of the pilot motor and so increasing the rate of acceleration.

Operation of Trolley Relay

This relay has its coil connected between trolley and ground and, therefore, the relay will drop whenever the car passes under a trolley break. This performs three control functions if the car is in a power position.

The opening of TR will drop R1 re-inserting some accelerator resistance.

The opening of R1 opens the circuit from 7B to 7C on the pilot motor feed and stops the operation of this motor.

The opening of R1 interrupts the circuit to 4D, opening the field contactors.

When TR recloses, the normal power functions are resumed.

This operation ensures that the accelerator will not advance during the interruption of main power and provide a cushioning effect on the resumption of power.

Coasting

Returning the master controller to the off position by releasing the power pedal allows the car to coast. The opening of R1, LS & M1 as previously noted disconnects the main circuits to the motors.

If the accelerator, before shutting off, was advanced to the position where the field switches were closed, the opening of R1 would tend to open them but the opening of M1 would immediately reclose F1 and F3 and the opening of M2 and R1 would reclose F2. F4, however, would remain open since the opening of M2 interrupts the circuit from 4J to B-.

The opening of LS establishes a circuit from 4D to 4E and through the coils of contactors B1 and B2 to B-. This sets up the main motor circuits for spotting or braking by connecting A3 on the #3 motor circuit to 1-on the accelerator and A2 on the #2 motor circuit to 2-on the accelerator.

Spotting is essentially dynamic braking at such a low rate that its effect on car retardation is not perceptible.

Due to the slight resistance of the circuits and the unbalanced field conditions, a small current will be generated and this current, passing through the main and spotting coils of the limit relay, will operate the accelerator in such a manner that the rollers will always be in a position corresponding to car speed so as to give prompt and correct response for an application of either power or dynamic braking.

In the operation of the pilot motor during spotting the circuit from 7B passes through an interlock on B1 to 7D through an accelerator cam switch 30-99 to 7E, through the OFF field to 7F, through another interlock on B1 to 7J and through a resistor to B-. The circuit from 7E through the armature is the same as for acceleration but the pilot motor is driven in the reverse direction and tends to move the accelerator back to the #1 position, cutting out the main resistance.

As the accelerator travels from positions #32 to 30 a change in the pilot motor operation is effected. The feed from 7D transfers to the accelerator cam switch 3-32 and through it to 7G, through an interlock on B2 to 7H, through the ON field in reverse direction to 7E and from there through the OFF field and armature as before. Since the reverse current through the ON field is directly additive to the normal current in OFF field the pilot motor field strength is increased and its speed reduced. Thus more accurate spotting is obtained in the lower position of the accelerator where it is of value in providing smooth braking.

The circuit through the spotting coil during coasting

is from X3 on the main circuit through an interlock on B2 to X3A, through an interlock on F2 to X3B, through the motor cutout switch to X1B, through the coil to X1A, and through the motor cutout switch to X1 on the main circuit, placing the coil in parallel with the fields of motors #3 and 4. Should motors 3 and 4 be cut out, the coil would be in parallel with apportion of the accelerator resistance.

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 dynamic braking current, thereby increasing the spotting coil excitation. This extra pull on the moving contact will move the relay moving contact over to complete a circuit to 7K. This causes a current to flow through a portion of the control resistor and through the OFF field in a reverse direction. This operates the pilot motor as a series motor under low power to move the accelerator toward the full on position, increasing the dynamic braking resistance and lowering the spotting coil current until the relay contact can break the circuit to 7K.

When the moving contact of the limit relay moves to energize 7K, the back contact is brought over to energize 7L placing a shunt across the pilot motor armature and keeping the speed under control.

Spotting continues with the accelerator maintaining a position corresponding to car speed until there is either a power or brake application. For a power application the

circuits change to those previously described.

Braking

When the brake pedal is depressed, the necessary circuits are set up to change from spotting to active dynamic braking.

When the brake controller is advanced to 11° the F2 contactor is opened by the interruption of the circuit B2 to 6A. At 14° the rate resistor circuit of the rate coil is brought into effect by the interruption of the direct circuit from B2 to 5C. When F2 opens, the direct circuit from X3A to X3B is opened and a resistor is placed in series with the spotting coil to weaken this coil and make the relay responsive to the action of the series, tickler and rate coils, thus making deceleration more rapid and dynamic braking more pronounced in accordance with the position of the brake controller and its action on the rate coil. At 70° on the brake controller the rate coil is de-energized.

If the brake pedal is released before the car stops, the control will re-assume the coasting position.

If the brake pedal is depressed while the power pedal is still down, braking will proceed normally since at 11° on the brake controller the line switch is opened by interrupting the circuit from B2 to 6A. In this case R1 is not opened until the line switch has opened.

The dynamic braking effect is extended on this control so as to be effective until the car has almost stopped and, at the end of dynamic braking, a drum parking brake on the motor shaft is set.

Drum Parking Brake

The following points are to be noted with respect to the parking brake circuits.

The brake itself is spring set, coil released by an actuator, four brakes with actuator coils in parallel comprising a car equipment.

The following circuits are involved in the operation of the drum parking brake.

With the brake controller in the off position (before starting the car) a circuit exists from B16 through a brake controller switch to 11 and through the coil of FB1 to B- picking up this relay. The closing of FB1 completes a circuit from 11A through a contact on FB1 to 12A, through a contact on FB2 to 11D and through the actuator coils to B-. At the same time a circuit is established from 6 to B- through the lockout relay coil, closing this relay and establishing a circuit from 11B to 11D.

When the car is started and the accelerator reaches position #3 a circuit is established from 11A to 11B through accelerator cam switch 3-99. The circuit 11A-11B-11D through the accelerator cam switch and lockout relay parallels the other circuits to the actuators and keeps them energized as long as this circuit persists.

As the brake controller is advanced, at 11° the lock out relay 6-B- is de-energized but, in the meantime a second coil on this relay has been energized by a circuit from B1 to B11 on the accelerator and this second coil will hold the relay up until its voltage drops to a low value.

At 14° on the brake controller a circuit is established from B16 to 12 on a brake controller switch and, through the coil of FB2 to B-. The closing of FB2 opens the direct circuit from 12A to 11D and places a resistor in the parallel circuit 12A to 11D. At the same time a circuit is established from 11C to 12A. At 42° on the brake controller FB1 is opened which breaks a circuit from 11A to 12A, placing a second reistor in series with the first. At 70° on the brake controller FB2 is opened, leaving the actuator coils dependent on the lockout relay operation.

From the above it will be noted that the drum brakes are not fully set unless the brake controller is advanced to the parking position (beyond 70°). If braking is carried through at this rate the brakes will set immediately the lock out relay opens. If braking has been at a lower rate and the pedal is afterwards depressed to the parking position, the actuator coil circuit is weakened in two successive steps before being opened to ensure smooth brake operation.

Track Brakes

The operation of the track brakes from the brake controller will result if the controller is advanced beyond the parking position.

At 94° a circuit is established from B2 through a brake controller switch to 8 and through the coil of TB1 to B-. The closing of TB1 established a circuit from B+, through an 0.5 ohm resistor to 8A, through TB1 contacts to 8B,

through a 1.25 ohm resistor to 10A, through fuses to 10B and 10C and through the track brake coils to B-.

At 105° on the brake controller switch to 10 and through the coil of TB2 to B-. The closing of TB2 establishes a direct connection from 8A to 10A, parallelling the 1.25 ohm resistor and increasing the voltage on the brake coils.

At 116° on the brake controller the circuit B2-8 is opened. The consequent opening of TB1 establishes a direct circuit from B+ to 8A, parallelling the 0.5 ohms resistor and putting full voltage on the brake coils.

A circuit to allow the application of the track brakes if the B2 fuse blows is established when the brake pedal is depressed to the emergency position. The B+ feed is wired through two cam switches on the brake controller to the 10A wire. This circuit puts full voltage on the brake coils when closed.

Emergency Stopping

Should the emergency relay be de-energized while the car is being operated it will affect several circuits as follows.

It will open the circuit 3C-3E and 6A-6 to the line switch, cutting power from motors.

It will close a circuit to TB2 closing this relay and applying track brakes.

It will operate other circuits (sander, gong, stop light, door balancing relay) not shown in diagram.

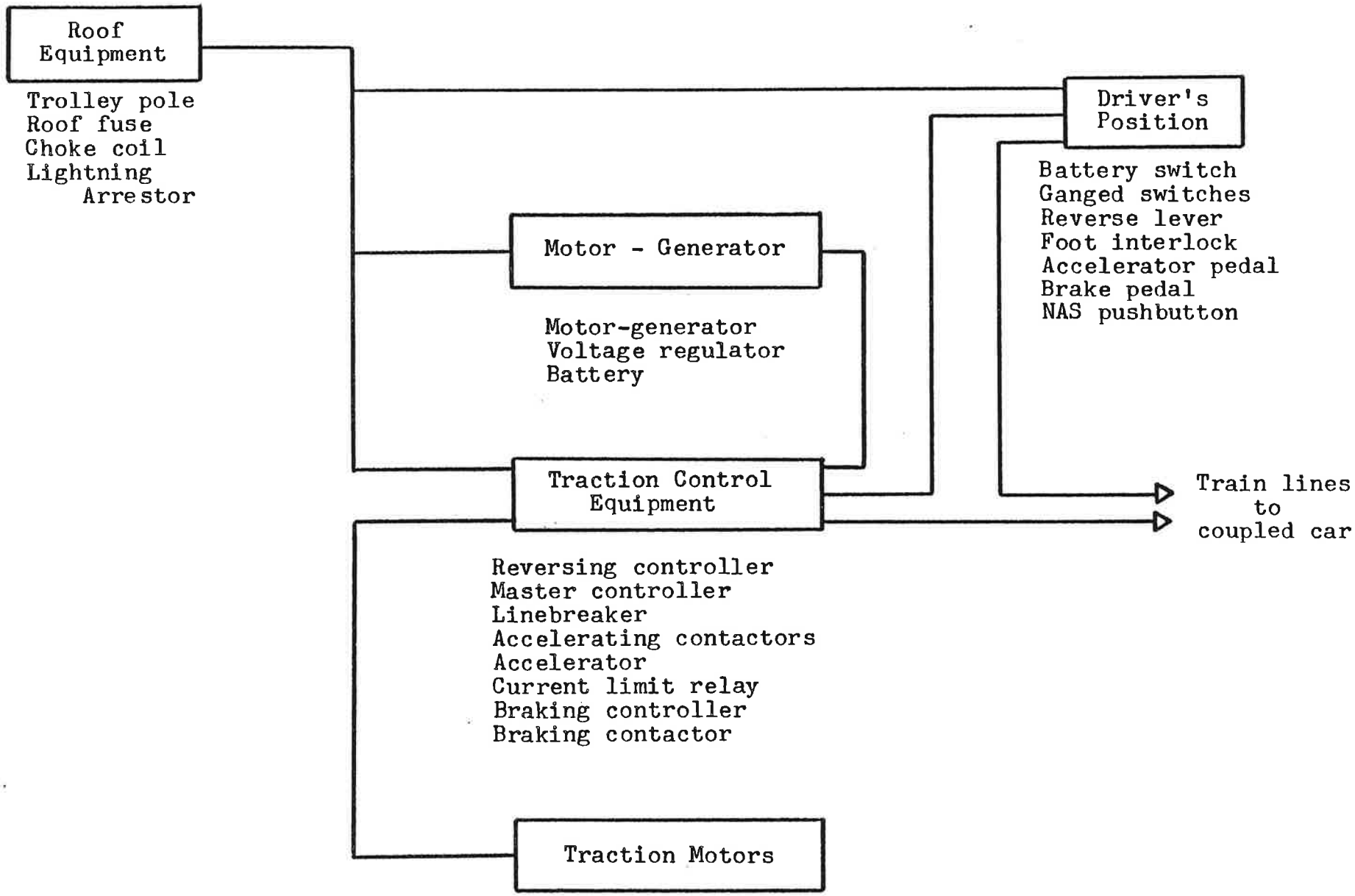
Reverser

Should the magnetic reverser be in the wrong position

when the car is started, the first operation when the master controller is advanced will be to energize coils F or R from circuits 1 or 2 through the reverse or forward interlock contacts. The closing of F or R will energize coils forward or reverse of the reverser proper from B2. When this operation is completed the interlock will de-energize the F or R coil and another interlock will complete the circuit from 1 or 2 to 3B for the line switch.

Train Operation

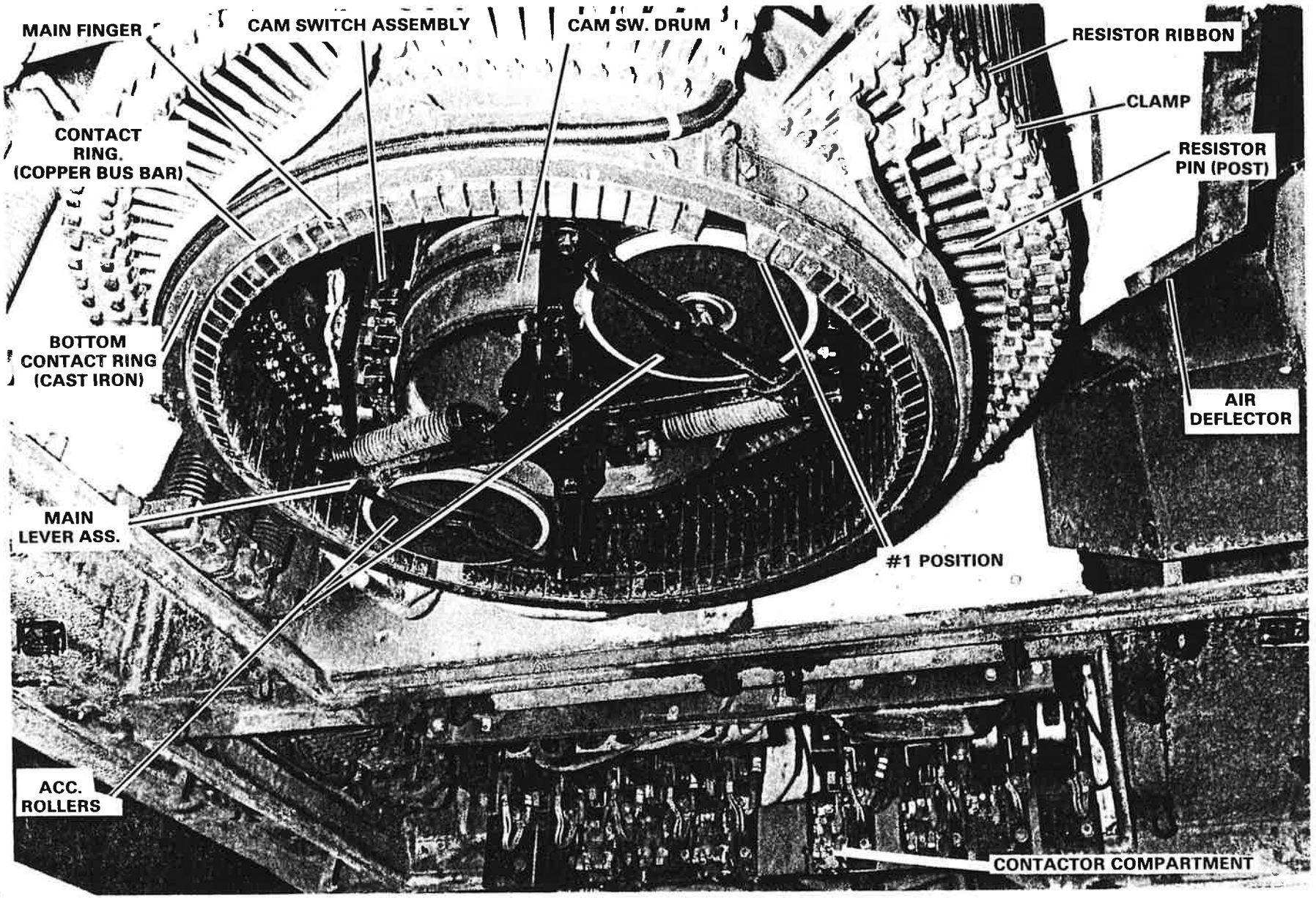
The car is provided with train line wires for all necessary functions so that full control of all cars in a train is obtained from any master controller point in the train and all safety features are retained under these conditions. The brake controllers in cars other than the operators cars must be set in parking position.

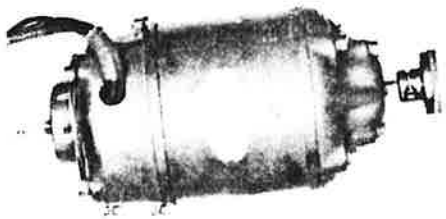


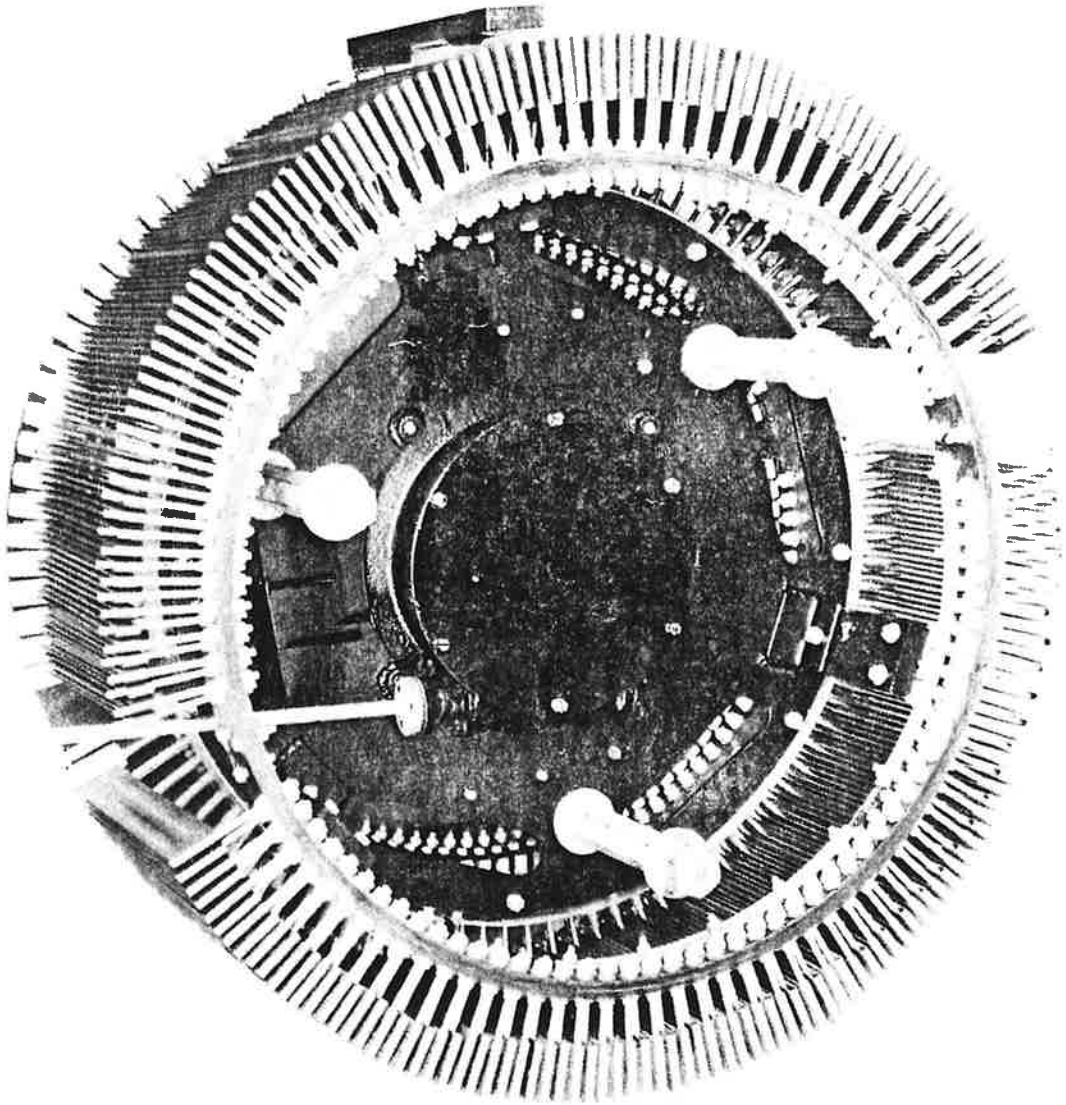
Multiple Unit P.C.C. Street Car

Basic Electrical Equipment

TYPE XD 473 ACCELERATOR (MAIN MOTOR RESISTOR UNIT)

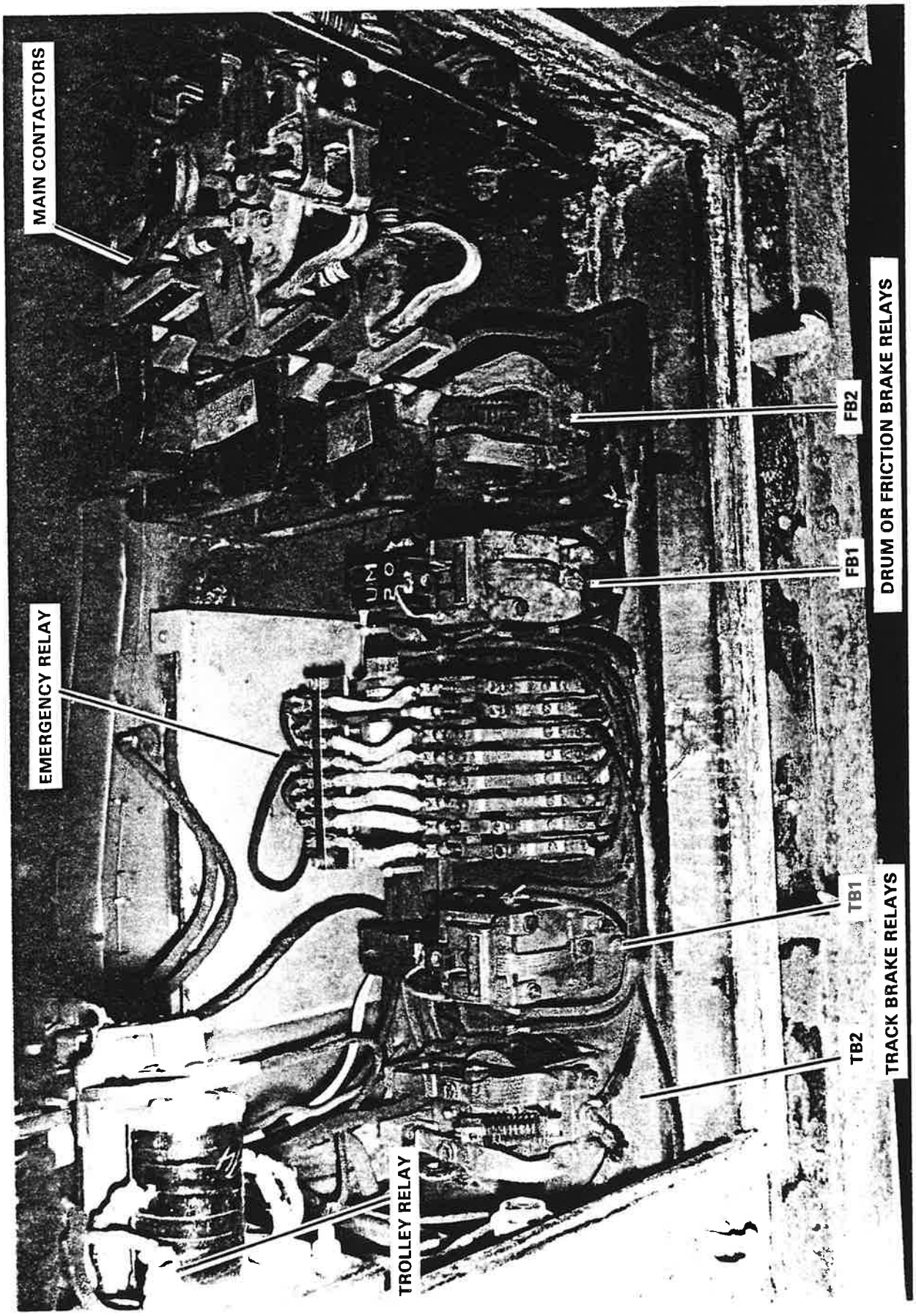




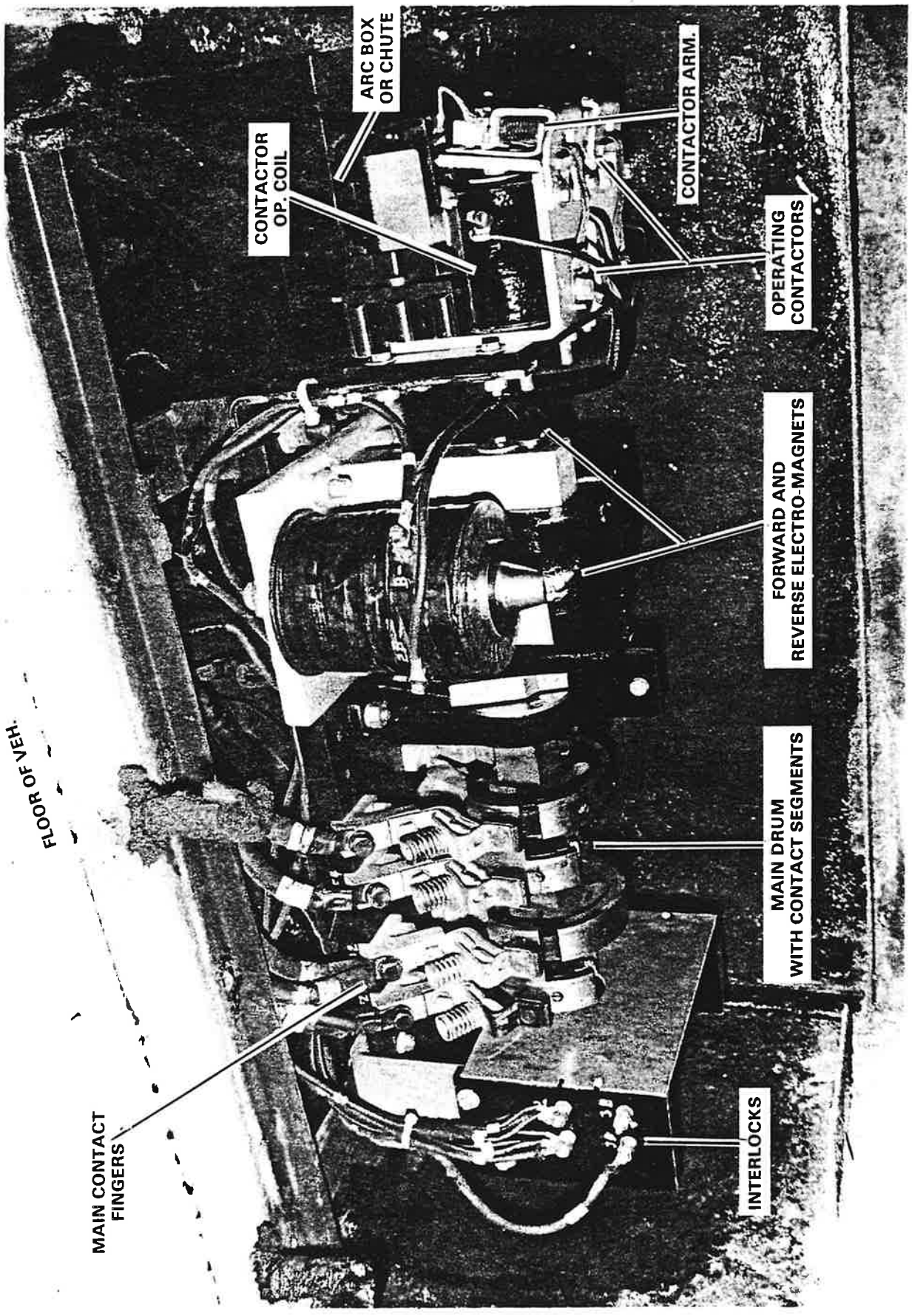


ACCELERATOR WITH PILOT MOTOR. TOP VIEW. TYPE XD-373.

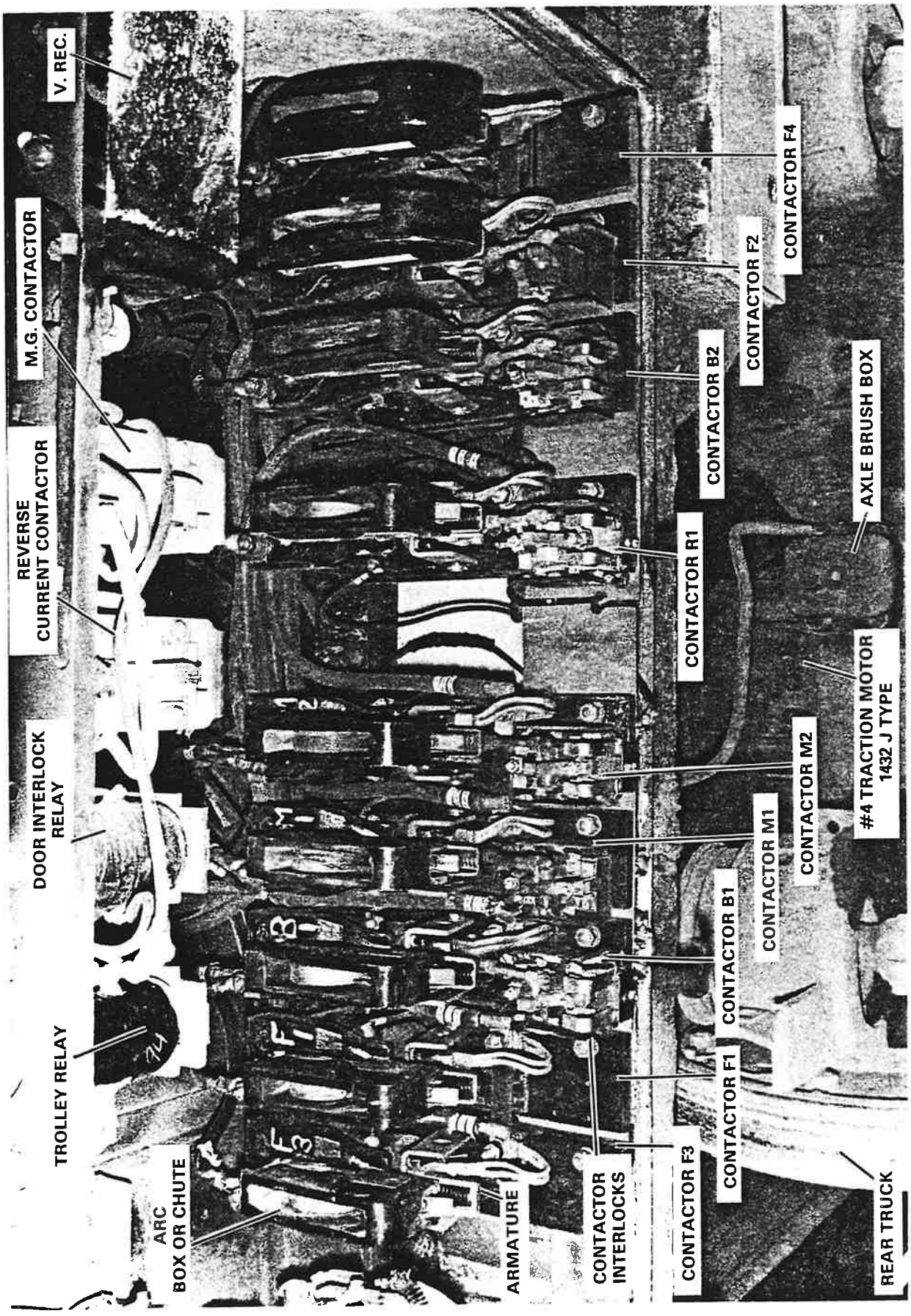
BRAKE CONTROL PANEL (IN CONTACTOR COMP.)
(LOOKING TOWARD O.S. OF VEHICLE)



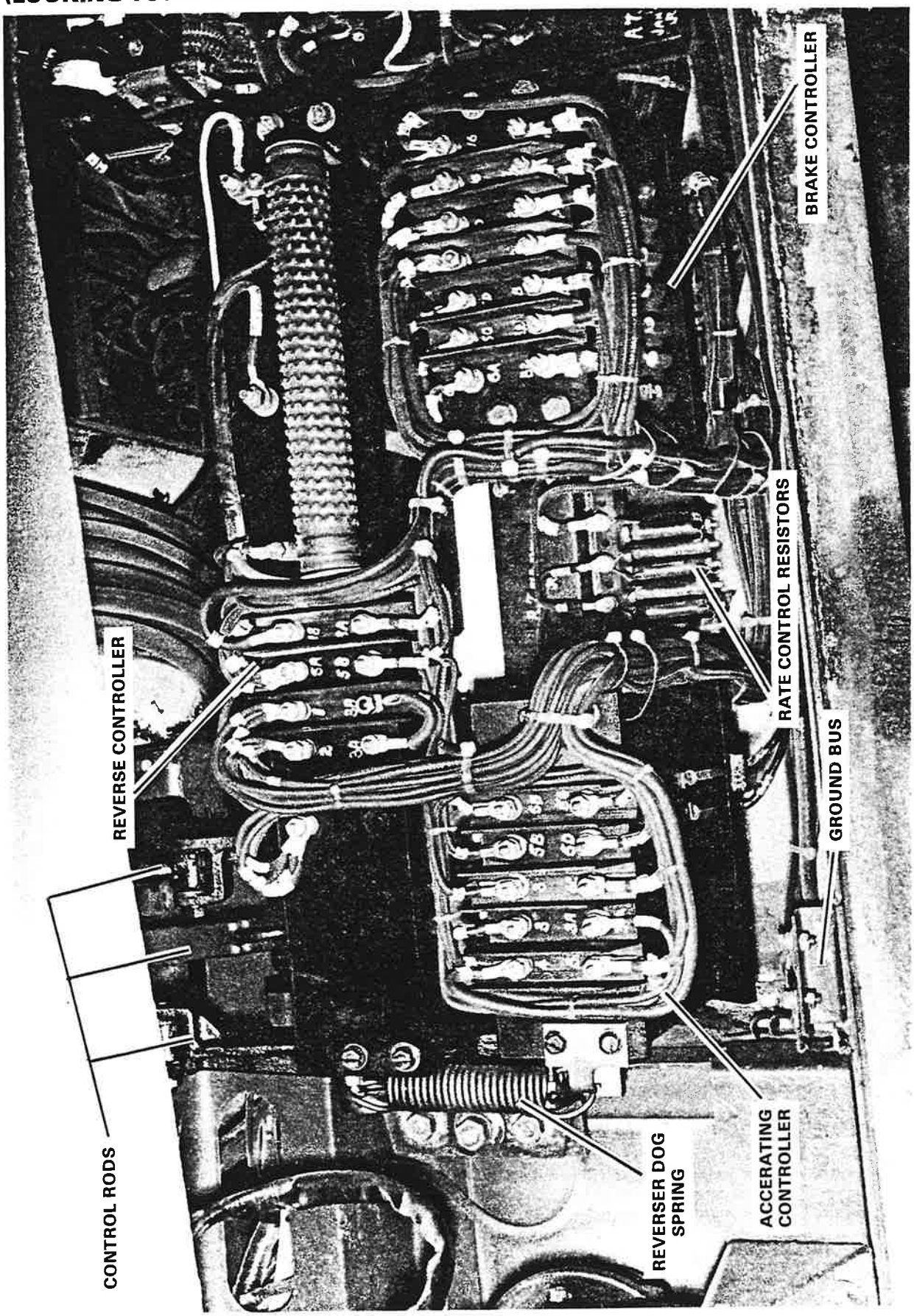
ELECTRO-MAGNETIC REVERSER TYPE XR85
(LOOKING TOWARD FRONT OF VEHICLE)
(HUNG FROM UNDER FLOOR)

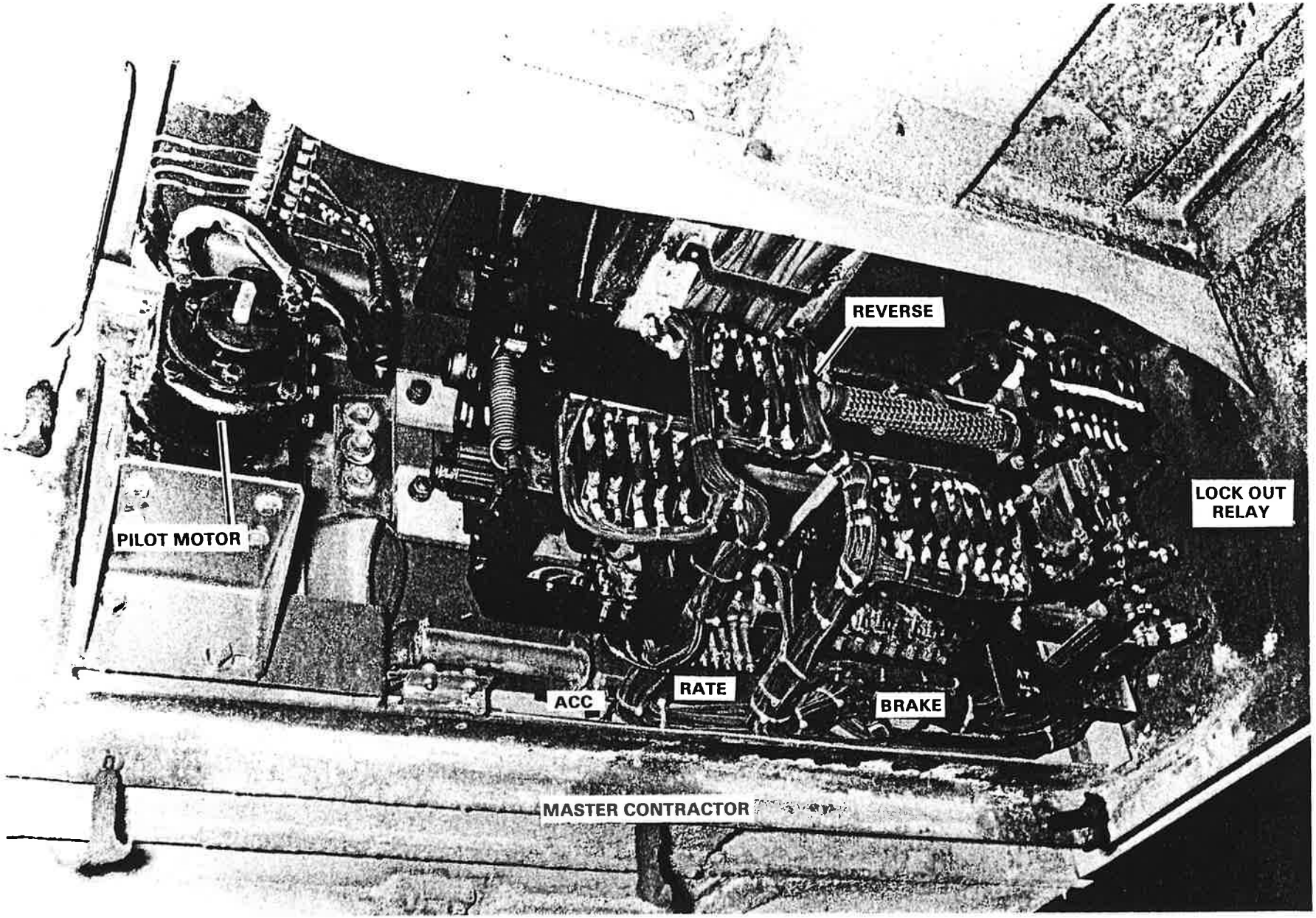


CONTACTOR COMPARTMENT
TYPE UMK 534G CONTACTOR ASSEMBLY

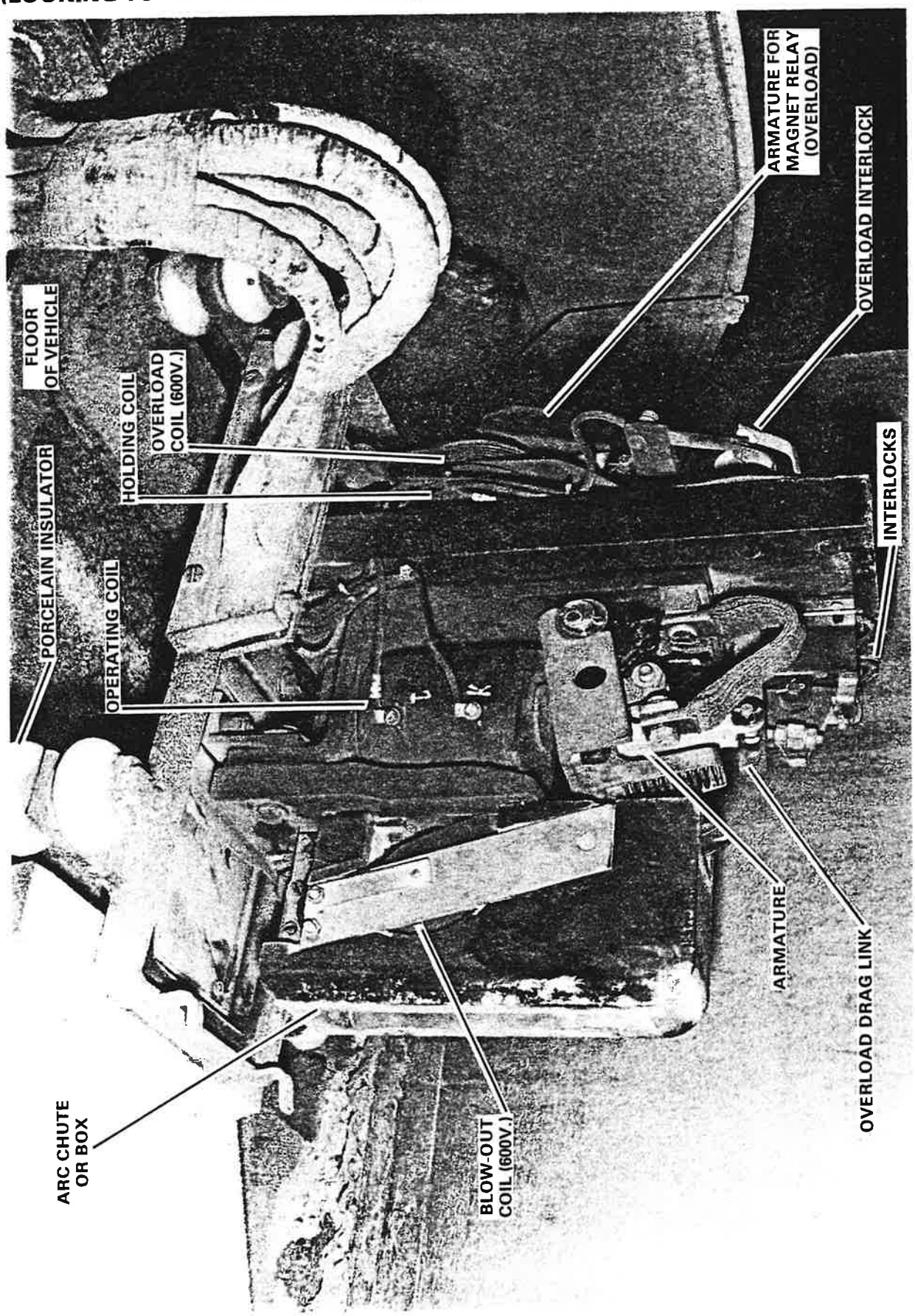


MASTER CONTROLLER COMP.
(TYPE XMA452)
(LOOKING TOWARD REAR OF VEHICLE)

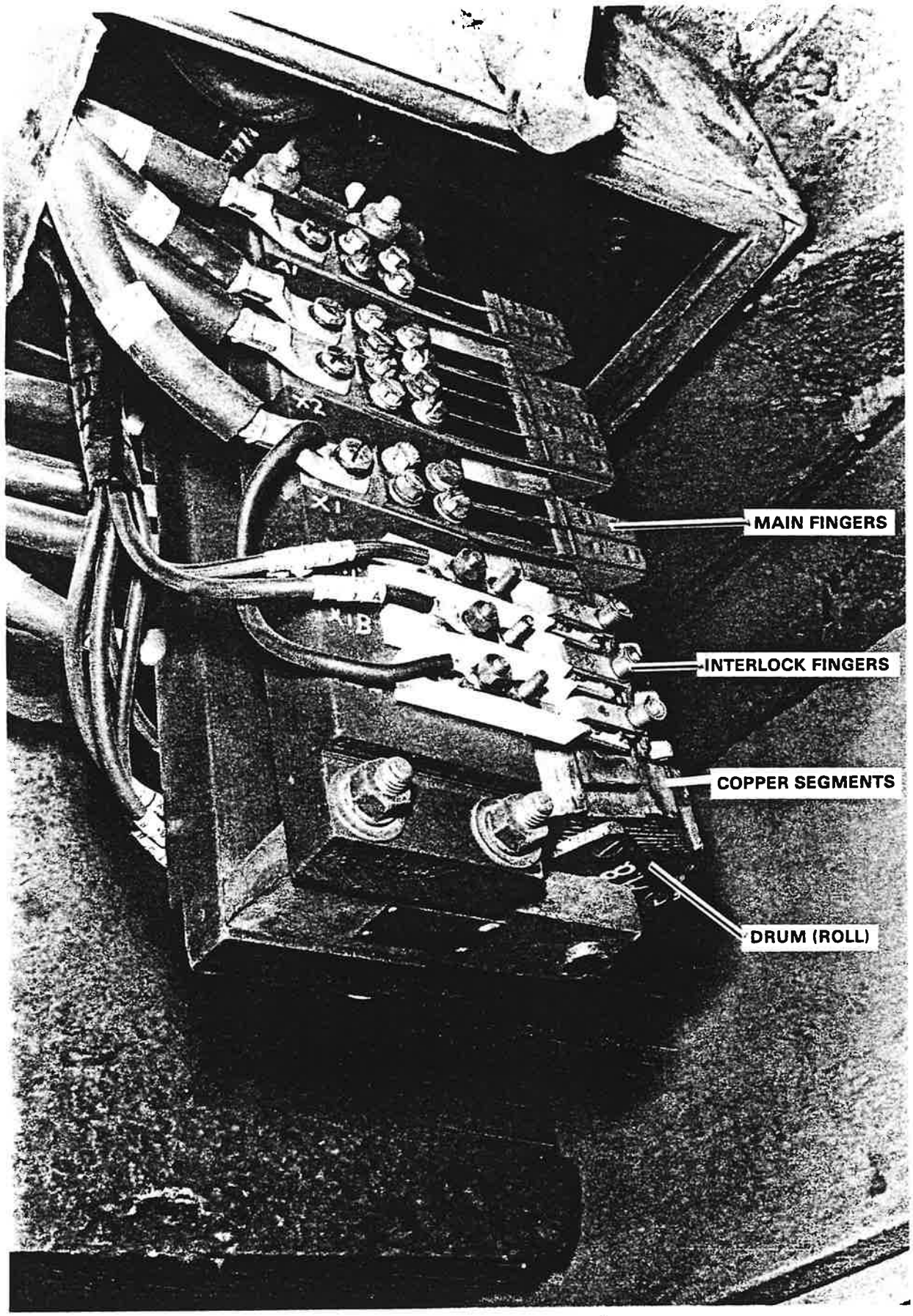



REVERSE
LOCK OUT
RELAY
PILOT MOTOR
ACC
RATE
BRAKE
MASTER CONTRACTOR

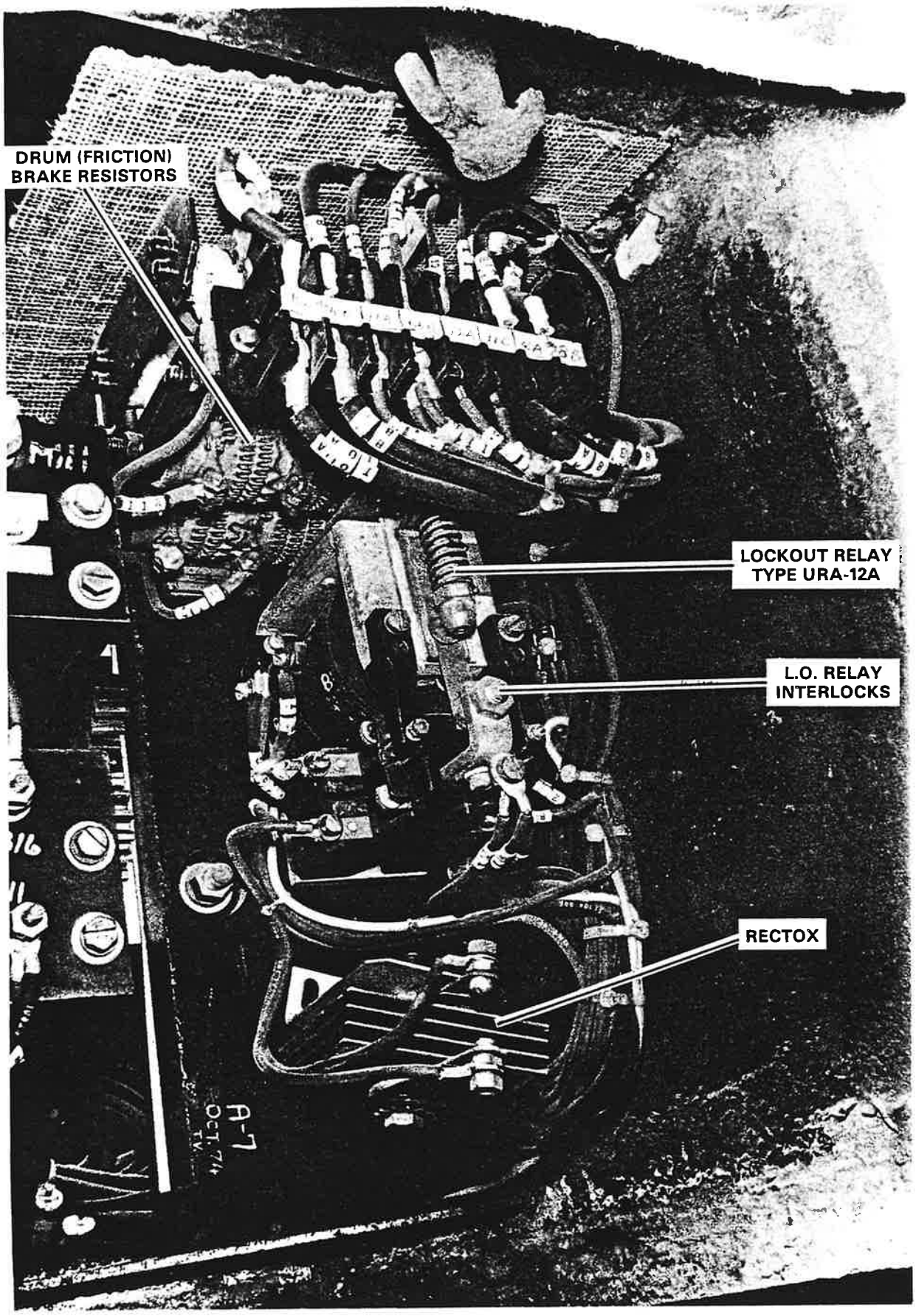
UMA — 25A LINE SWITCH
(LOOKING TOWARD FRONT OF VEHICLE)



MOTOR CUT-OUT SWITCH
TYPE XD137



LOCK-OUT RELAY PANEL



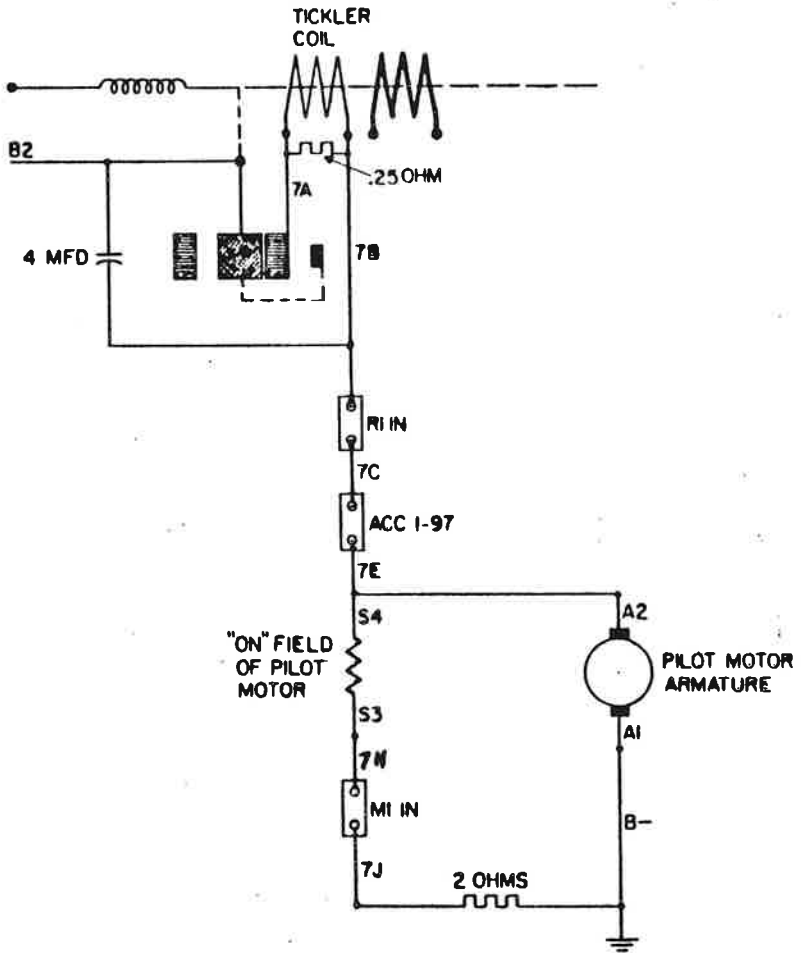
CURRENT LIMIT RELAY AND PILOT MOTOR OPERATION

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



REF. DWG. A5008

WS-JUNE 1966

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.

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".

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.

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-

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-

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

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.

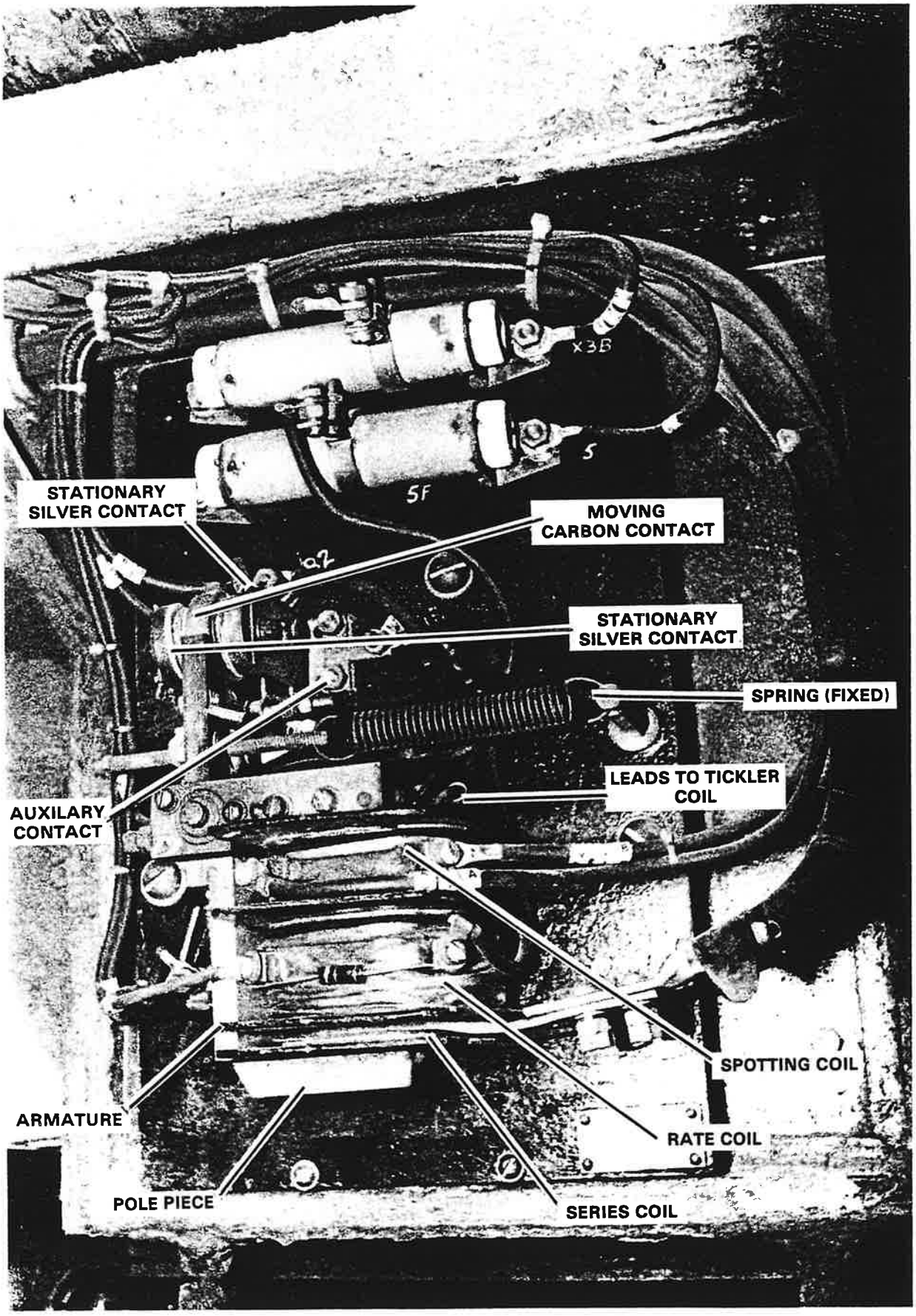
If traction motor trouble develops on a car and it is necessary to cut out motors #3 and #4, the limit relay circuit is changed somewhat. The series coil will be completely inoperative. The tickler coil and rate coil circuits will be unchanged. The spotting coil circuit will be energized during acceleration 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

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.

CURRENT LIMIT RELAY
(TYPE UV730B)



LIMIT RELAY ADJUSTMENTS

The brake pedal must be placed in the released position on the following cars: A6 - A8 - A9 - A13 - A14. The brake pedal must be in the latch position on the following cars: A7 - A11 - A12.

1. Remove all power and brush dirt from relay.

2. Using feeler gauge supplied, clean out dirt behind the hinge pin and between the moving armature and pole piece.

3. Installation of Carbon and Silvers

   Before installing (used or new) carbon and silvers, make sure that the carbon and silvers are seated. Use water sandpaper on a flat surface, and rotate carbon and silvers in a circular motion lightly to ensure seating is achieved.

4. Install the silvers to their support arms and place the carbon to the moving armature.

5. Using the gauge, check that the moving armature is set at 90° angle to the bottom stationary pole piece.

   NOTE: This is achieved by moving the right hand support arm in the direction required.

6. Flush the rear silver to the carbon by moving the right hand support arm slightly (either at the top or bottom of support arm) until the entire surface between the two contacts are flush. See diagram #1.

   NOTE: If all surfaces of contact are flush, tighten support arm bracket. If flushing cannot be achieved, change support arm bracket and repeat procedure. Recheck for flushing of contact after tightening support bracket.

7. Adjust the left hand support arm bracket until their is approximately 5/32 inches air gap (using thick part of gauge) when measured at the mid point between carbon and silver.

8. Pull in the moving armature as shown in diagram #2 and flush the silver to the carbon to make contact over the entire surface. If achieved, release moving armature and tighten support arm. Recheck with gauge.

   NOTE: The thin part of the gauge should fall through the silver and carbon. The thick part of the gauge should rest half way through the silver and carbon. Make adjustments until the above is achieved.

9. Auxiliary Contact Adjustment

Adjust the small moving contact (auxiliary finger) so that their is 1/8" air gap when relay is in the released position. When the relay is energized, the auxiliary finger must have 1/32" spring tension.

10. Setting Spring Tension

Apply the 36 volt supply. Using the test light and scale, set the relay to the designated spring tension as follows:

4300-4399 - 7 oz.	4675-4699 - 15 oz.
4400-4499 - 15 oz.	4700-4749 - 11 oz.
4500-4549 - 7 oz.	4550-4574 - 11 oz.
4625-4674 - 7 oz.	4750-4779 - 11 oz.

NOTE: Cars 4400-4499 and 4625-4699, when ckecking limit relay tension, the M.G. switch must be "ON" and the brake pedal in the "SERVICE LATCH" position. Tension is taken from the securing bolt at the top of carbon. Cars 4625-4674 due to the location of the limit relay, a special lever must be used to check tension. Tension is taken from the bottom of the special lever.

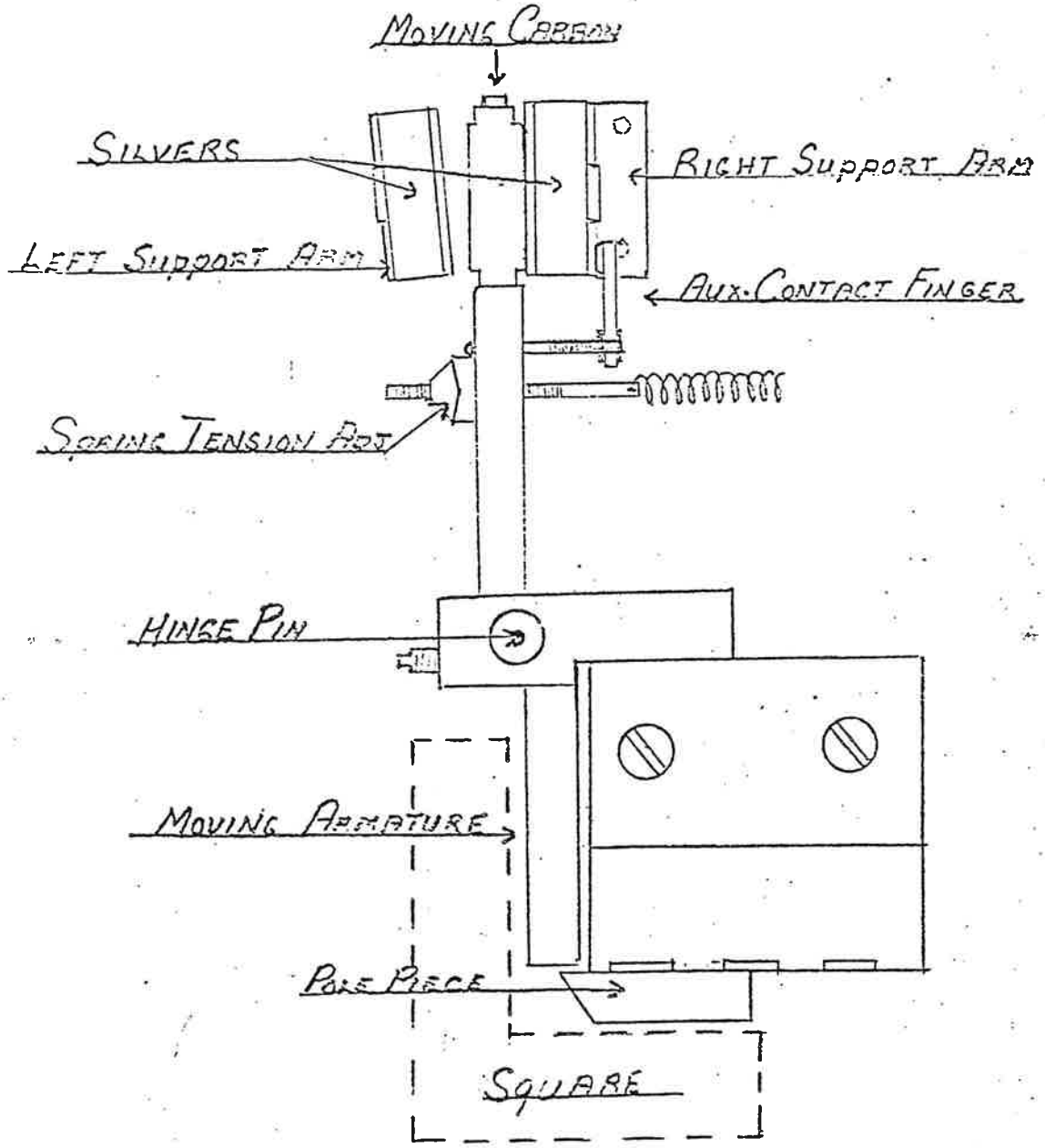
All other cars, tension is taken from the spring tension adjustor: WITH THE BRAKE PEDAL IN THE RELEASED POSITION.

C. James

March, 1976

No. 1

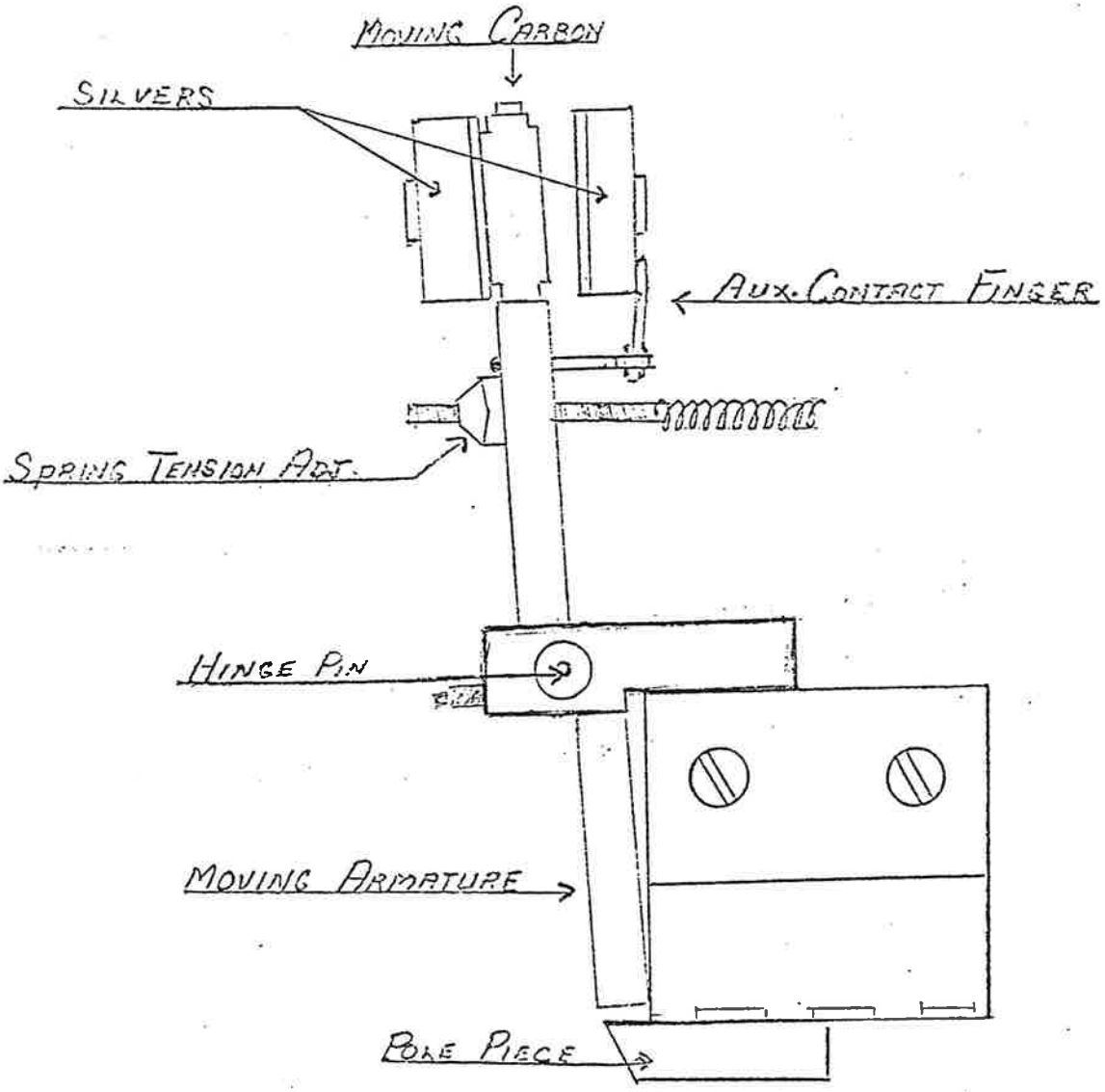
LIMIT RELAY



"DE-ENERGIZED" POSITION

No. 2

LIMIT RELAY



"ENERGIZED" POSITION

UV.380 VOLTAGE REGULATOR

The frame of the Westinghouse UV.380 voltage regulator is constructed of specially treated soft iron parts to obtain good magnetic characteristics. The armature which carries the moving carbon contact is supported by a stainless steel hinge spring which is spot welded to it. The armature rocks on two stainless steel balls which are pressed into the edge of the frame top plate. The two arms of the hinge spring fit over dowel pins in the top plate in order to accurately maintain the air gap between the bottom edge of the armature and the beveled bottom plate.

Two stationary silver contacts are supported by brackets mounted on the regulator base panel in such a manner that the carbon contact may move freely between them. The moving carbon contact is supported on an insulated mount which is fastened securely to the regulator armature. Current is carried to and from the moving contact by means of an insulated flexible shunt.

The regulator coil assembly comprise of two windings, a shunt winding having about 18 ohms resistance and a series winding of approximately 0.005 ohm resistance. The shunt winding is connected in series with a resistor directly across the generator output leads. The series winding is connected in series with the lead-acid battery carried on the vehicle.

The calibration spring has a hooked end which fits over a notched knife edge on the armature assembly. The combination of the knife edge and the ball pivots insures a friction-free

movement necessary for satisfactory regulator operation. Adjustments in the regulated voltage are made by turning a knurled nut which controls the tension of the calibration spring.

Description of Operation

The operator starts the M-G set by closing the M-G control switch on the front dash of the vehicle. This causes a contactor to pick up and connect the motor end of the M-G set to trolley voltage.

The M-G set will start to rotate, and at first the generator voltage will be below the setting of the regulator. Consequently, the regulator calibrating spring will hold the moving carbon contact against the right-hand stationary contact. The generator shunt field series resistor is short-circuited and the generator field will be at maximum strength. This is illustrated in Fig. 1.

As the generator speed increases, the output voltage will rise. This rising generator voltage is applied to the shunt coil of the voltage regulator through its series resistor. The magnetic field set up in the regulator will increase in strength until it is sufficiently strong to move the regulator armature against the pull of the calibrating spring. When the armature moves, the carbon contact will leave the right-hand stationary contact and the series resistor will be inserted into the generator shunt field circuit. See Fig. 2.

Insertion of resistance into the generator field circuit will cause the output voltage to drop. The magnetic strength of the

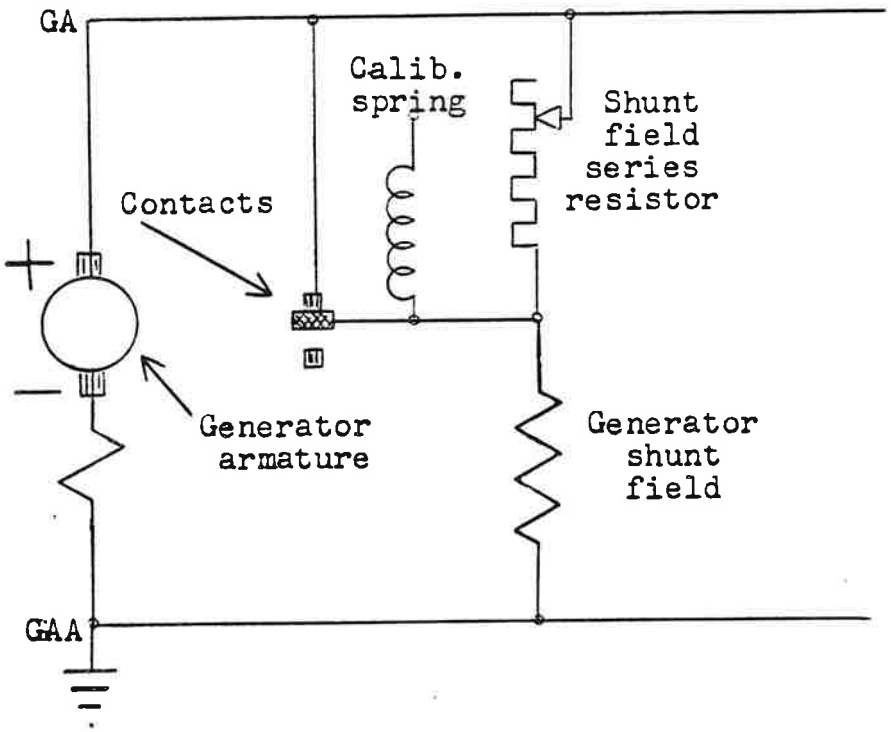


Figure 1

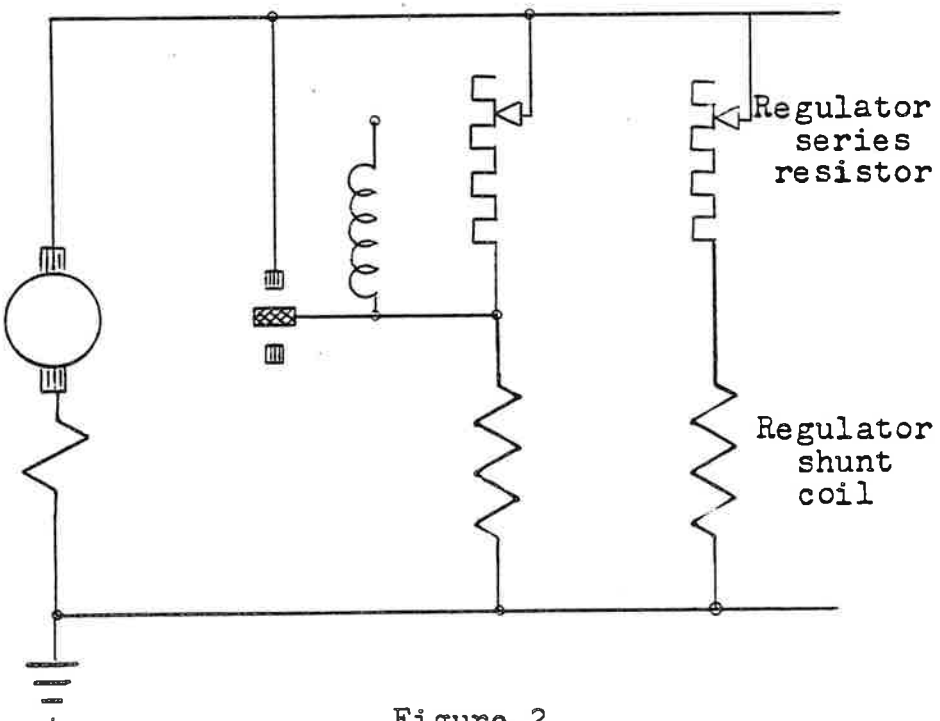


Figure 2

regulator coil will decrease and the calibration spring will pull the carbon contact against the right-hand stationary contact once more. The shunt field resistor is again short-circuited and the generator voltage will rise. The carbon contact will now move to and from the stationary contact, regulating the generator voltage to the value determined by the tension on the calibrating spring.

In the event of generator over-speed or minimum loading on the generator, the circuit described will not be sufficient to maintain the desired voltage. To provide control under these conditions, a resistor is connected between the left-hand stationary contact and GAA. As the carbon contact moves from the right-hand contact, resistance is placed in series with the generator field. Now, with this additional connection, resistance is shunted across the generator field, weakening it still more. The circuit will now be as in Fig. 3.

In actual practice, it was found that this arrangement of the regulator shunt operating coil and the associated resistors was not entirely satisfactory. Quite appreciable changes in generator voltage resulted as the moving contact oscillated or "hunted" between the two fixed contacts.

It was found that the addition of a fourth resistor would cause the moving contact to "flutter" against the stationary contacts. This may be explained by calculating the voltage at each end of the 1200 ohm resistor for the various contact positions, then

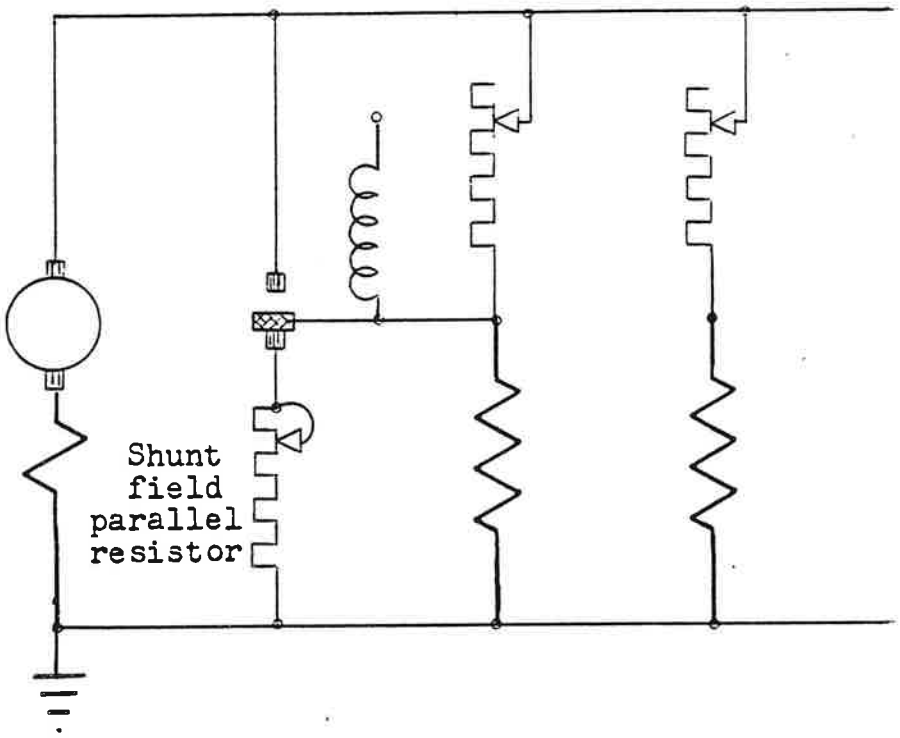


Figure 3

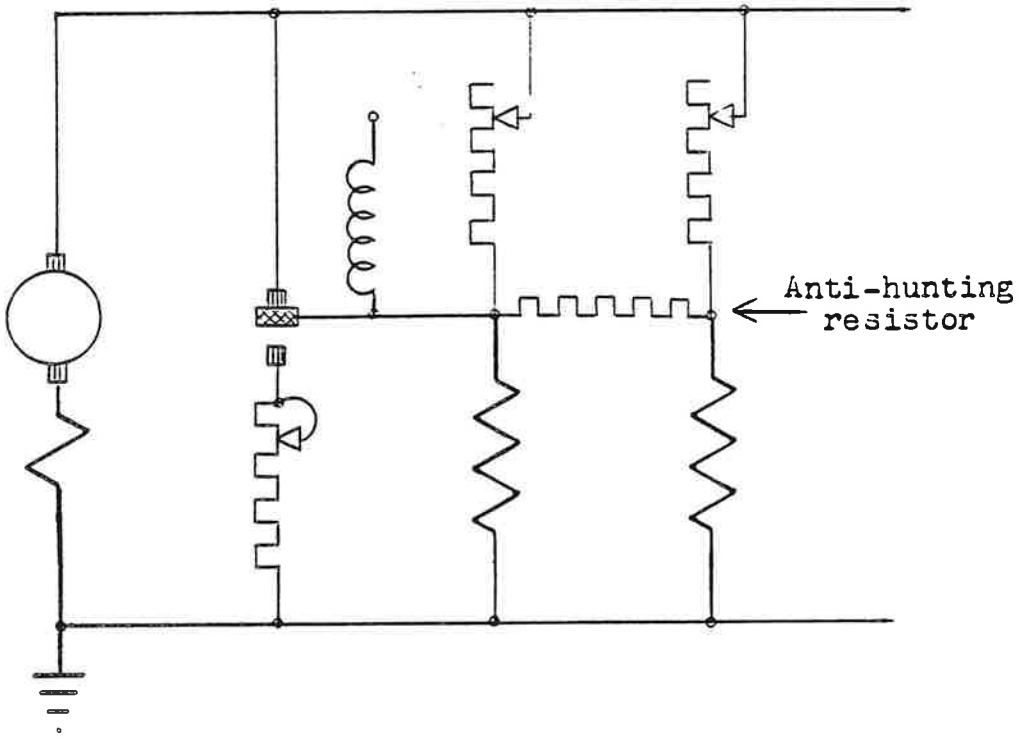


Figure 4

finding the current through it. This current will affect the magnetic strength of the operating coil. It will be seen that in each case, the change of current in the operating coil from contact made to contact broken on either side is such as to encourage the contacts to re-make.

The regulator as used on P.C.C. cars will have the moving contact vibrating lightly against one or the other of the stationary contacts. This vibration is evidenced by light sparking on the contact surface. The rate of vibration and the length of time during which the contacts touch is such that the average value of the field current is sufficient to maintain the generator voltage at the required value. Fig. 4 shows the anti-hunting resistor in circuit.

As stated previously, the regulator coil assembly has a low resistance winding which is connected in series with the car battery. This coil carries only the battery current and not any other load current.

The circuit is so arranged that the series coil "aids" the regulator shunt coil. Current to the battery will therefore tend to lower or "droop" the generator voltage. Under normal operating conditions, the battery is "floated" across the generator and the current through the series coil will be small. This causes only a slight reduction in the regulated voltage. If, for any reason, the battery becomes abnormally discharged, the increased

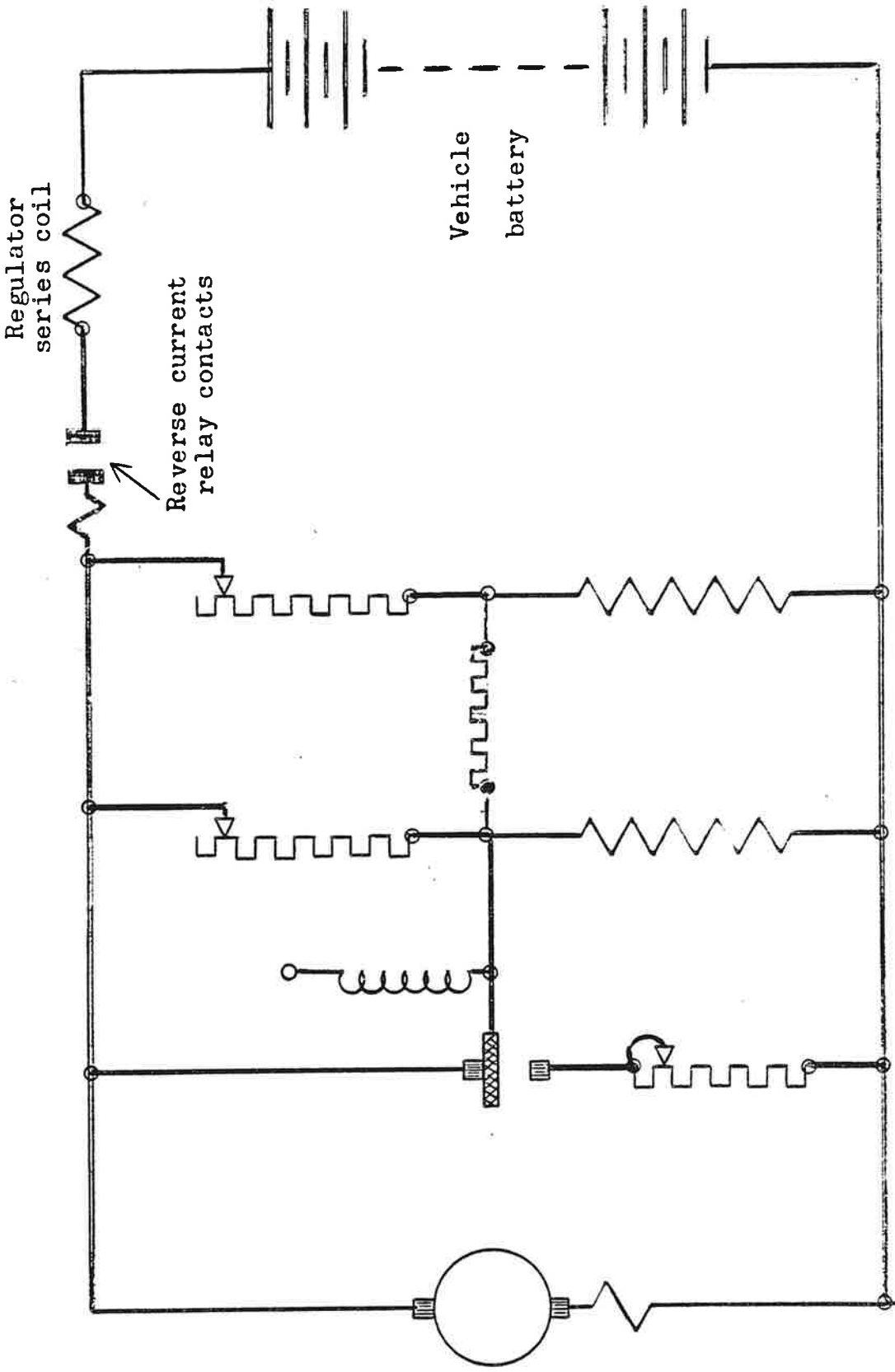

Regulator
series coil
Reverse current
relay contacts
Vehicle
battery

Figure 5

charging current will result in the droop coil lowering the regulated voltage enough to prevent battery damage. The regulator series coil connection is shown in Fig. 5.

Under normal operating conditions, the moving carbon contact will vibrate against the left-hand or field shunting contact. When the track brakes are applied, the heavy load will result in the carbon contact moving over and vibrating against the right-hand or field boosting contact. Unusually low trolley voltage will result in the M-G set running more slowly. Under these conditions, also, the carbon will flutter against the right-hand contact to maintain generator voltage.

The complete motor-generator and voltage regulator circuit is shown in Fig. 6.

Technical Data

Shunt field resistor..... 17 ohm resistor tapped at 15 ohms

Regulator series resistor... 78 ohm resistor tapped at 65 ohms

Shunt field parallel resistor..... 5 ohm resistor tapped at 3 ohms

Anti-hunting resistor..... 1200 ohms (non-adjustable)

Generator shunt field..... 9 ohms

Regulator shunt coil..... 18 ohms

Regulator series coil..... 0.005 ohm

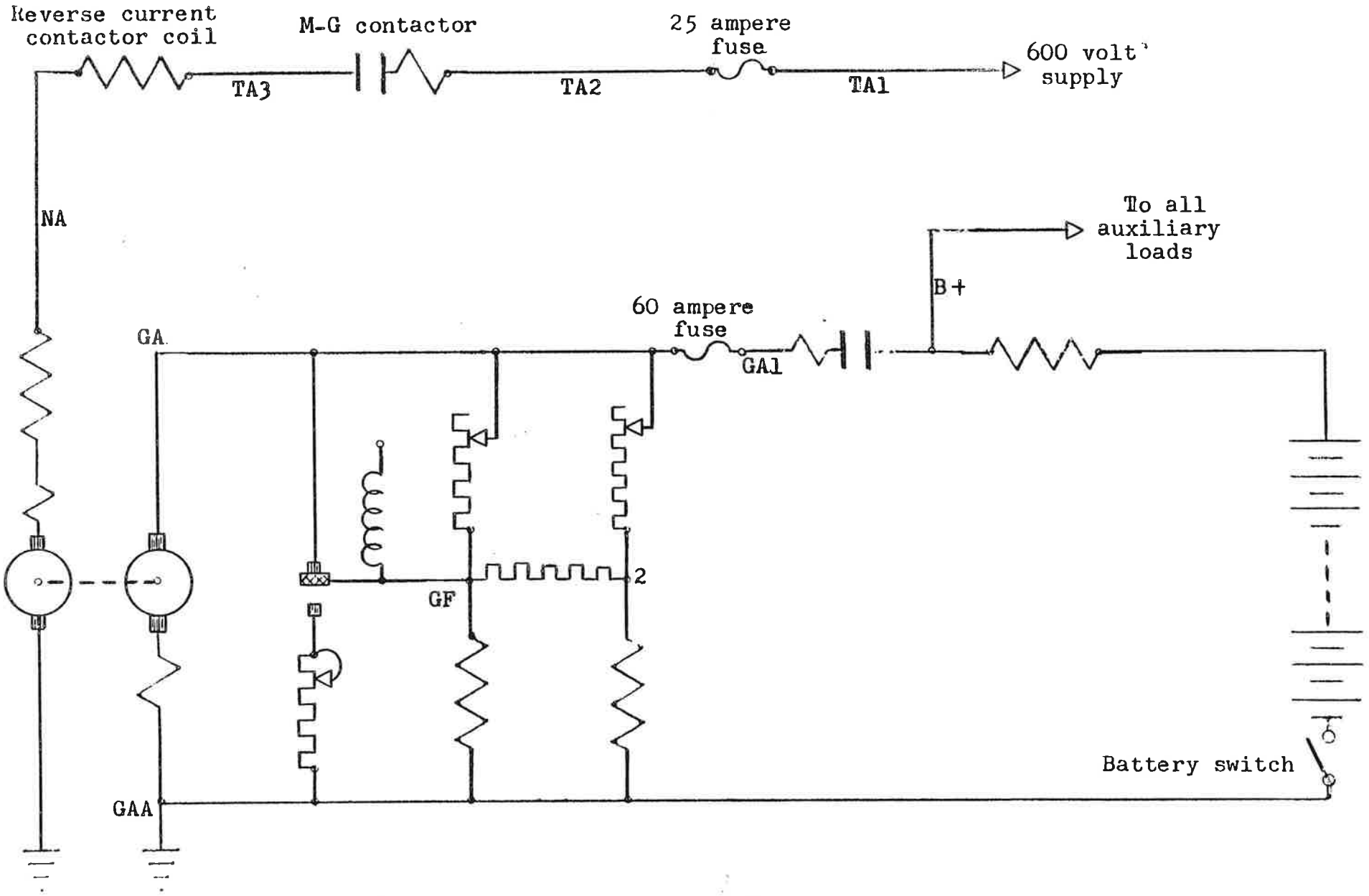
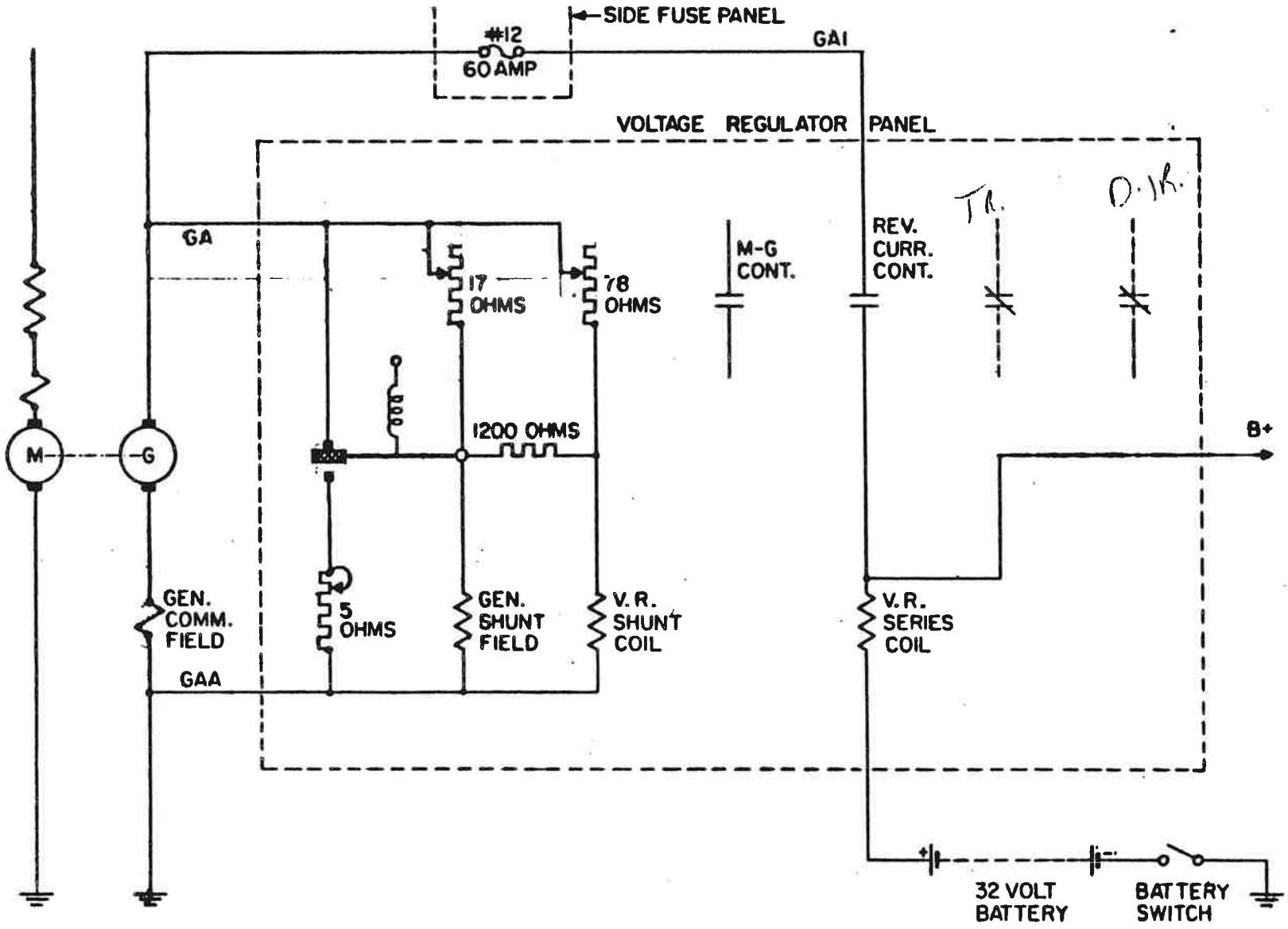

Reverse current contactor coil
M-G contactor
25 ampere fuse
600 volt supply
TA3
TA2
TA1
NA
To all auxiliary loads
B+
60 ampere fuse
GA
GA1
GF
2
Battery switch
GAA

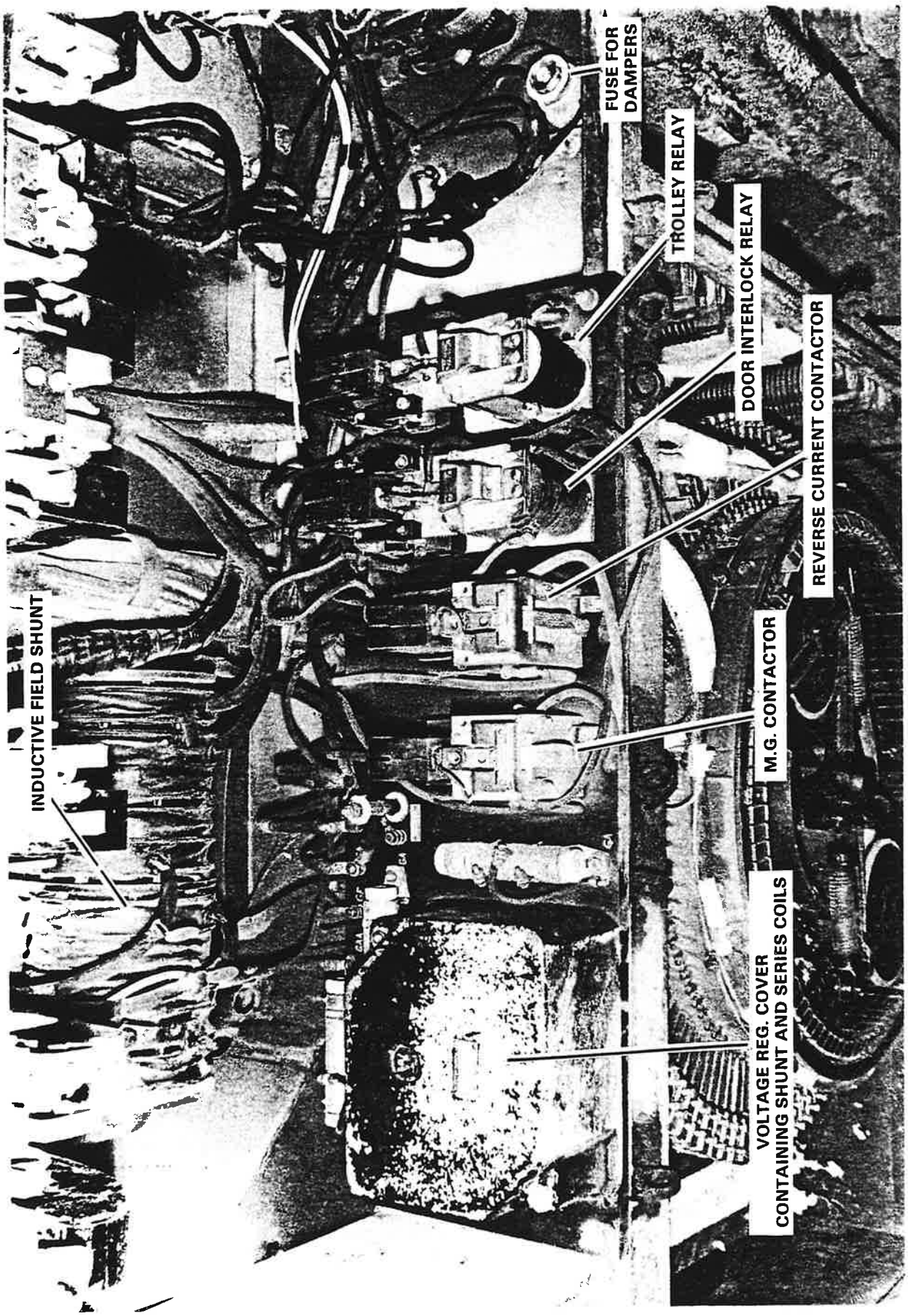
Figure 6



REF. DWG. A 5959

REVISED AUGUST 1967

VOLTAGE REGULATOR PANEL
(LOOKING TOWARD FRONT OF VEHICLE)



PREPARATION FOR EXTENDED STORAGE

BODY EXTERIOR

- winter storage should be inside if possible
- if not possible vehicle should be covered with plastic sheeting
- all exhhaust and intake ducts should be blocked and sealed for example M.G. intake ducts, heating dampers, roof vents
- all windows closed and front and side drivers vents sealed

BODY INTERIOR

- empty sand boxes and block hose hole
- check floor seams for leaking and remove and replace old caulking as necessary
- close and seal roof vents

TRUCKS

- block enough wheels to secure the vehicle and release all drum brakes
- lubricate drum brake actuator lever arms
- lubricate drum brake shoe fulcrum points with Shell Extrema E.P. Grease
- check actuator splash guard covers
- lubricate locknuts and lever rods to ensure easy adjustment S.A.E. 20
- Drive shafts - lubricate all universal joints and drive shaft splines with Shell Extrema E.P. Grease
- Centre Bearings - remove lower centre bearing dust cap - jack-up car body clear of centre bearings - lubricate surface of upper and lower bearings - Shell Extrema E.P. Grease
- Swing Link and Bolster Bearings - while car body is raised high enough to relieve body weight from truck bearing surfaces lubricate all swing links and bolster trunnion bearings using Shell Extrema E.P. Grease

COUPLERS

- check multi-core cable protective covering for chafing and repair
- lubricate radius bar with a film of S.A.E. 20
- inspect coupler pin covers and repair or replace as necessary
- place green plastic garbage bag over the head of the coupler and secure in place

LIFEGUARD

- lubricate all shaft bearings and clevis pins with S.A.E. 20
- lubricate lifeguard hold-up cables exposed to the wheather with Imperial Rustban #326

DRAW BAR AND COMPARTMENT

- remove emergency draw bar and store inside the vehicle
- remove accumulated dirt and build-up from storage box and lubricate catches and hinge pin with S.A.E. 20

TRACTION MOTORS

- remove all carbons from the traction motors and clean brush holder
- check condition of motor bellows for torn canvas and repair

M.G. SET

- remove all carbon brushes and clean brush holders
- seal motor generator air intake screens with a plastic sheet

FOOT PEDALS AND REVERSER LEVER

- clean and lubricate - apply grease to all grease fittings, until it shows around bearing surface
- lubricate reverser lever pins with approved oil
- lubricate brake pedal pad hinge pin located above car floor

BATTERY

- if vehicle to be stored out doors remove the batteries and store in a warm, dry location

UNDER FLOOR EQUIPMENT COMPARTMENTS

- check compartment pans for proper fitting weather stripping and replace as necessary

- repair or replace pan hooks as necessary to ensure tight fitting covers

HEAT CONTROL DAMPERS

- check damper doors clean and secure in the heat position closed to the outside

MOTOR CUTOUT

- rotate the motor cutout to the all out position and lubricate the top and bottom bearing surfaces

TROUBLE SHOOTING

SAFETY

IF practical all trouble shooting and repair work should be done with all power removed. If it is necessary to trouble shoot the problem under a power up condition ensure that the proper safety precautions are taken .

All repairs should be made in a power down position with the trolley pole secured and the rear of the vehicle signed.

" CAUTION KEEP POLE DOWN "

If it is necessary to work under the vehicle even on the auxiliary curcuit the motors should be cut out or the reverse lever removed. This will ensure that no movement of the vehicle can occurr.

TEST EQUIPMENT

Most trouble shooting on a P.C.C. car can be done with the following equipment.

1. Voltmeter (See operating instruction in rear of book)
2. Test Light 36 volt
3. Buzzer Continuity Tester 12 volt battery supply
4. Megger
5. Controller operating wrench (Back Scratcher)

PREPARATIONS FOR TROUBLE SHOOTING

1. Remove pole from overhead and pull the battery sw.
   (sign car as in above)
2. Remove the cover from the motor cut-out switch box and move the switch to the all out position.

PREPARATIONS FOR TROUBLE SHOOTING CONT.

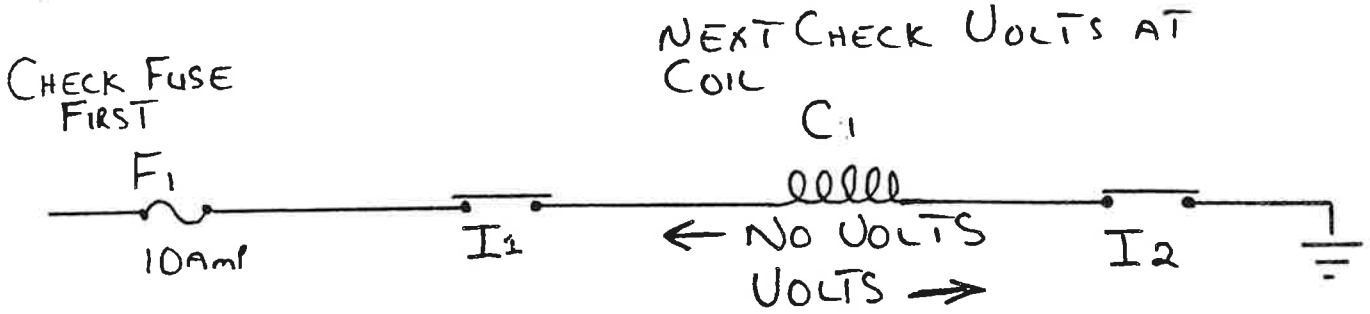
3. Lock the foot interlock pedal in its running position to do this place the switch iron loop end over the foot interlock pedal and the shank supported by the route and destination sign index board to hold it in its running position.
4. Move the Reverser handle to the forward position.
5. Connect the master voltmeter across the G.A. and G.A.A. terminals on the voltage regulator panel.
6. Place the trolley pole on the trolley wire.
7. Move the M.G. switch and the front door switch to their " ON " positions.
8. Close the battery knife switch and after the motor generator set has started open the battery knife switch.
9. Close the front door from the outside of the car by moving the switch located under the right hand advertising hood to the door closed position.
10. By means of the knurled calibration screw on the voltage regulator panel reduce the generator voltage to 24 volts.
11. Place asmall piece of paper between the moving carbon and back silver contact of the limit relay.
12. By means of the proper controller operating wrenches operate the master controller as follows.
13. REfer to the sequence procedure for the type or cars being tested.

TROUBLE SHOOTING PROCEDURES

ALL TROUBLE SHOOTING SHOULD BE APPROACHED IN A SYSTEMATIC MANNER.

1. Establish the problem and obtain any available information on symptoms and sequence of events.
2. Once the problem area is identified establish voltages with which you are working. If unsure of the voltage treat as 600 volt potential until confirmed other wise by measurement.
3. Visually inspect the area with the power removed the problem maybe evident and not require IN DEPTH trouble shooting.
4. Once the problem area has been identified obtain an electrical schematic and familiarize yourself with the circuit in question.
5. Check fuses and curcuit breakers first.
6. Start your voltage measurement in the middle of the curcuit and work towards the problem end.

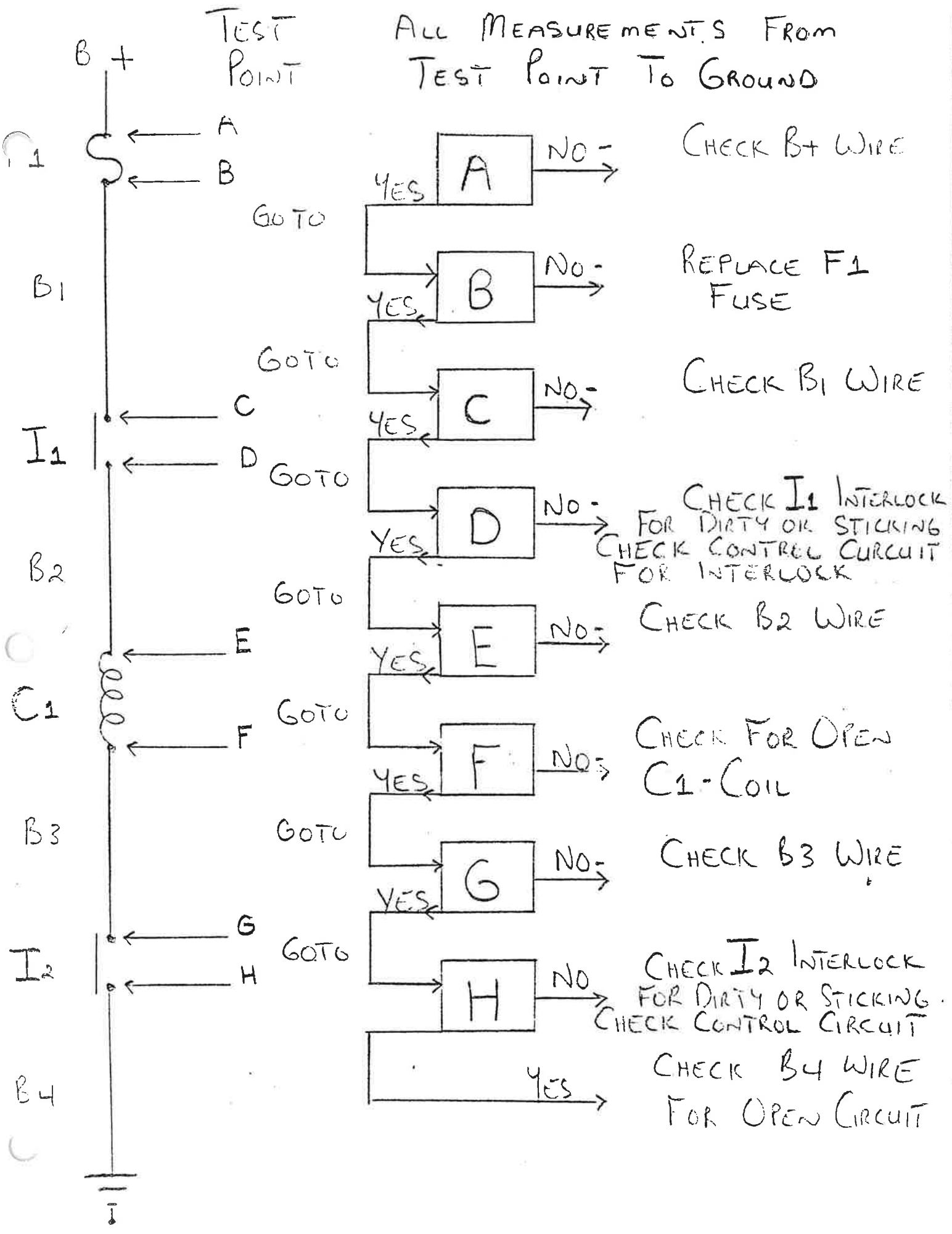
EXAMPLE: PROBLEM - COIL WILL NOT ENERGIZE



It should be remembered that in the process of trouble shooting you could provide the path with your test equipment that will operate the circuit. For example on the next page is a curcuit and a flow chart describing the YES (volts here) , the NO (no volt) here and the probable cause and next step in trouble shooting. If the fault in this curcuit was a lack of ground

TROUBLE SHOOTING PROCEDURES CONT.

after the C 1 coil applying the test light between the C 1 coil and ground will energize the coil.


TEST POINT
ALL MEASUREMENTS FROM TEST POINT TO GROUND
B +
A
B
F1
B1
C
I1
D
B2
E
C1
F
B3
G
I2
H
B4
GOTO
YES
NO
A
B
C
D
E
F
G
H
CHECK B+ WIRE
REPLACE F1 FUSE
CHECK B1 WIRE
CHECK I1 INTERLOCK FOR DIRTY OR STICKING
CHECK CONTROL CIRCUIT FOR INTERLOCK
CHECK B2 WIRE
CHECK FOR OPEN C1-COIL
CHECK B3 WIRE
CHECK I2 INTERLOCK FOR DIRTY OR STICKING.
CHECK CONTROL CIRCUIT
CHECK B4 WIRE FOR OPEN CIRCUIT

T.T.C. CLASS	BUILDER	PROPULSION EQUIP.	PROPERTY BUILT FOR
A.6 4300-99	C.C.&F.Co.	WESTINGHOUSE	T.T.C.
A.7 4400-99 M.U.	"	"	"
A.8 4500-49	"	"	"
A.9 4550-74	ST.LOUIS CAR	"	CINCINATTI
A.11 4625-74 M.U.	PULLMAN CO.	"	CLEVELAND
A.12 4675-99 M.U.	ST.LOUIS CAR	"	CLEVELAND
A.13 4700-47	PULLMAN CO.	"	BIRMINGHAM

NOTE - M.U. = MULTIPLE UNIT

ELECTRICAL SYMBOLS USED ON P.C.C. CAR

SCHEMATIC DIAGRAMS

Capacitor



Coil



Fuse



Gang(ed) Switch



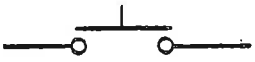
Incandescent Lamp



Passenger Signal Switch



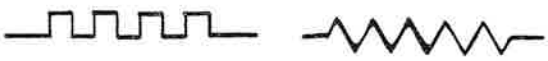
Pushbutton
(Normally open)



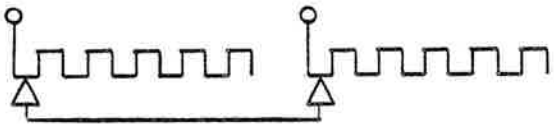
Rectifier



Resistor



Accelerator



Camswitch Contacts

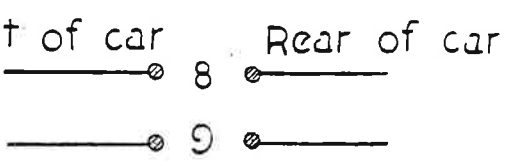
Controllers



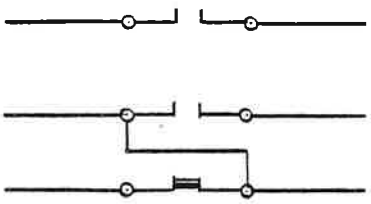
Doors



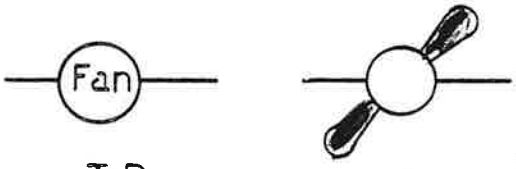
Coupler Contacts



Coupler Drumswitch Contacts

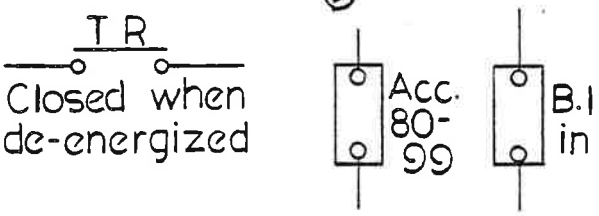


Defrost Fan



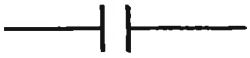
Interlock

(Contactor, Lineswitch, Relay)

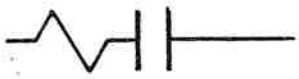


Main Contacts

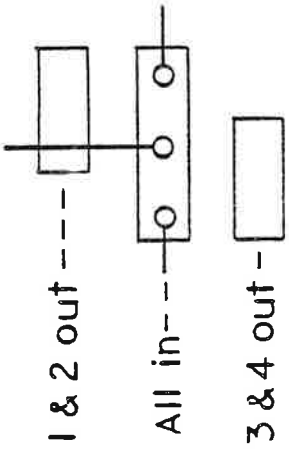
(Contactor, Lineswitch)



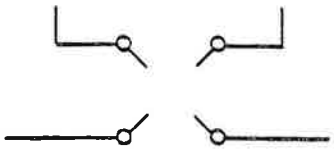
Main Contacts with Blowout Coil



Motor Cutout Switch



Reverser



Relay Contacts

Normally open (NO)

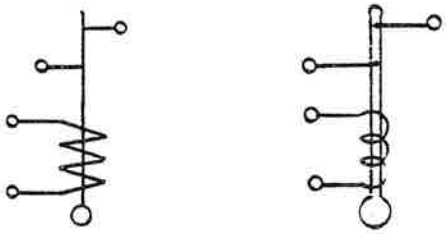


Normally closed (NC)

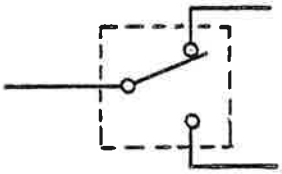


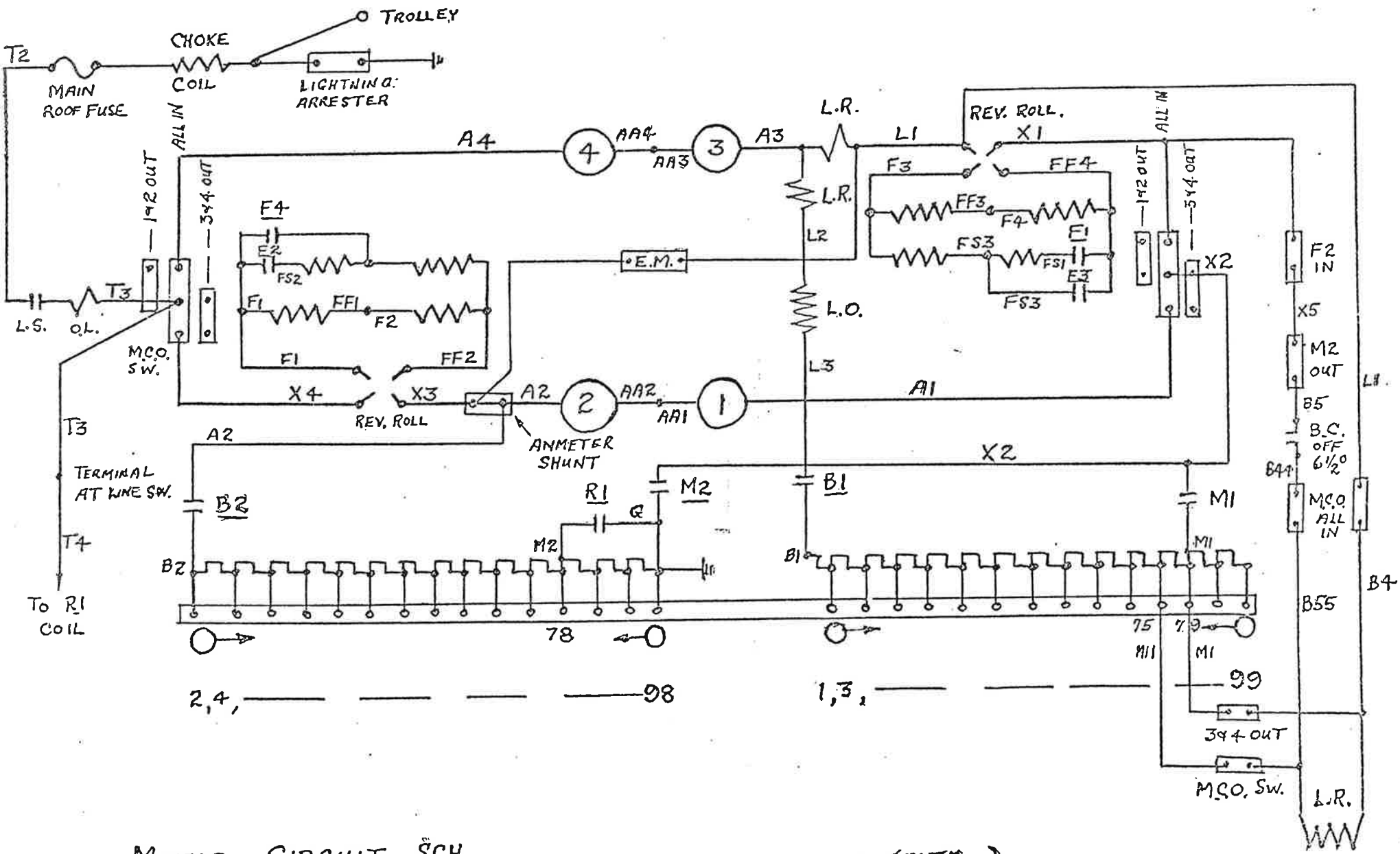
Thermostat

Vapor Heating



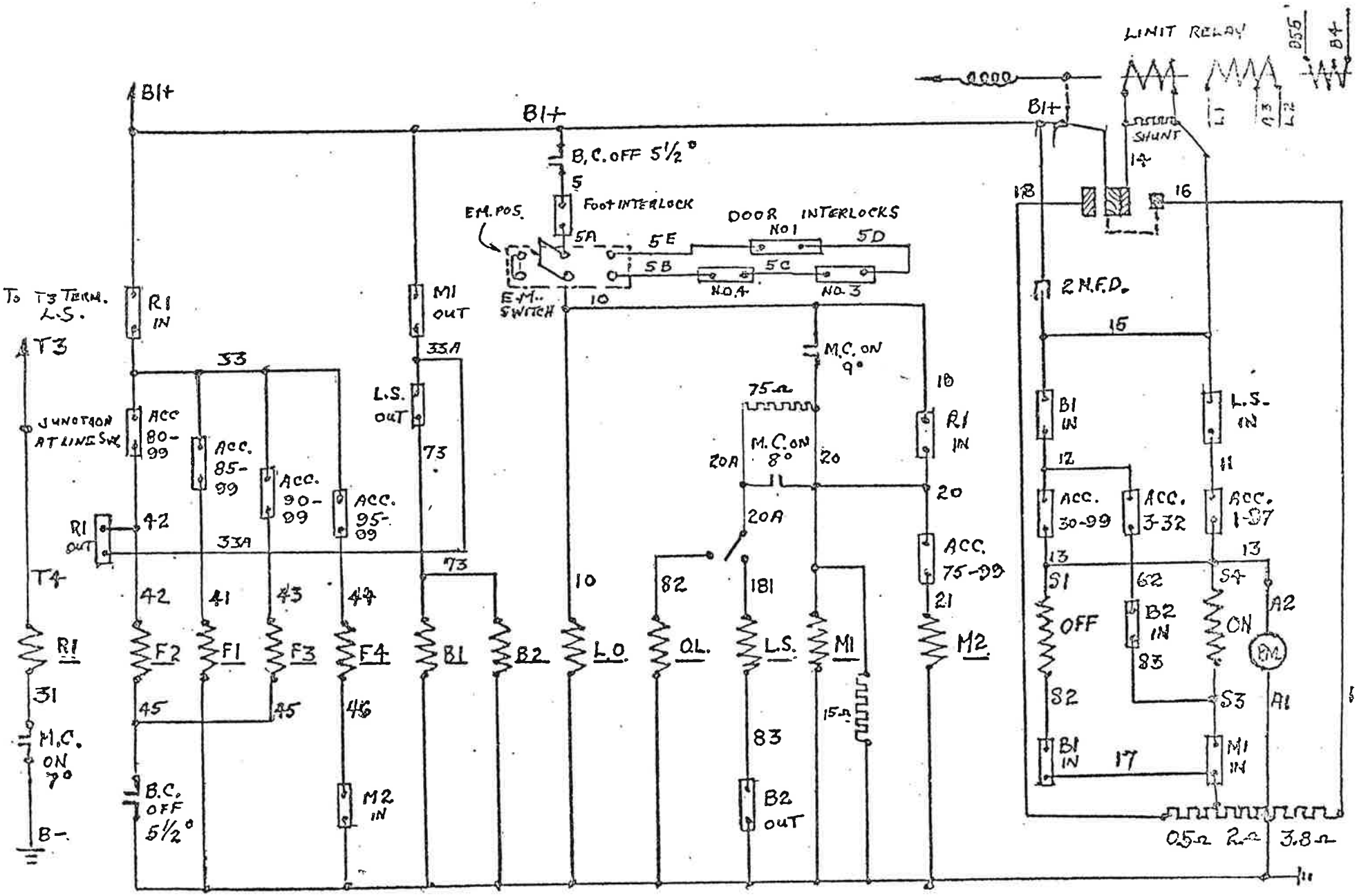
Honeywell





MOTOR CIRCUIT SCH.
A6. P.C.C. CARS 4300-4399. (FROM PRINT C 6732)

J.R. WORWOOD OCT 1964



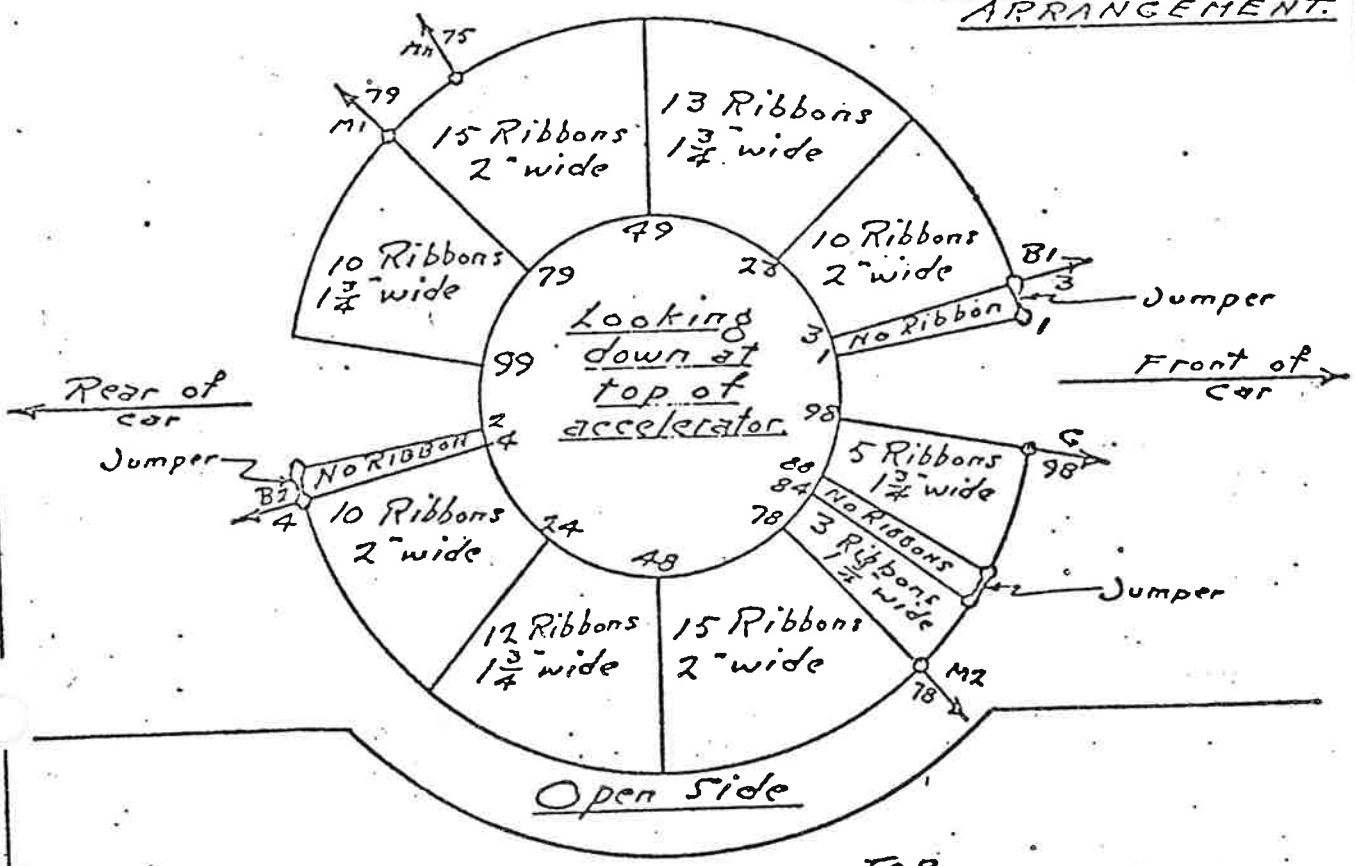
AC CONTROL CIRCUIT SCH. PCC. CARS 4300-4399 (FROM PRINT C 6732)

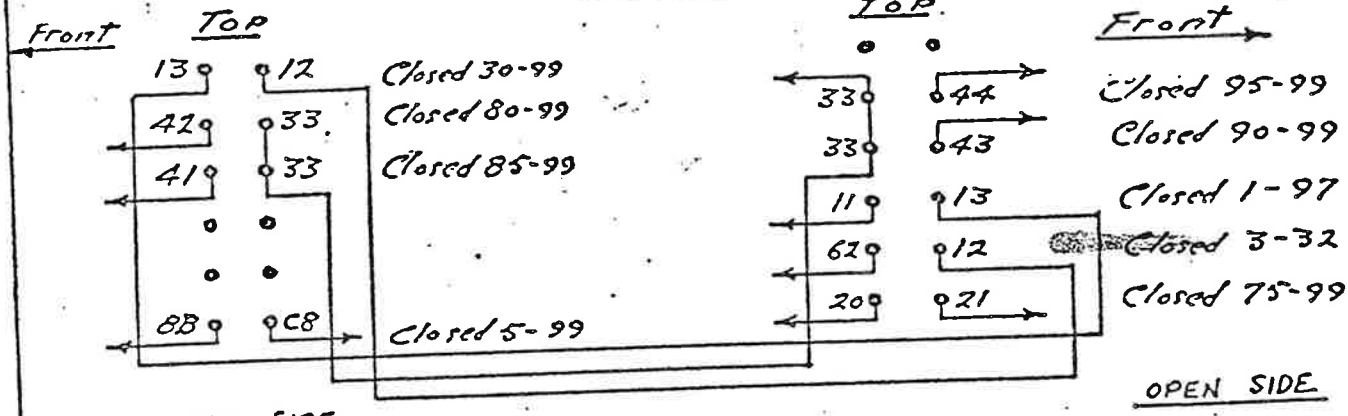
LIVERWOOD OCT. 1964

E110

Closed Side

RESISTANCE RIBBON ARRANGEMENT.

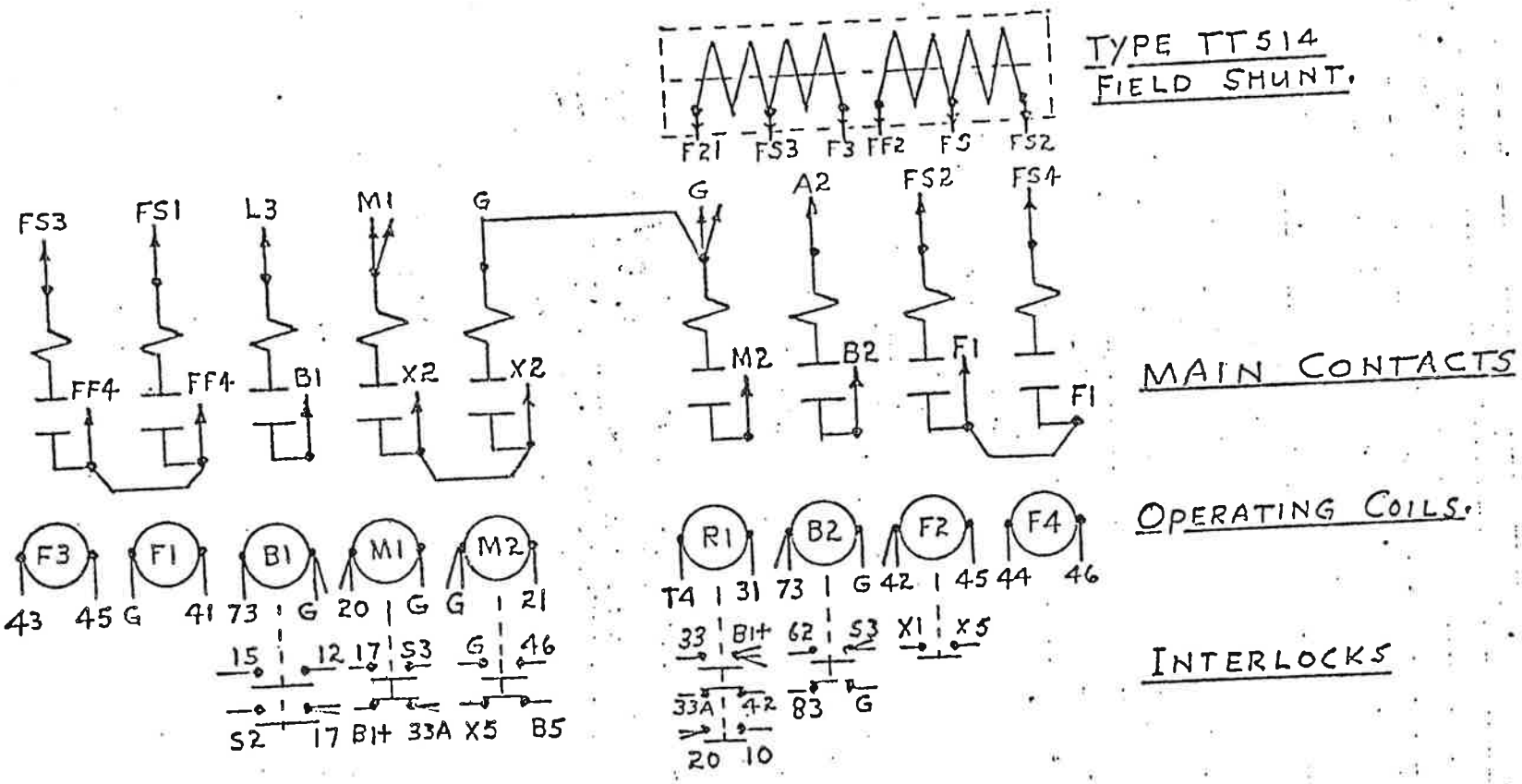


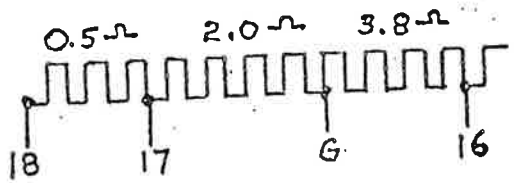


INTERLOCK BOARDS
TYPE XD473 ACCELERATOR
P.C.C. CARS 4300-4399

Oct. 5, 1951

A6 CONTROLLER
REVERSER
- TRACTION MOTORS LOCK-OU
10 FROM ACCEL. CONTROLLER
RECTIFIER
8B
C8
L3
L2
7.0Ω
7.0Ω
.5Ω
1.25Ω
8.0Ω
8A DRUM BRKS.
8B DRUM BRKS.
9A
9C TRACK BRKS
9B
C8
C9
8B
TEST SHUNT
A2
X3
SANDER A1
B3
TRACK BRAKES
9D
DRUM BRAKES
8C
C9
C9
9A
9B
9C
C8
8A
8B
F3+F2 A5
LINE Sw. S
STOP LTS S3
DOORS Z8
GONG B-
SPOTTING B44
G
B1+
B1+
B7
76
B5
LINE Sw. 20A
R1 PICK-UP G.
20
31
10 M1,M2 + LS.
20
LIMIT RELAY
TICKLER COIL
SPOTTING COIL
SERIES COIL
L1
B4
16
18
61+
15
B55
L1
OCT 20/71
GAE



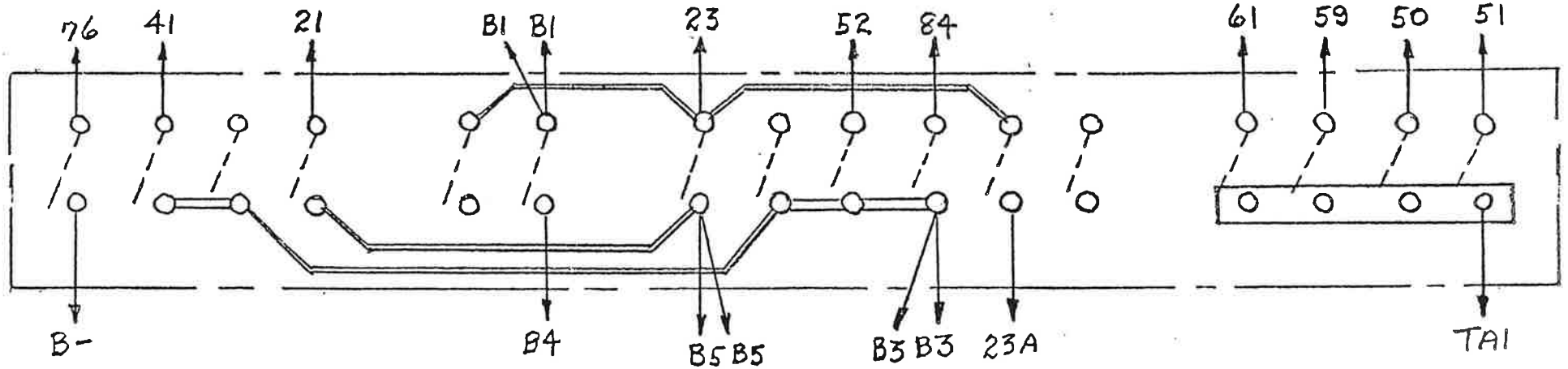


PILOT MOTOR RESISTOR ARRANGEMENT.

A6-4300-4399- CONTACT, FIELD SHUNT AND PILOT MOTOR CONNECTIONS.

9-29/71 G.A.F

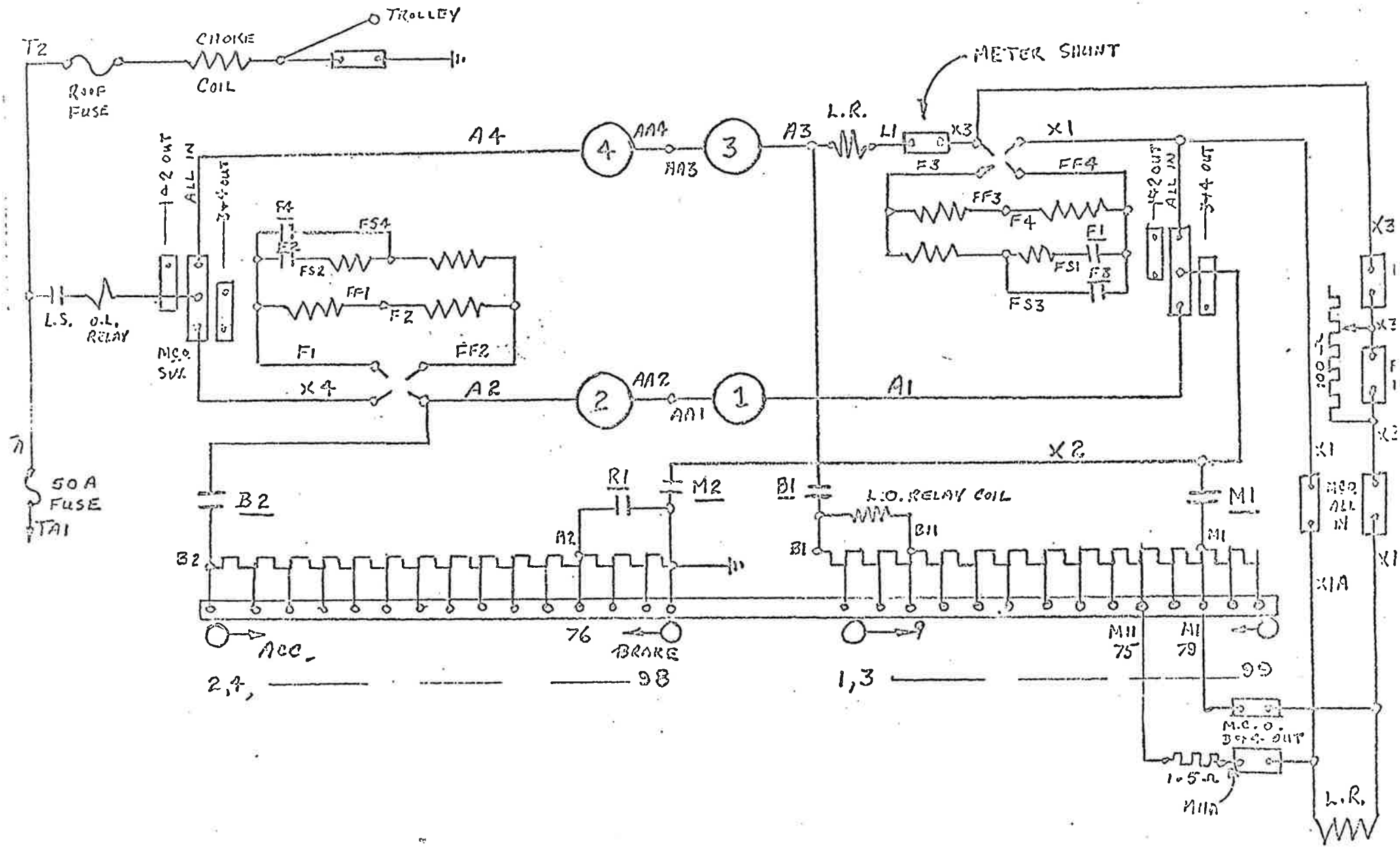
1	2	3	4	5	6	7	8	9	10	11	12	13	14		15	16	17	18
GONG (SPRING RETURN)	SANDER (SPRING RETURN)	SPARE (SPRING RETURN)	DOORS (TOGGLE)	SPACER	SPARE (SPRING RETURN)	M.G. SET (TOGGLE) ADD SHUNT	SPACER	EXIT CONTROL (TOGGLE)	SPARE (TOGGLE)	HEADLIGHT (TOGGLE)	DEFROSTER FAN (TOGGLE)	CENTRE ENT. (TOGGLE) REMOVE HALF OF HANDLE.	SPARE (SPRING) CUT OFF HANDLE	SPACER	CAB HEAT (TOGGLE) 600 VOLTS	ADV. LIGHTS (TOGGLE) 600 VOLTS	BODY LIGHTS (TOGGLE) 600 VOLTS	BODY LIGHTS (TOGGLE) 600 VOLTS



NOTE: CONTROL SW. AS VIEWED FROM BOTTOM.

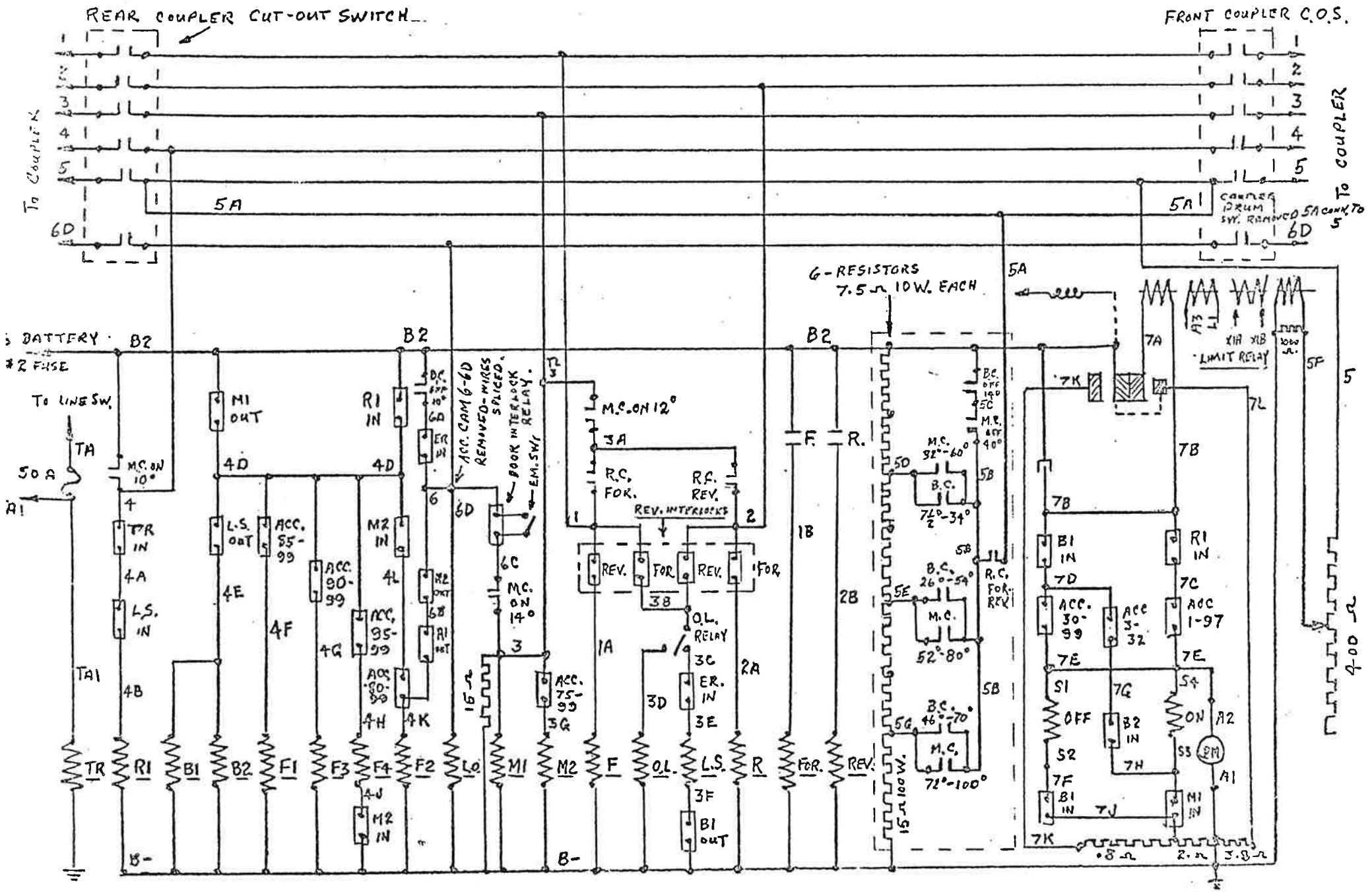
CAR WIRING — CONT. SW. WIRE JUMPER — COPPER JUMPER

A6 - [illegible]C. CARS 4300 - 4399 CONT[illegible] SWITCH 1603/1



MOTOR CIRCUIT SCH. A7 PCC. CARS 4400-4499 FROM DWG A5008

J.R. WORWOOD NOV. 1964



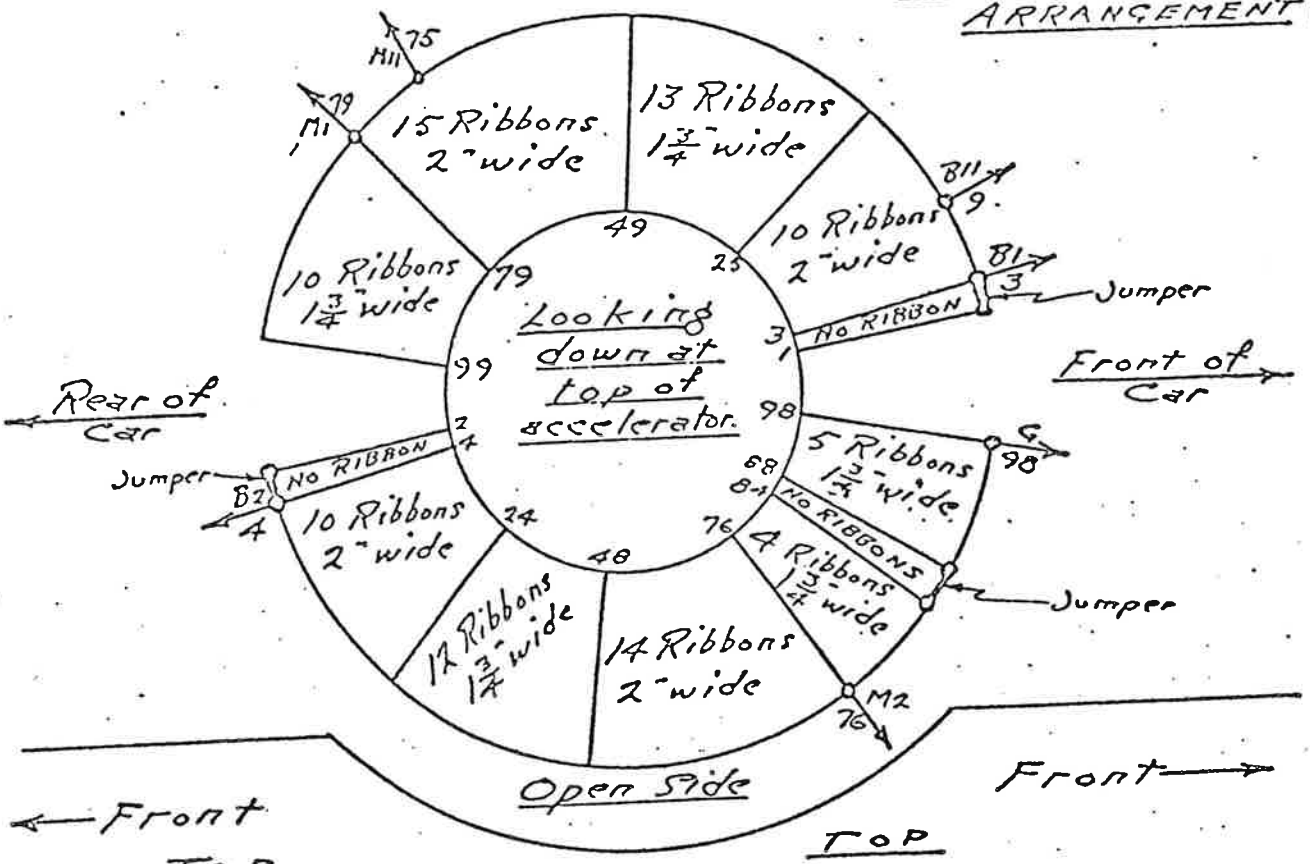
AT - CONTROL CIRCUIT SCH. - P.C.C. CARS 4400 - 4499 - (FROM PRINT A5008

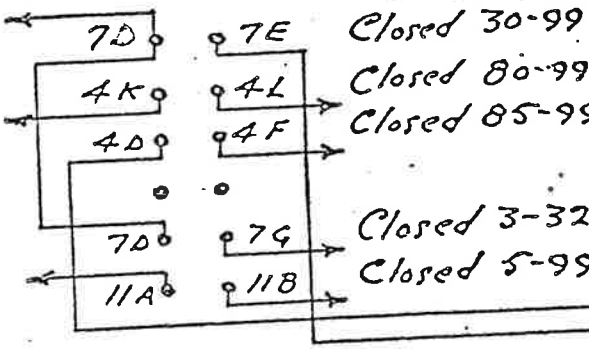
J.R. WORWOOD NOV. 1964

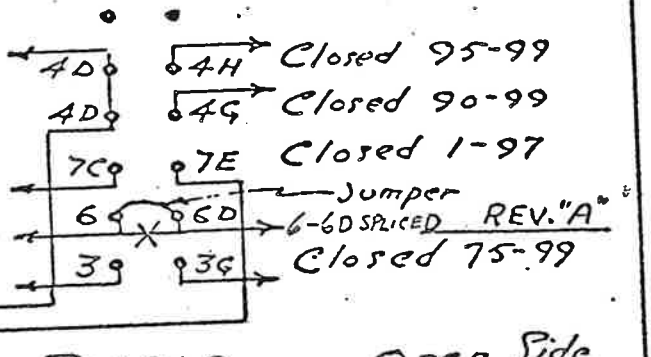
E-011-A

Closed Side

RESISTANCE RIBBON ARRANGEMENT







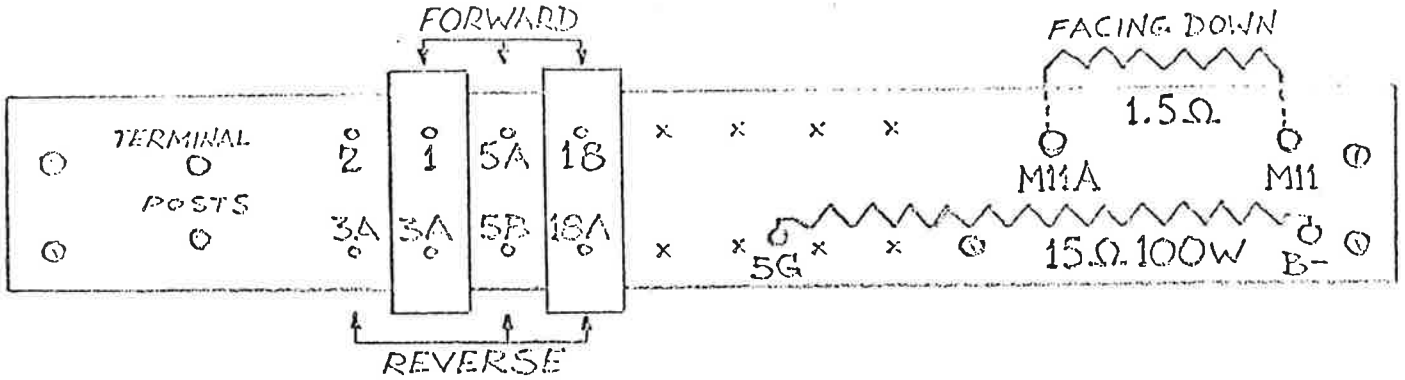
Closed Side — INTERLOCK BOARDS — Open Side

TYPE XD473 ACCELERATOR

P.C.C. CARS 4400-4499

Oct. 5, 1951:

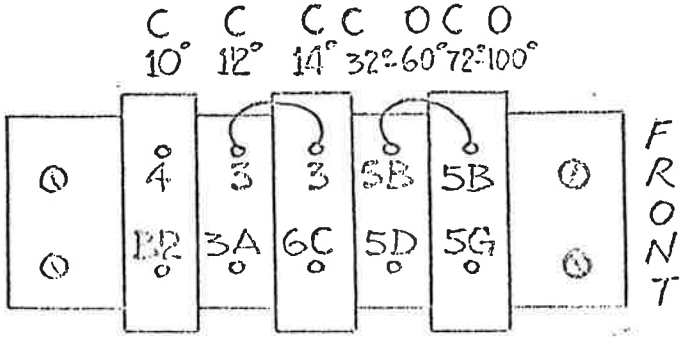
REV. A. - 6 TO 6D SWITCH REMOVED — WIRES SPLICED MAY 24/63



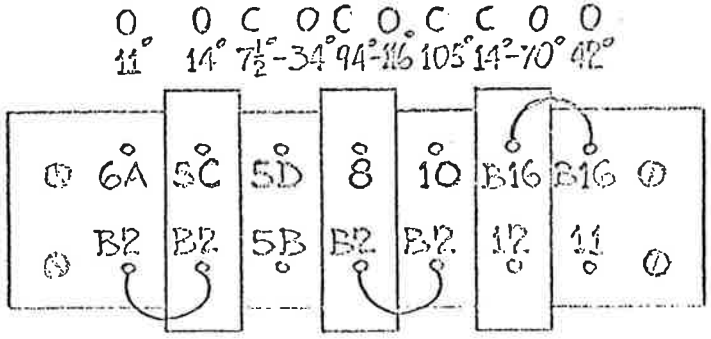
"A7"

MASTER CONTROLLER XMA-452

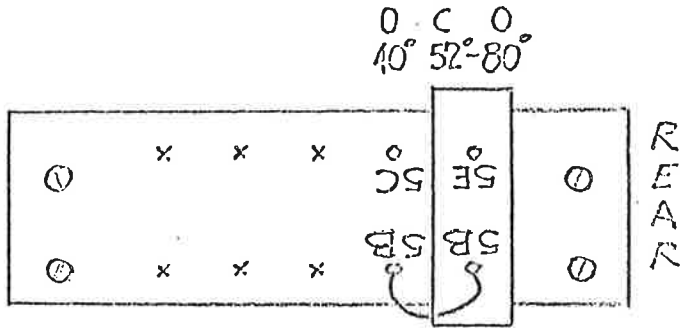
4400-4499

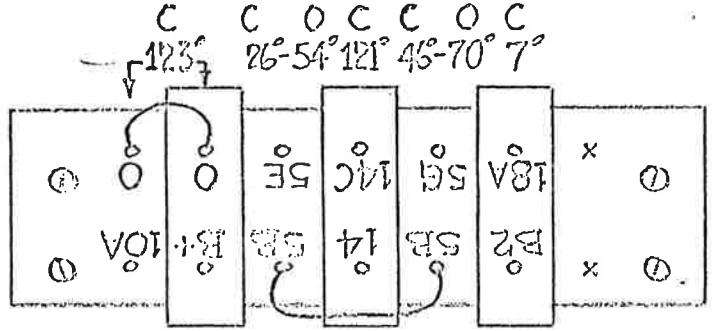


MASTER

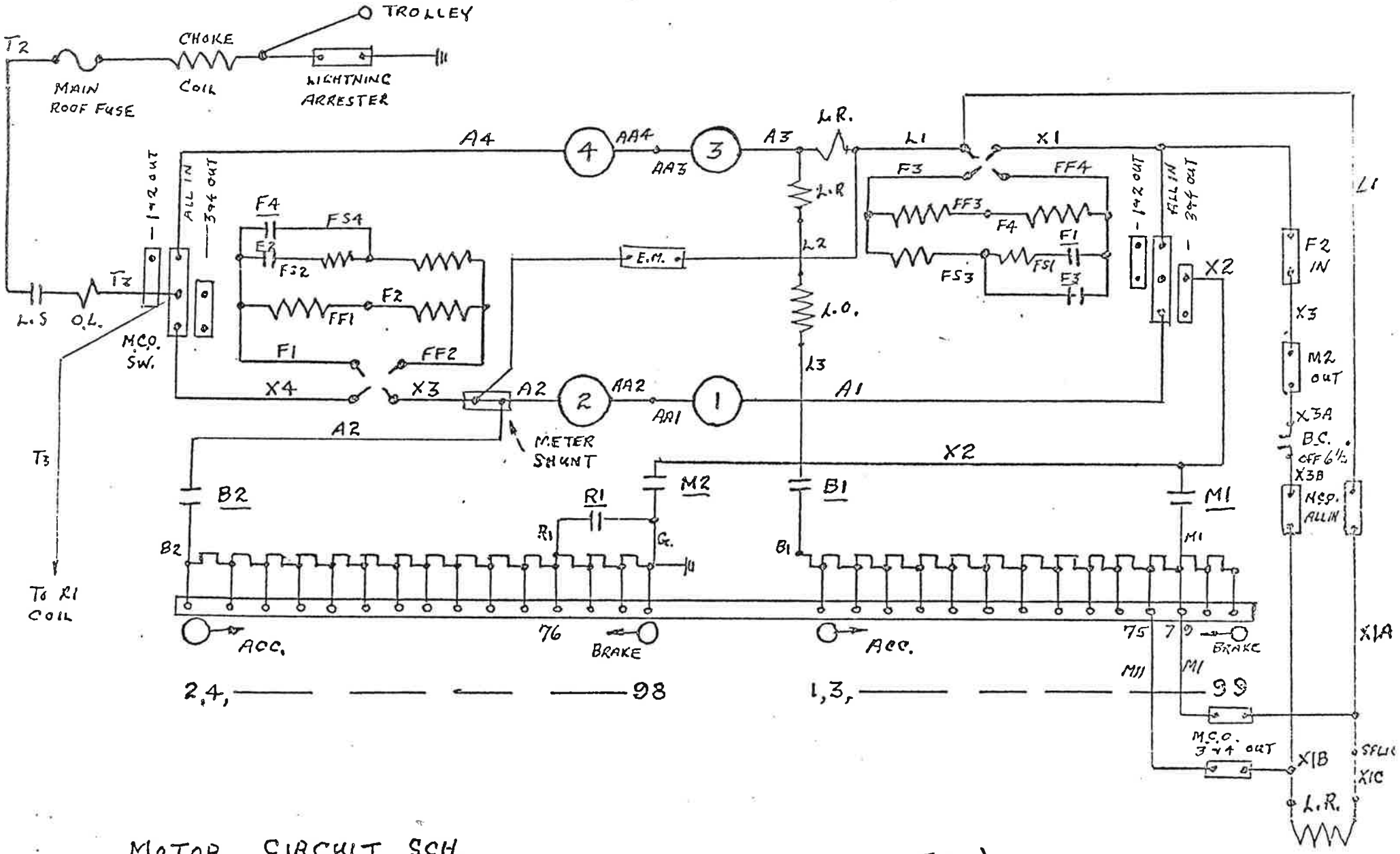


BRAKE



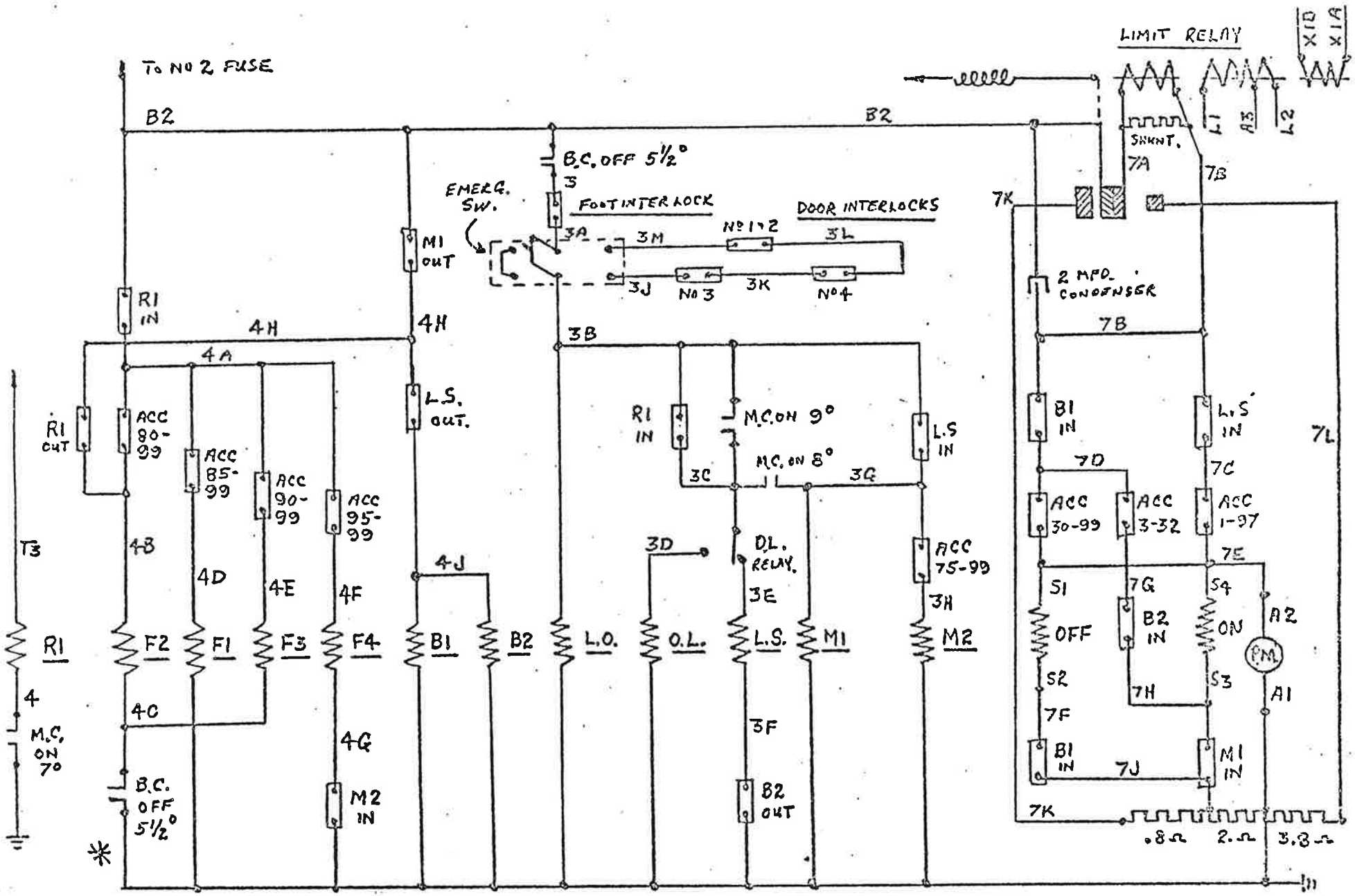


SEPT. 2. 65.
F.E.S.



MOTOR CIRCUIT SCH.
A8 P.C.C. CARS 4500-4549 (FROM PRINT D 5450)

J.R. WORWOOD OCT. 1964



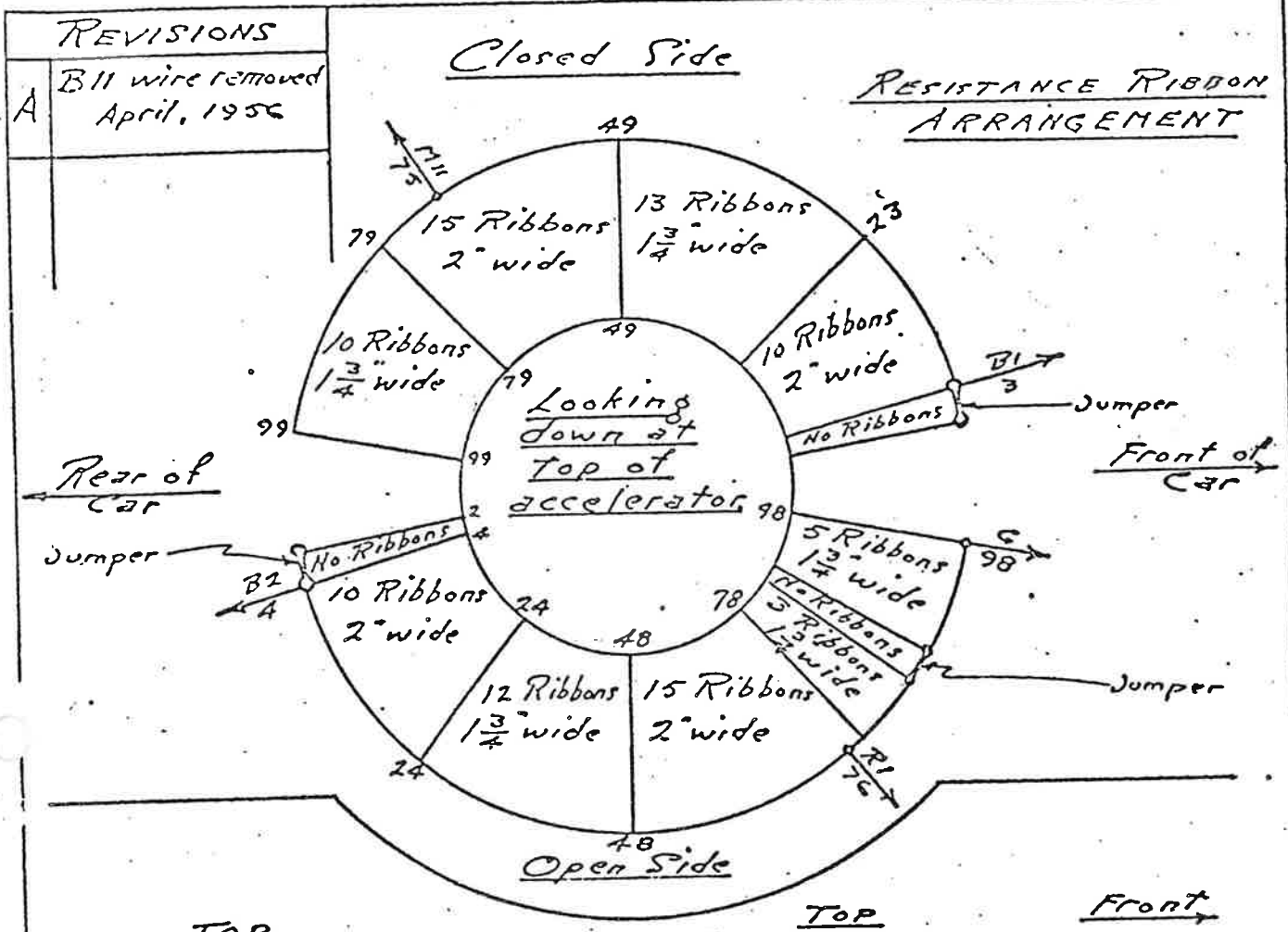
* NOTE: DUAL BRAKE MOD (SEE PRINT A5476

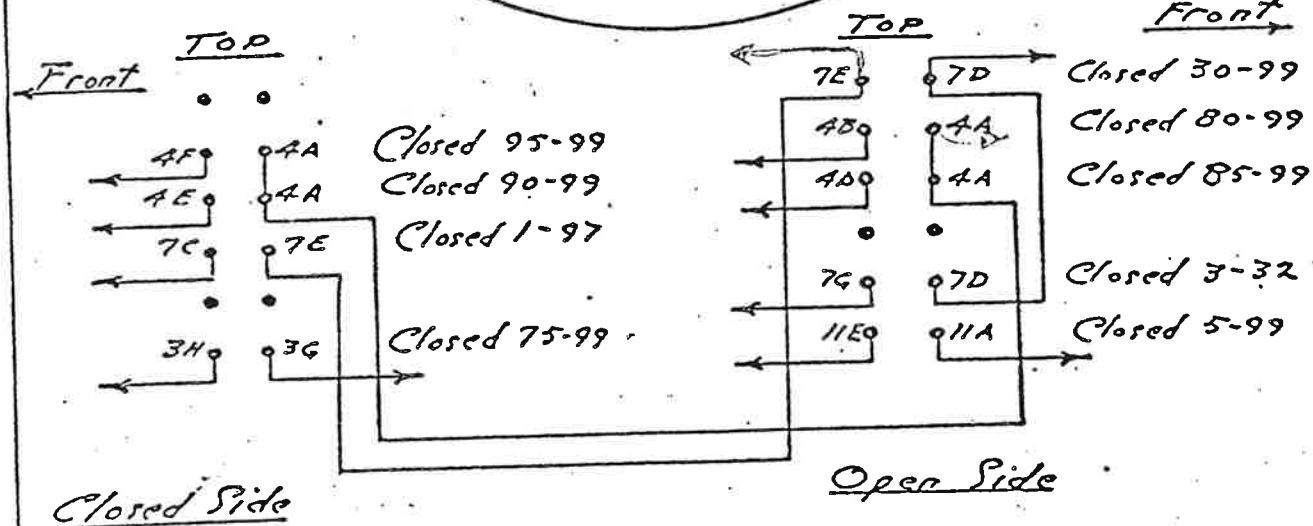
A8 CONTROL CIRCUIT SCH. PCC CARS 4500-4549 (FROM DNG. D5450)

J.R. WORWOOD NOV. 1964

E6112-A

REVISIONS	
A	B11 wire removed April, 1956

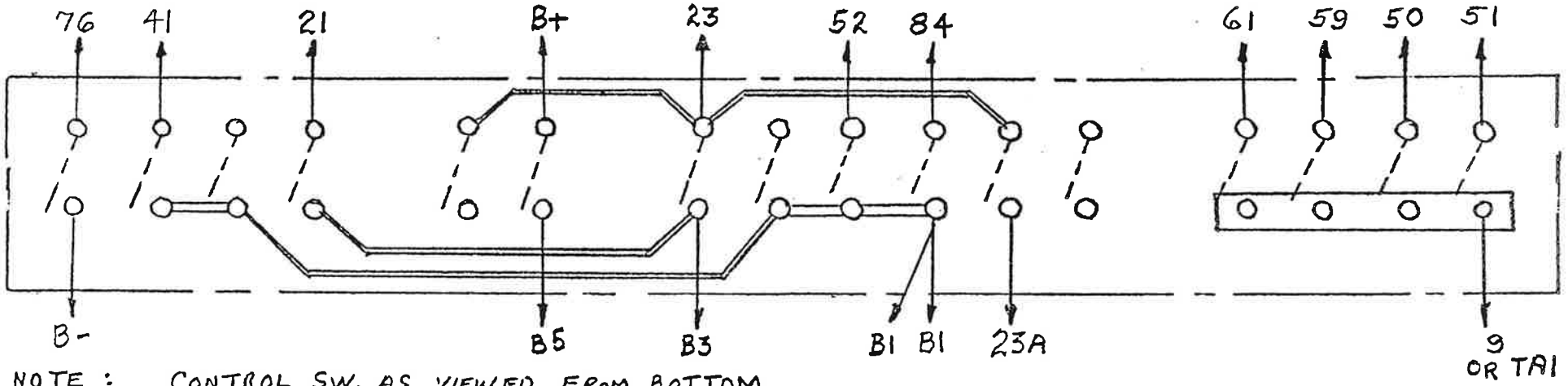




INTERLOCK BOARDS
TYPE XD 473 ACCELERATOR
P.C.C. CARS 4500-4549

Oct. 30, 1951

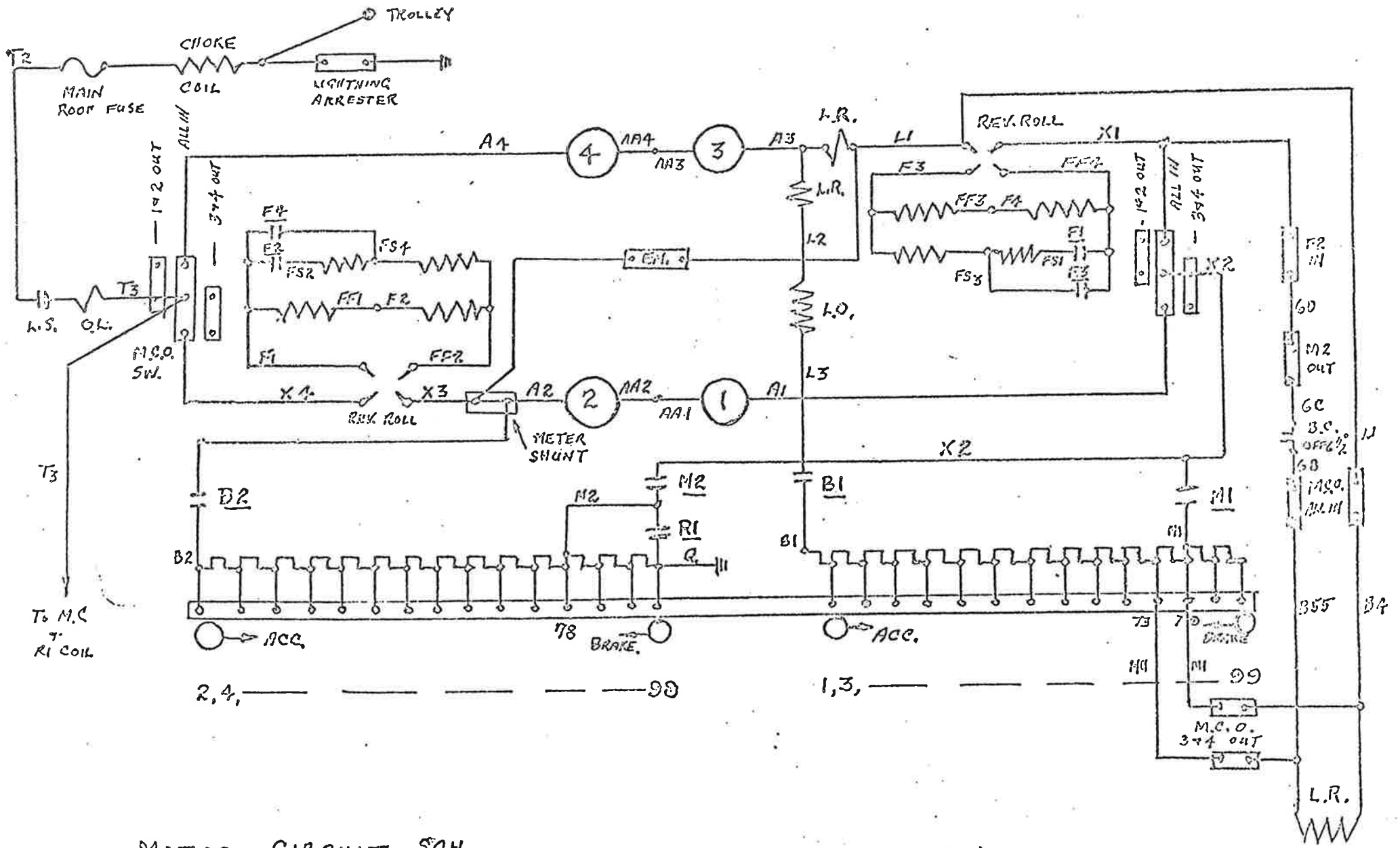
GONG (SPRING RETURN)	SANDER (SPRING RETURN)	SPARE (SPRING RETURN)	DOORS (TOGGLE)	SPACER	SPARE (SPRING RETURN)	M.G. SET (TOGGLE) ADD SHUNT	SPACER	EXIT CONTROL (TOGGLE)	SPARE (TOGGLE)	HEADLIGHT (TOGGLE)	DEFROSTER FAN (TOGGLE)	CENTRE ENT. (TOGGLE) REMOVE HALF OF HANDLE.	SPARE (SPRING) CUT OFF HANDLE	SPACER	CAB HEAT (TOGGLE) 600 VOLTS	ADV. LIGHTS (TOGGLE) 600 VOLTS	BODY LIGHTS (TOGGLE) 600 VOLTS	BODY LIGHTS (TOGGLE) 600 VOLTS
1	2	3	4	5	6	7	8	9	10	11	12	13	14		15	16	17	18



NOTE : CONTROL SW. AS VIEWED FROM BOTTOM

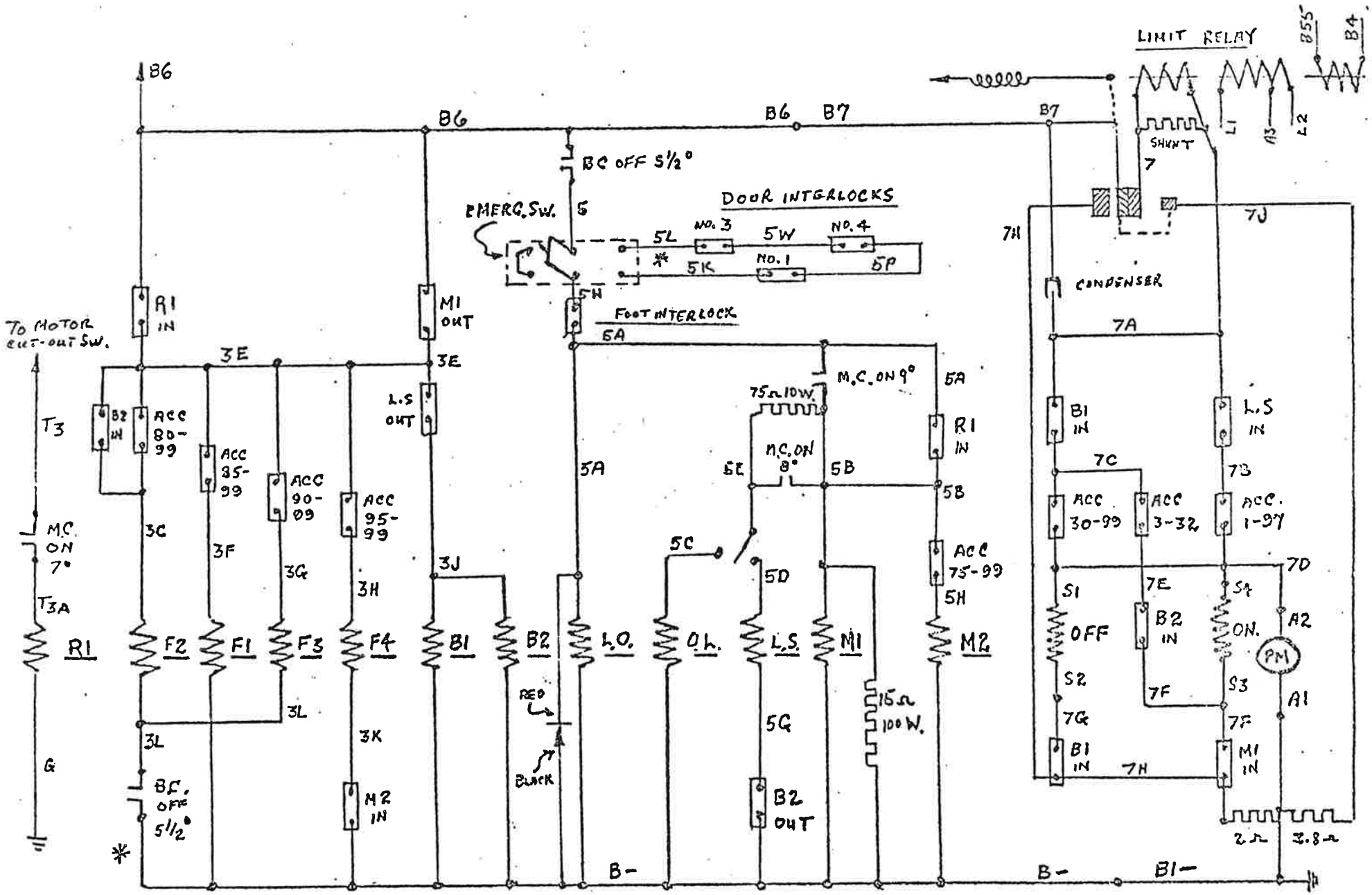
CAR WIRING — CONT. SW. WIRE JUMPER — COPPER JUMPER

A8 - P.C.C. CARS 4500 - 4549 CONTROL SWITCH. A6603/1



MOTOR CIRCUIT SCH.
A9. PCC. CARS 4550 - 4574 (FROM PRINT D 5388)

J.R. WORWOOD OCT. 1964



* NOTE: DUAL BRAKE MOD. SEE PRINT E6663

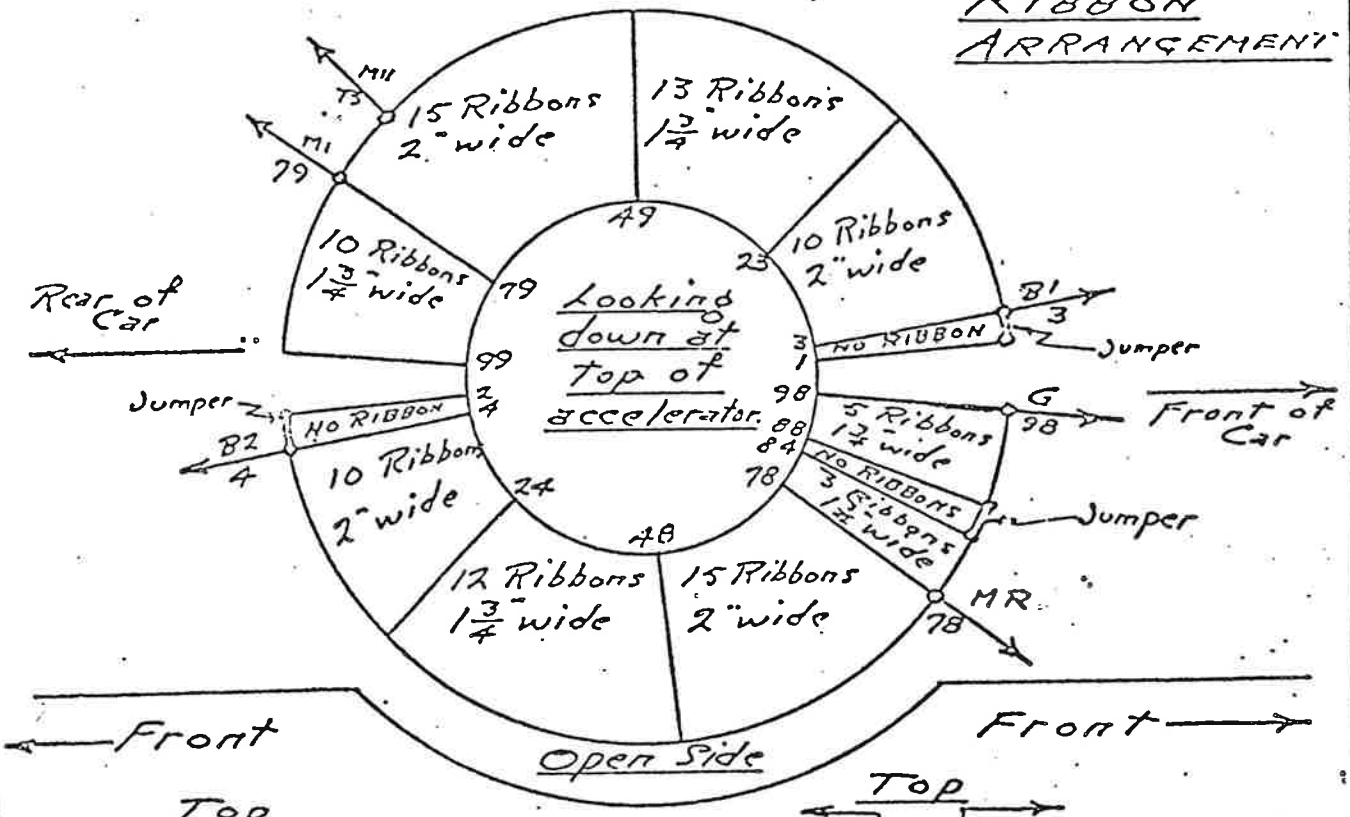
NOTE: RECTIFIER CONNECT. ON L.O. COIL RED +(5A) BLACK -(G)

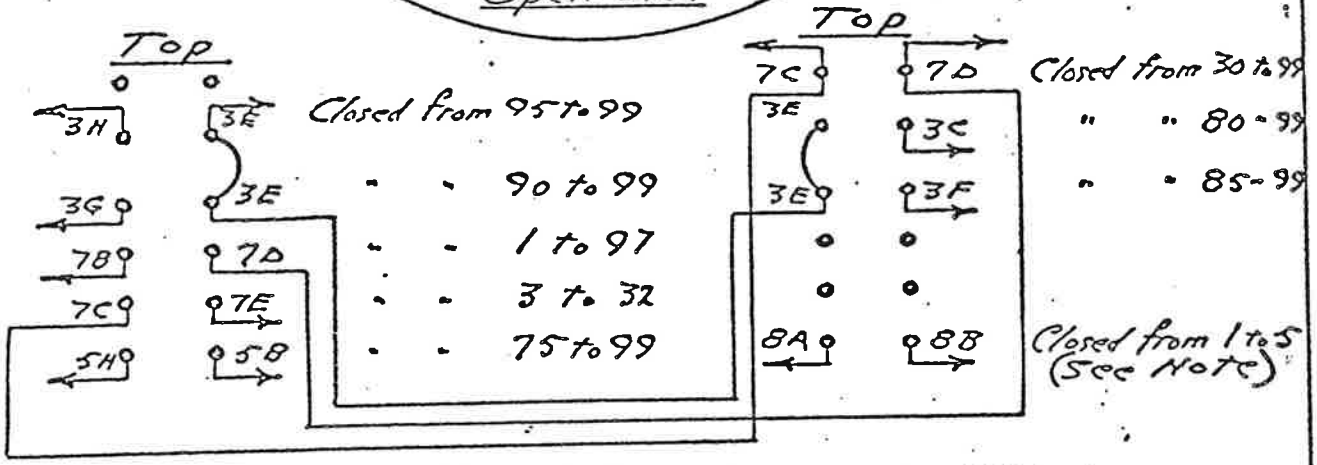
A9 CONTROL CIRCUIT SCH. P.C.C. CARS 4550-4574 FROM DWG. D5388

J.R. WORWOOD NOV. 1964.

Closed Side

RIBBON ARRANGEMENT





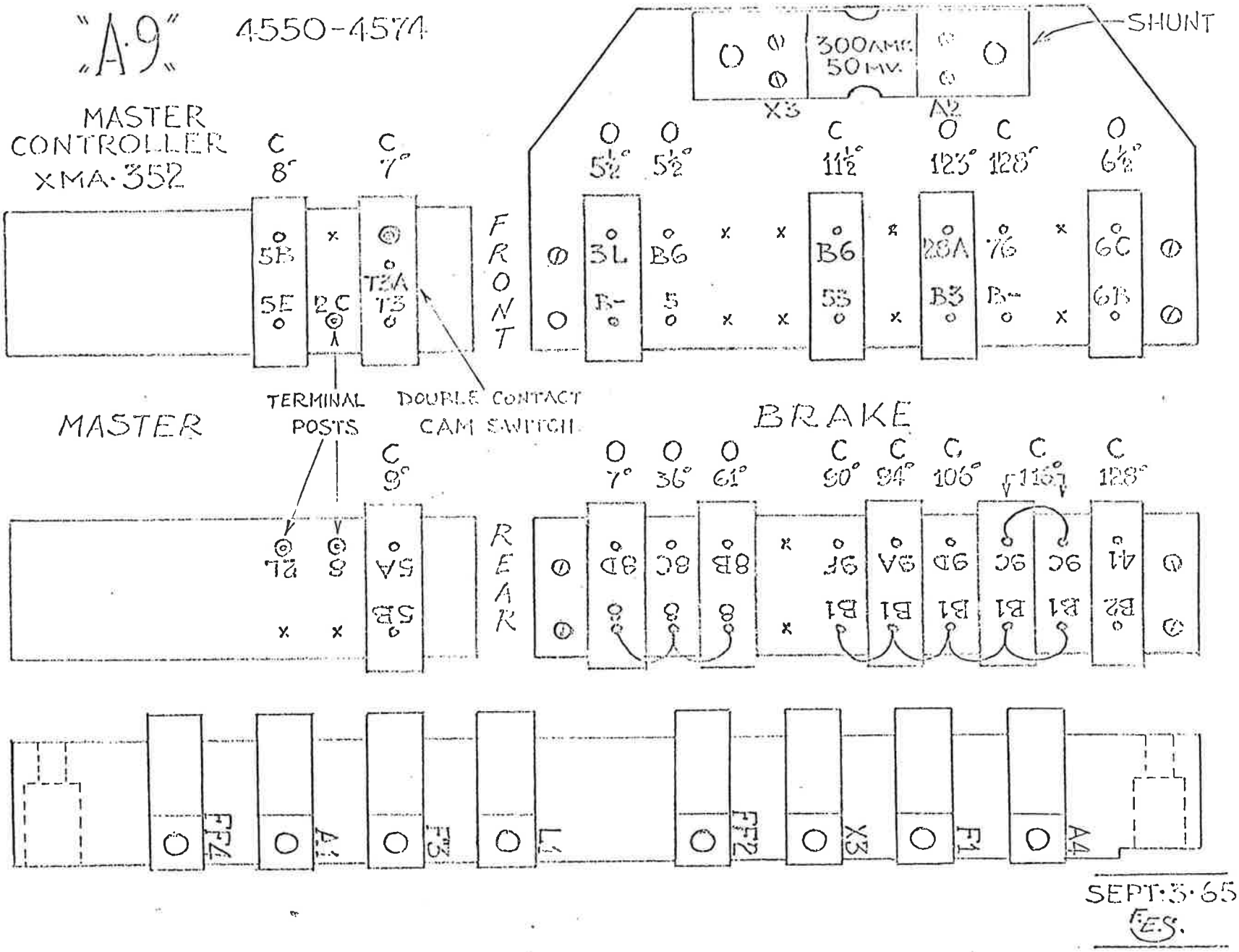
Closed Side — Cam Switch Boards — Open Side

NOTE: On cars having 6"dia. drum brake actuators (cars 4571-74 at date shown) switch 8A-8B is replaced by 8C-8B, which is closed from 3 to 99.

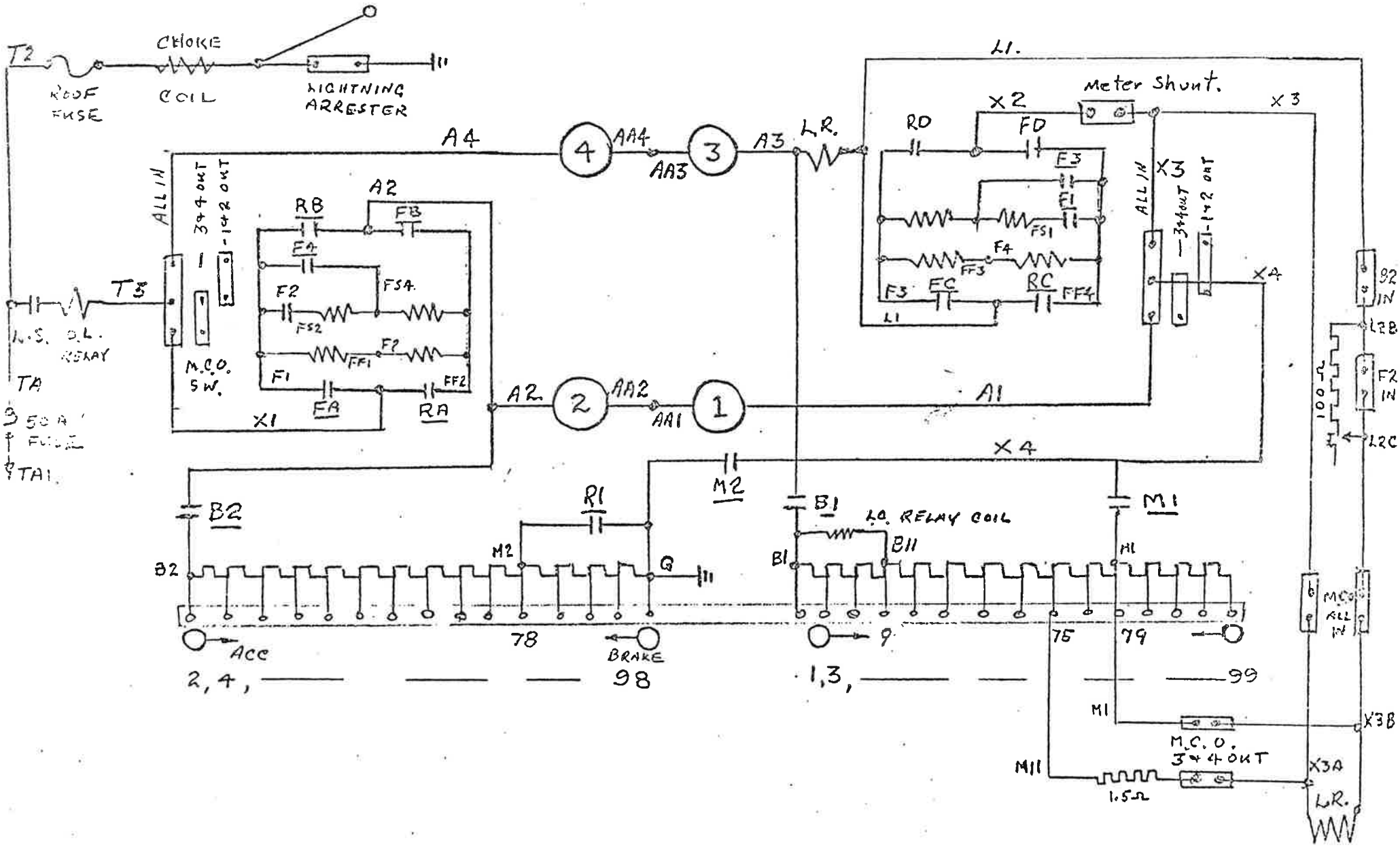
XD 473 ACCELERATOR
P.C.C. CARS 4550-4574

Oct. 1, 1951

"A-9" 4550-4574

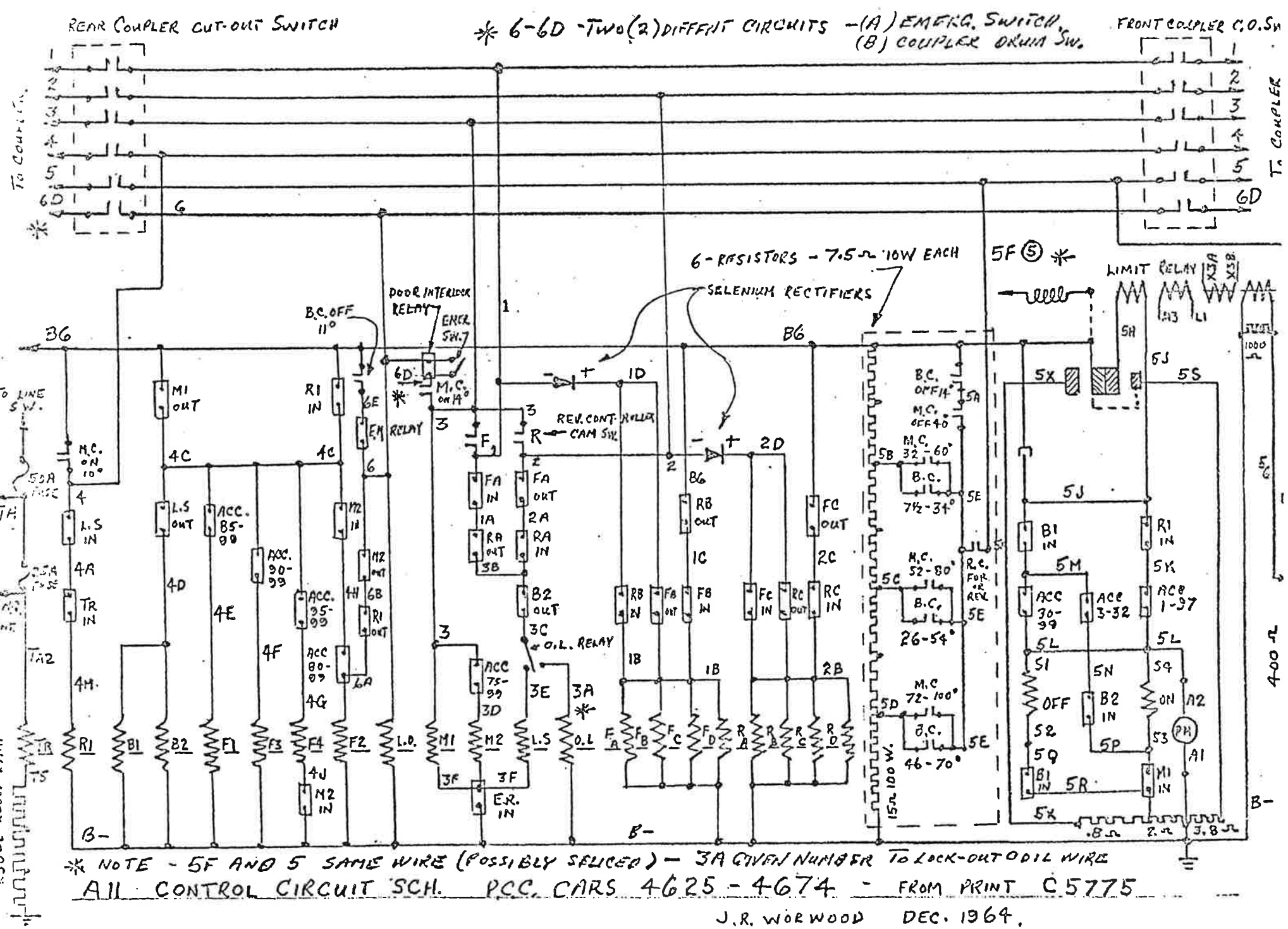


SEPT·3·65·
F.E.S.



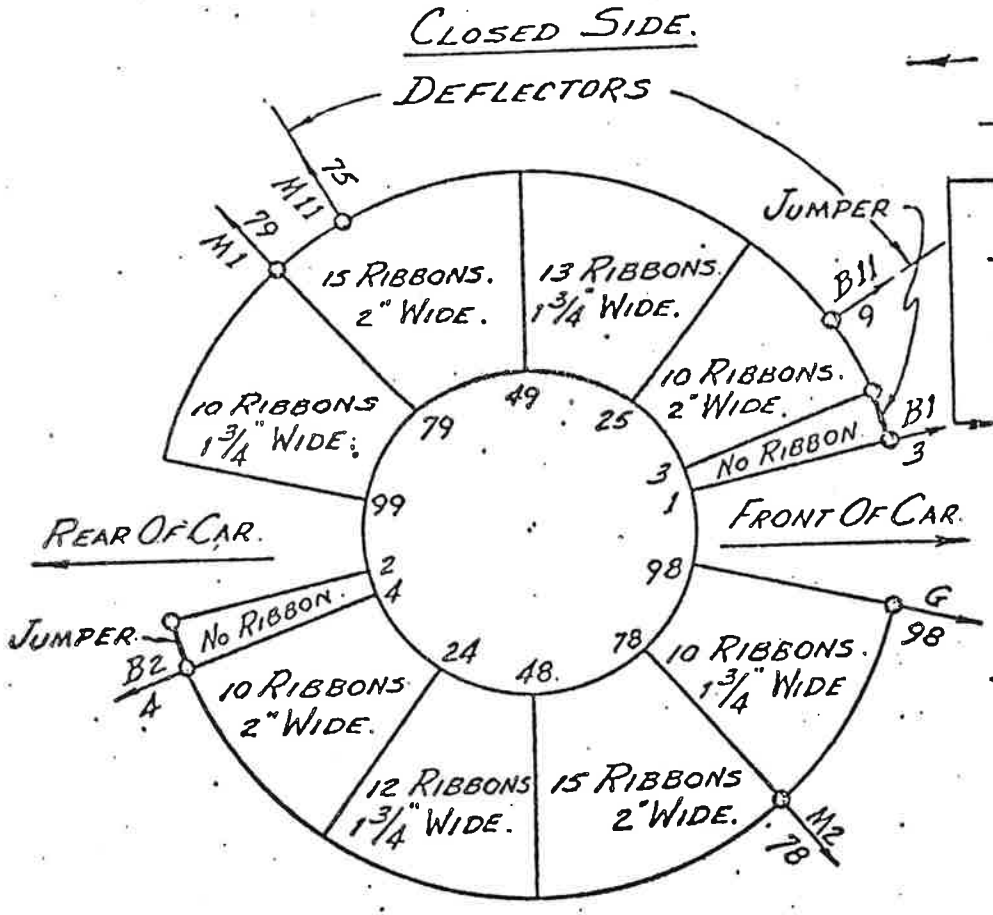
MOTOR CIRCUIT SCH. A11 - RCC. CARS 4625 - 4674 (FROM DWG. C 5775)

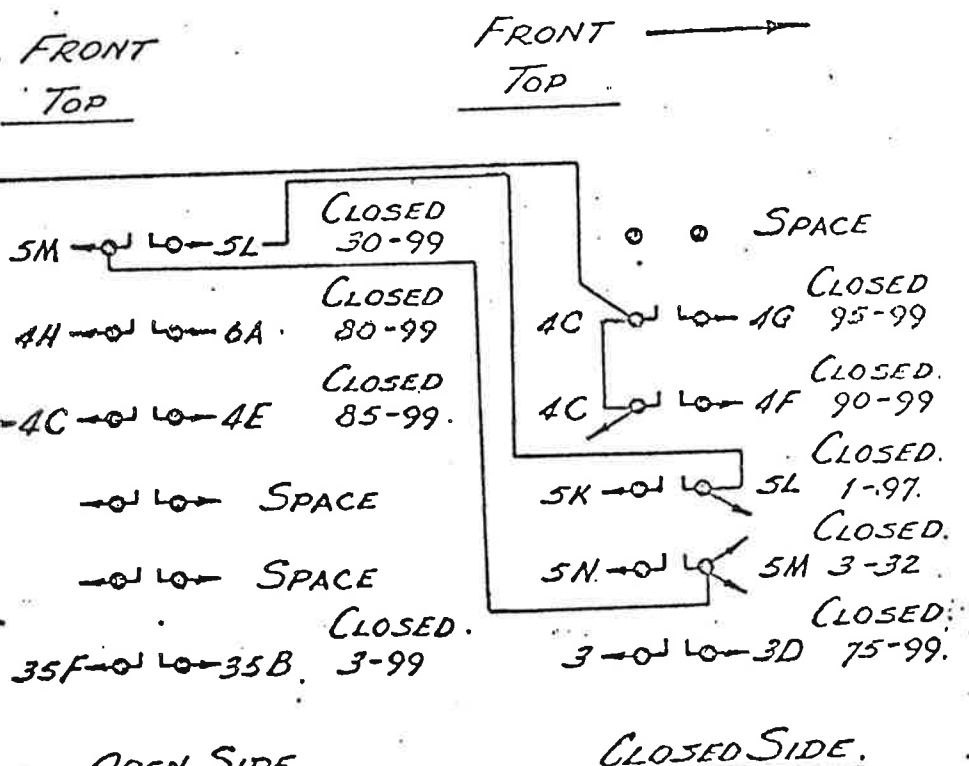
J. R. WORWOOD NOV. 1964.



All Control Circuit Sch. PCC. Cars 4625 - 4674 - From Print C5775

J.R. Worwood Dec. 1964.





TOLERANCE ± 0.005" UNLESS OTHERWISE SPECIFIED

TORONTO TRANSIT COMMISSION
EQUIPMENT DEPARTMENT

TYPE XD 423P. ACCELERATOR RIBBON ARRANGEMENT P.C.C. CARS 4625 - 4674.

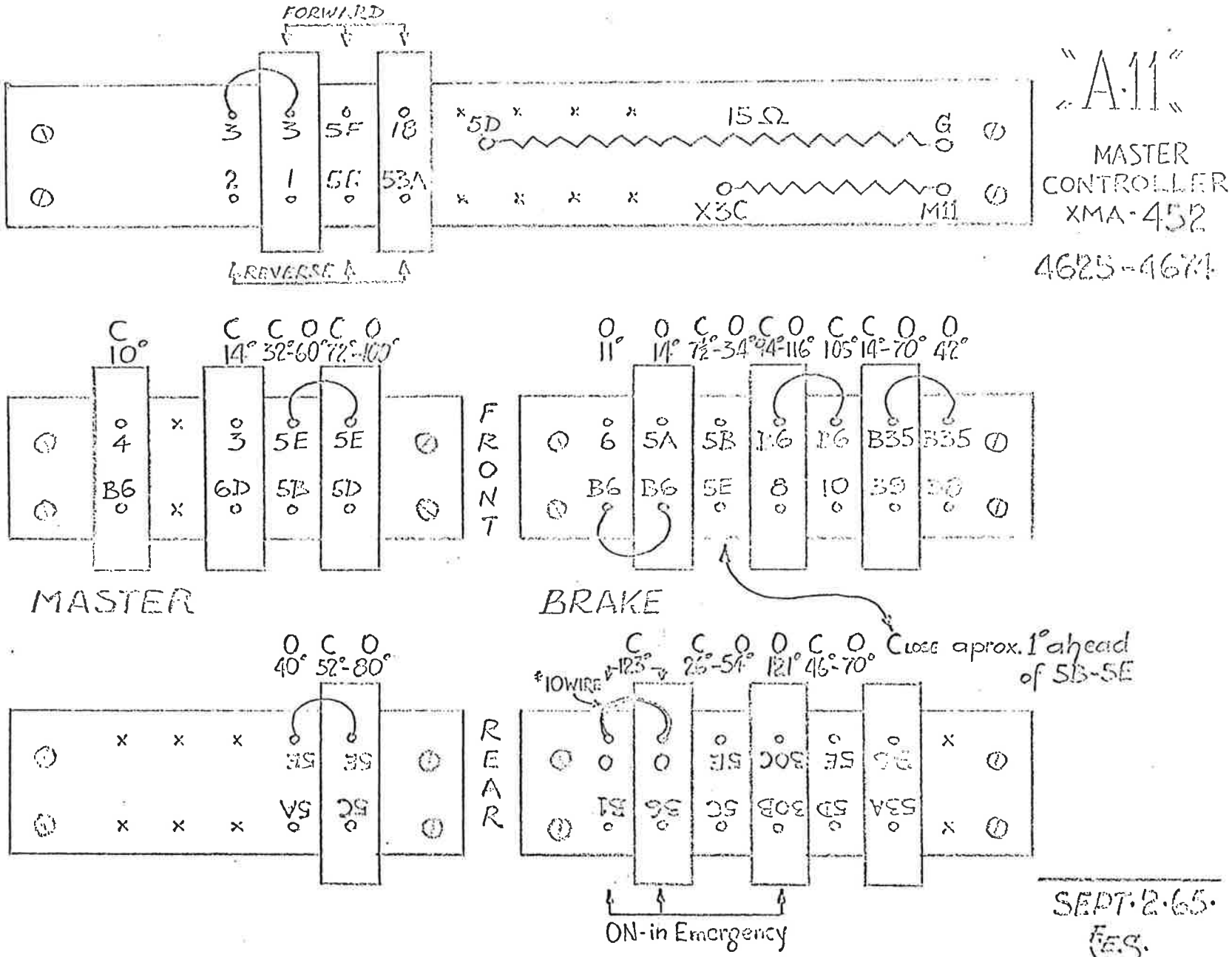
REF. DWGS. _____

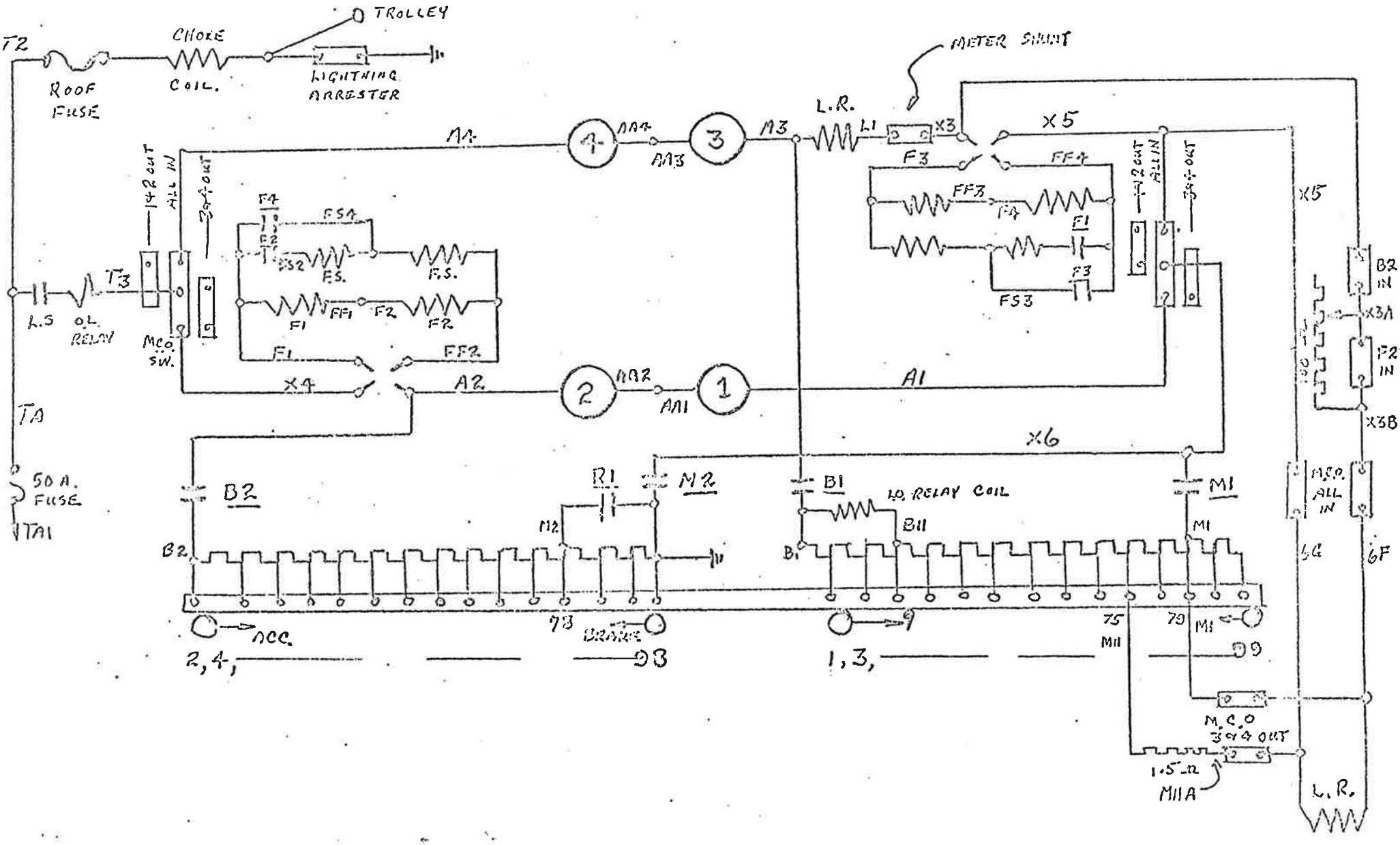
SCALE Do Not DR. R.A. TR. R.A. CK. J.S.T. DATE Nov 25/55.

APPROVED BY Lew Gardiner
SUPT. OF ELECTRICAL EQUIPMENT

DRAWING NO. E 6451 A

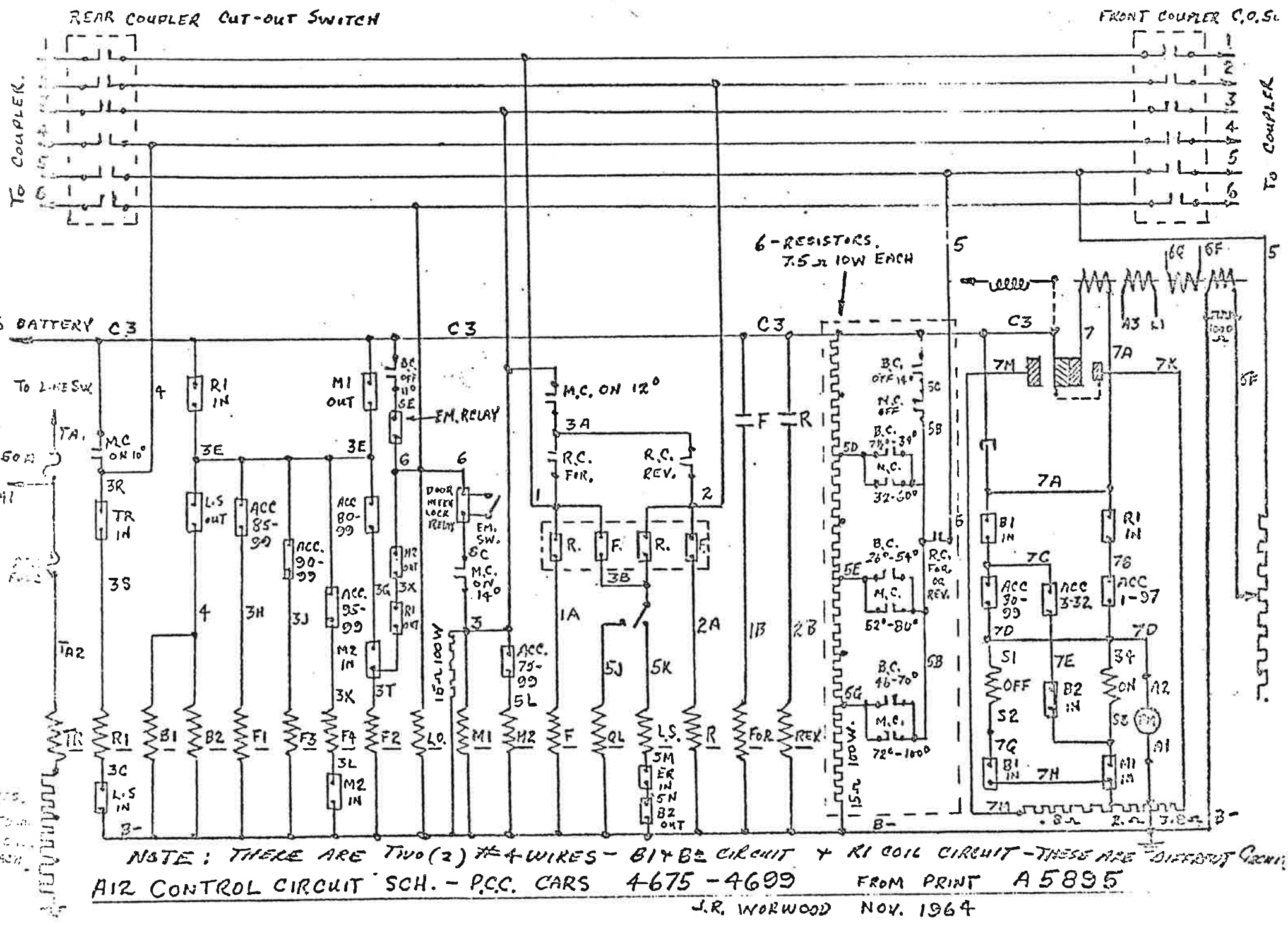
A	OPEN & CLOSED SIDE ON INTERLOCK BOARD REVERSED.	AUG 14/56
	REVISION	DATE.


FORWARD
REVERSE
3
3
5F
18
2
1
5E
53A
5D
15Ω
G
X3C
M11
"A-11"
MASTER CONTROLLER XMA-452
4625-4674
C 10°
C 14° C 32-60° O 72°-100° C O
4
B6
3
6D
5E
5B
5E
5D
FRONT
MASTER
O 11° O 14° C 7½-34° O 74-116° C 105° C 14-70° O 42°
6
B6
5A
B6
5B
5E
1-6
8
1-6
10
B35
B9
B35
B9
BRAKE
O 40° C 52°-80°
5E
5A
5E
5C
REAR
C 12½° C 25°-54° O 121° C 46°-70° O
*10 WIRE
Close aprox. 1° ahead of 5B-5E
ON-in Emergency
SEPT·2·65·
E.S.



MOTOR CIRCUIT SCH. A12 RES. CARS 4675-4699 (FROM DWG. A5895)

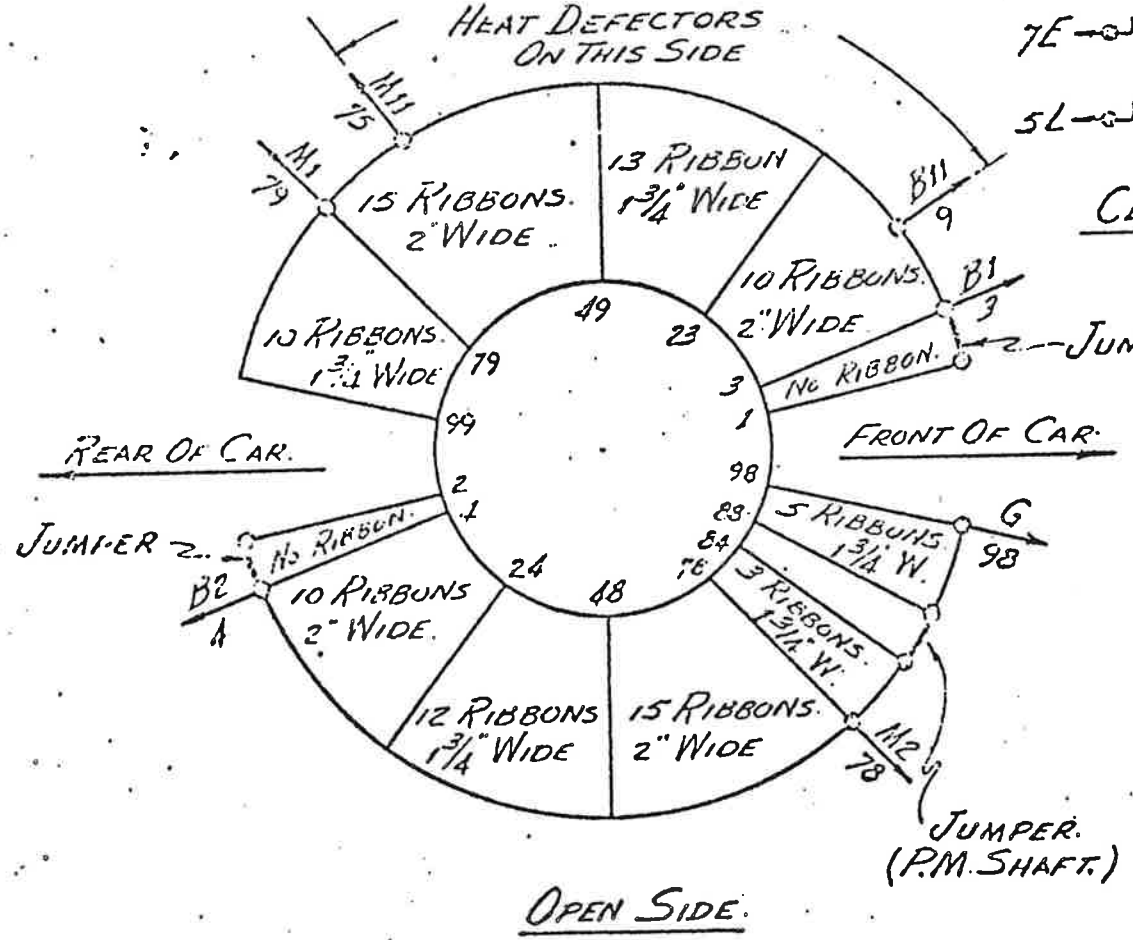
J.R. WORWOOD NOV. 1964

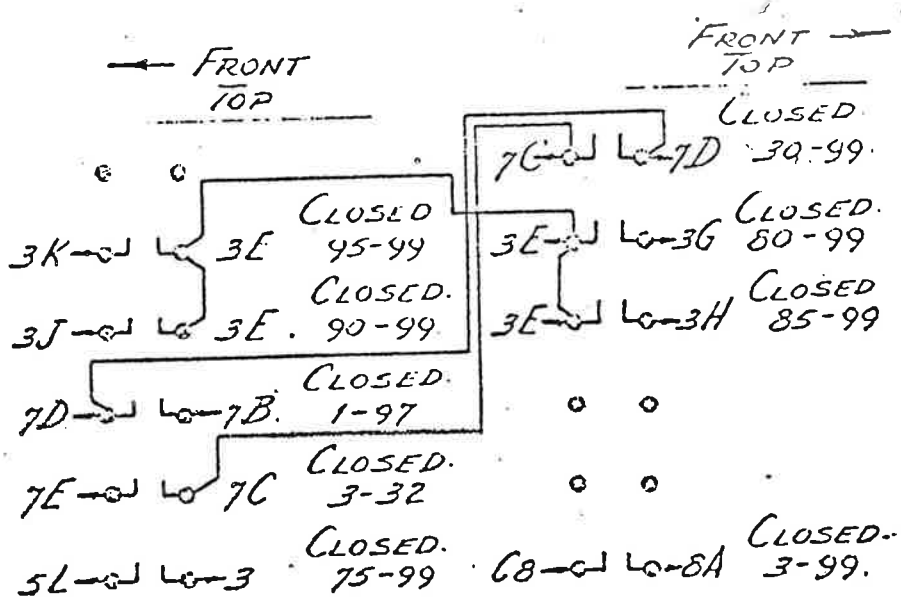


NOTE: THERE ARE TWO (2) #4 WIRES - B1 + B2 CIRCUIT + R1 COIL CIRCUIT - THESE ARE DIFFERENT GRADE

AIR CONTROL CIRCUIT SCH. - P.C.C. CARS 4675-4699 FROM PRINT A5895

J.R. WORWOOD NOV. 1964





INTERLOCK BOARDS.

TOLERANCE ± 0.005" UNLESS OTHERWISE SPECIFIED

TORONTO TRANSIT COMMISSION
EQUIPMENT DEPARTMENT

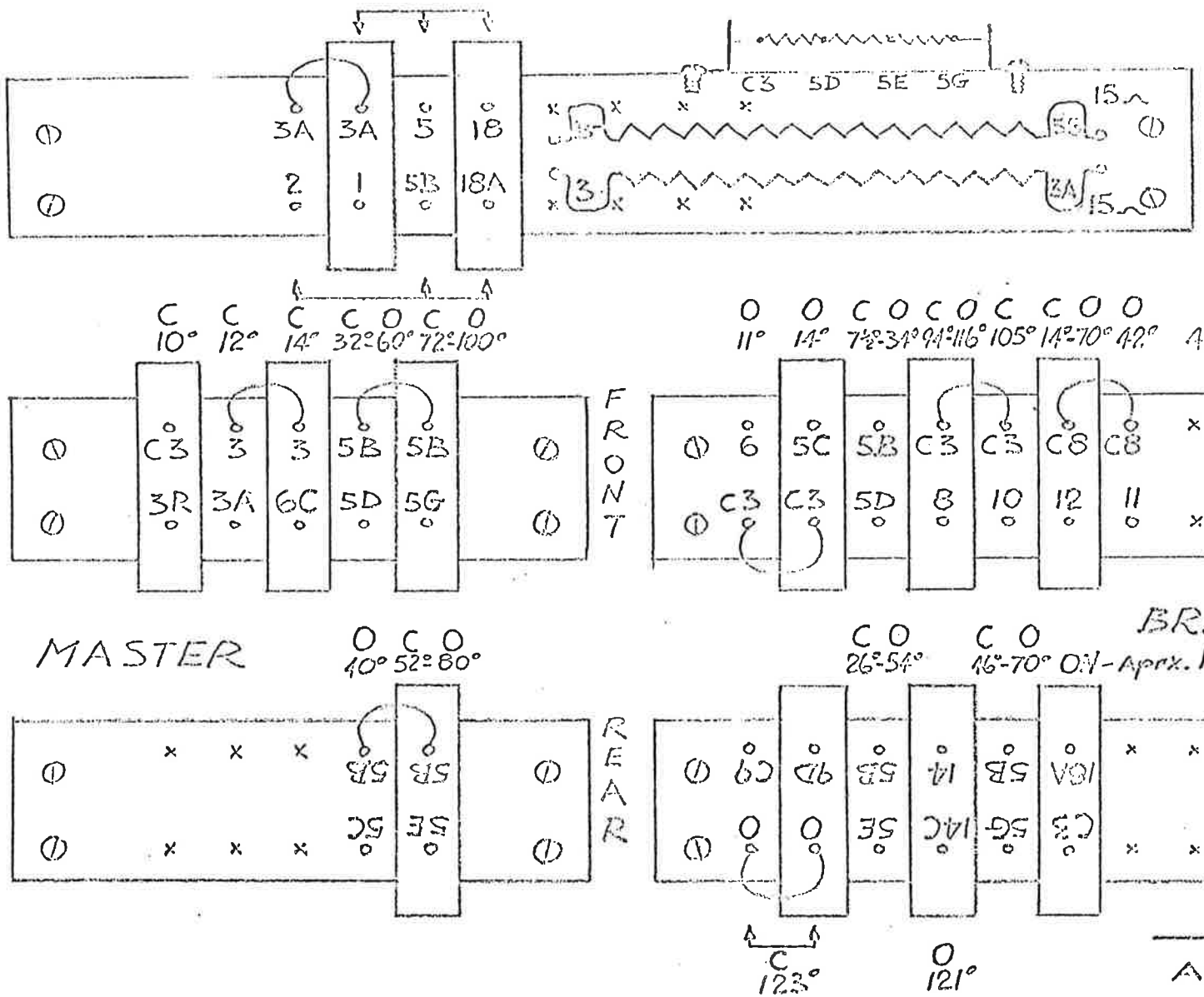
TYPE XD. 473. ACCELERATOR RIBBON ARRANGEMENT P.C.C. CARS 4675-4699.

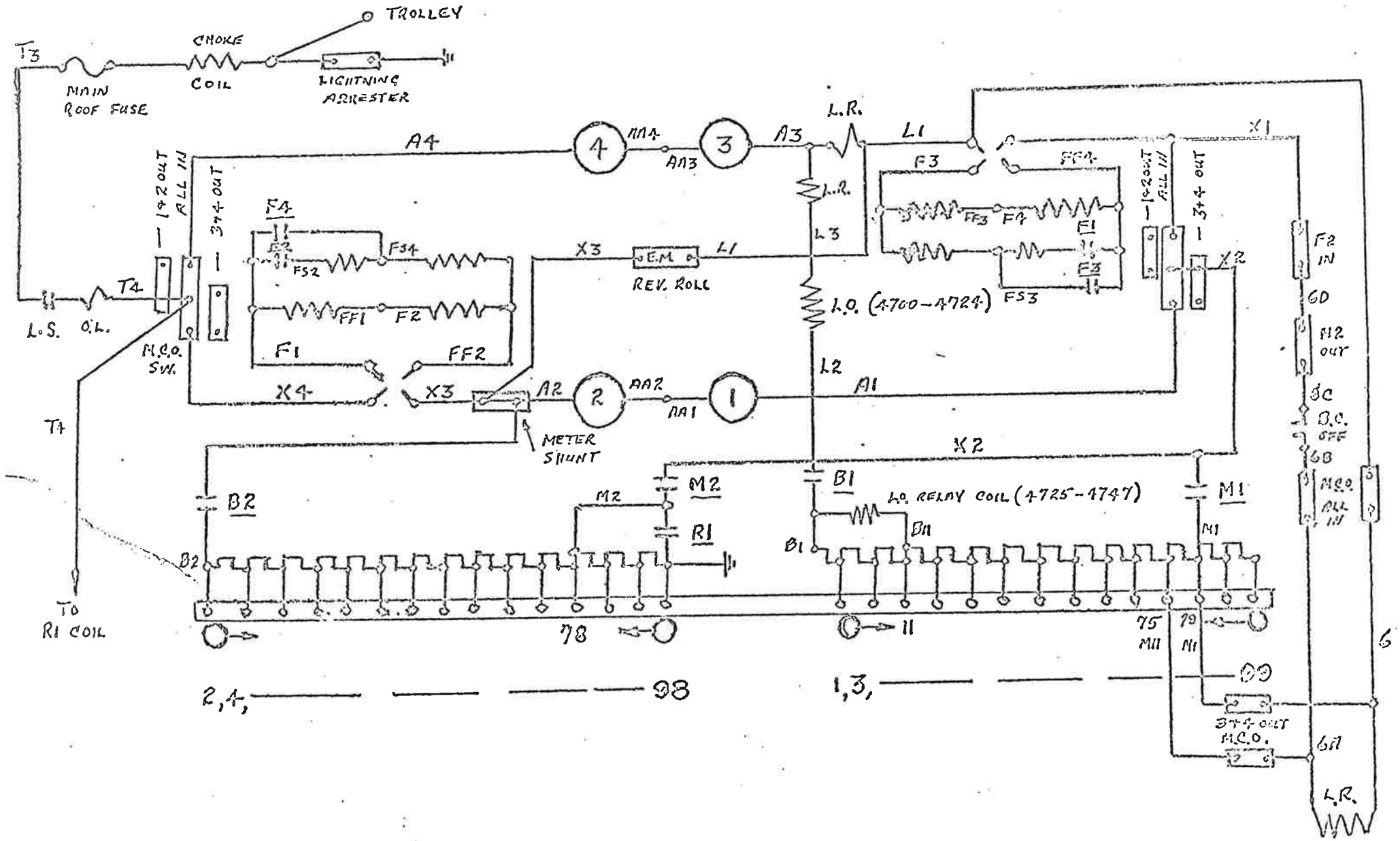
M.E. DWGS.

SCALE Do Not. DR. R.A. TR. R.A. CK. DATE Nov 20/46

APPROVED BY Leas Sandelin
SUPT. OF ELECTRICAL EQUIPMENT

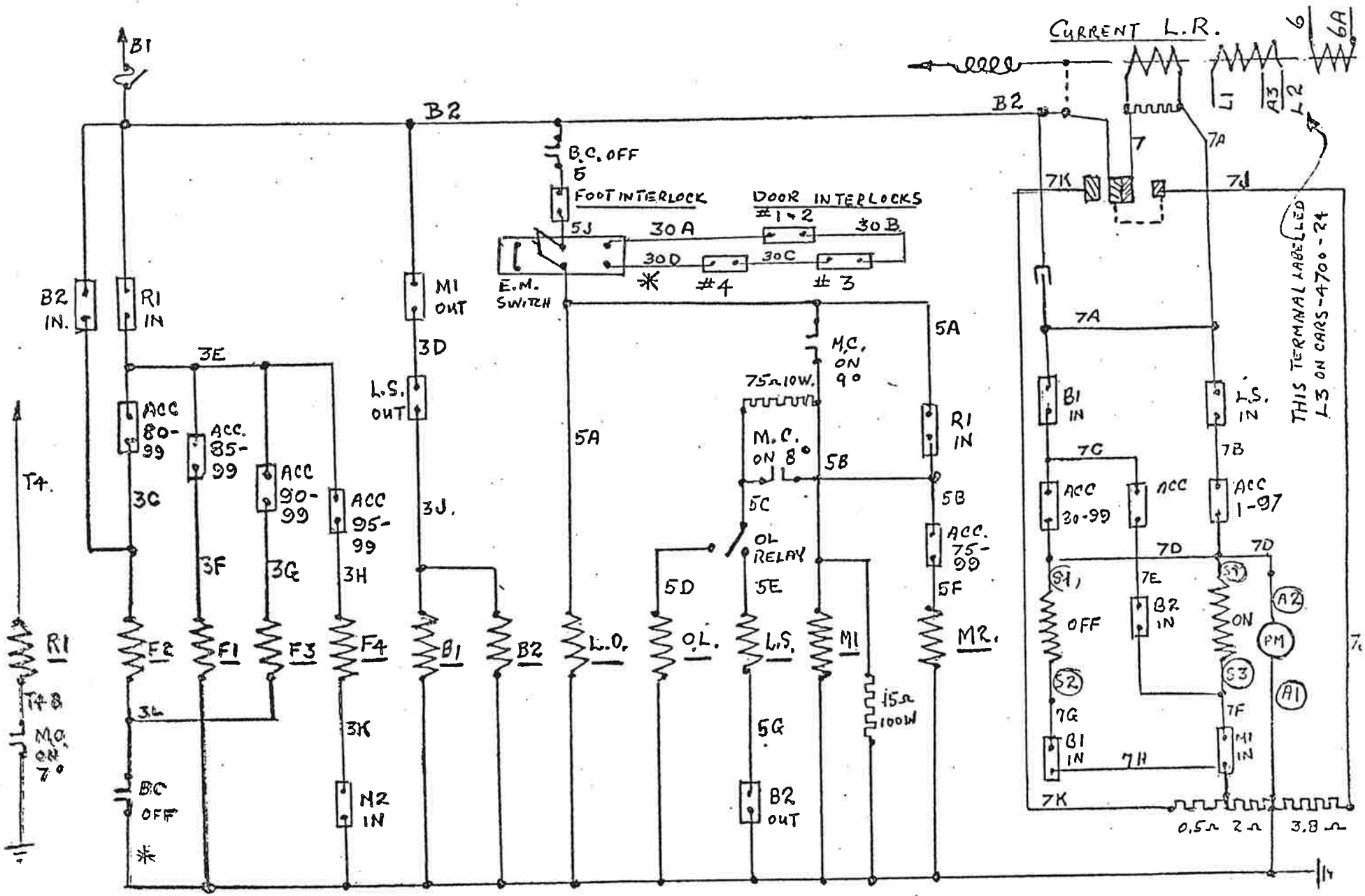
DRAWING NO. E 6452


"A-12"
MASTER
CONTROLLER
XMA 452
MOUNTED
FOR M-U
4675 - 4699
FRONT
REAR
MASTER
BRAKE
O.N. - Aprx. 1° Ahead of
5B-5D
AUG-19-65.
F.E.S.



MOTOR CIRCUIT. SCH. A13 P.C.C. CARS 4700 - 4747 (FROM DWG. D 5772)

J.R. WORWOOD NOV 1964



(* NOTE: DUAL BRAKE MOD. SEE PRINT E6664.)

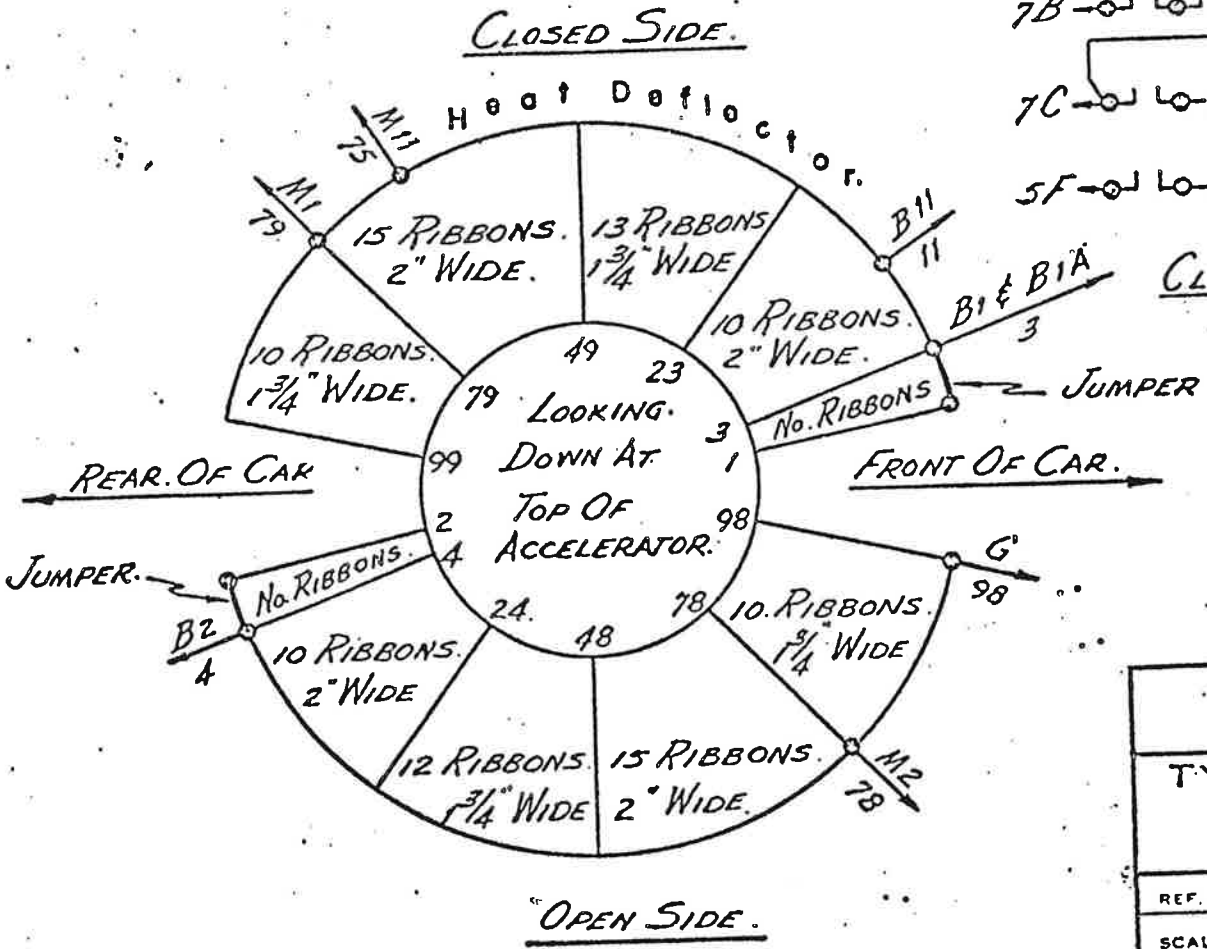
SCHEMATIC CONTROL CIRCUIT A13 - PCC 4700-4747 (PRINT D5772)

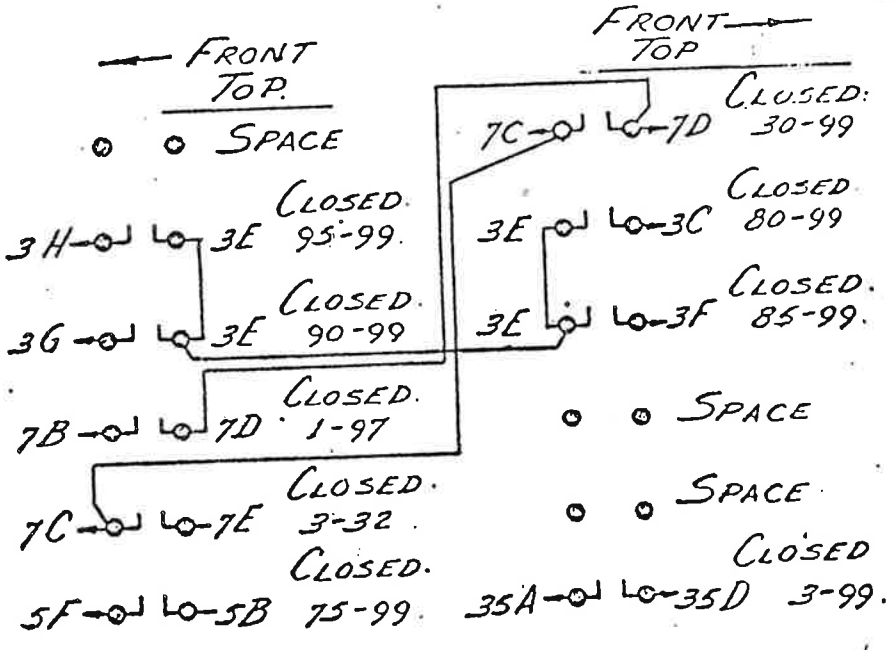
J.R. WORWOOD OCT. 1964

NOTE:

B1A & B11 SHUNT LOCKOUT COIL.
4725 - 4747.

SERIES LOCKOUT COIL
4700 - 4724.





TOLERANCE ± 0.005" UNLESS OTHERWISE SPECIFIED

TORONTO TRANSIT COMMISSION
EQUIPMENT DEPARTMENT

TYPE XD 423P ACCELERATOR.
RIBBON ARRANGEMENT
PCC. CARS. 4700-4747.

REF. ....

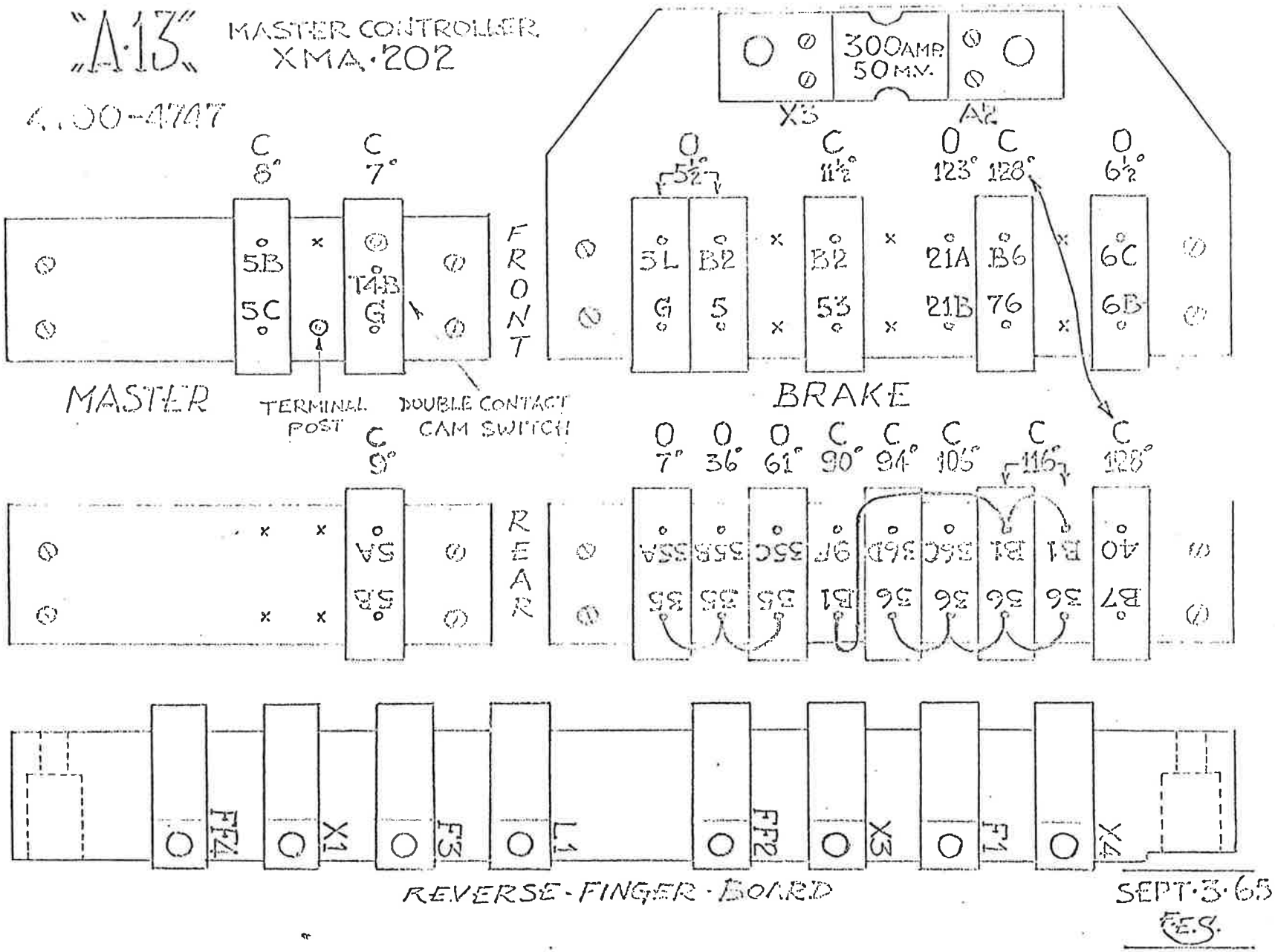
SCALE Do Not. DR. R.A. TR. R.A. CK. [illegible] DATE Nov 26/56

APPROVED BY Lew Sandels
SUPT. OF ELECTRICAL EQUIPMENT

DRAWING NO. E 6453

"A-13" MASTER CONTROLLER XMA-202

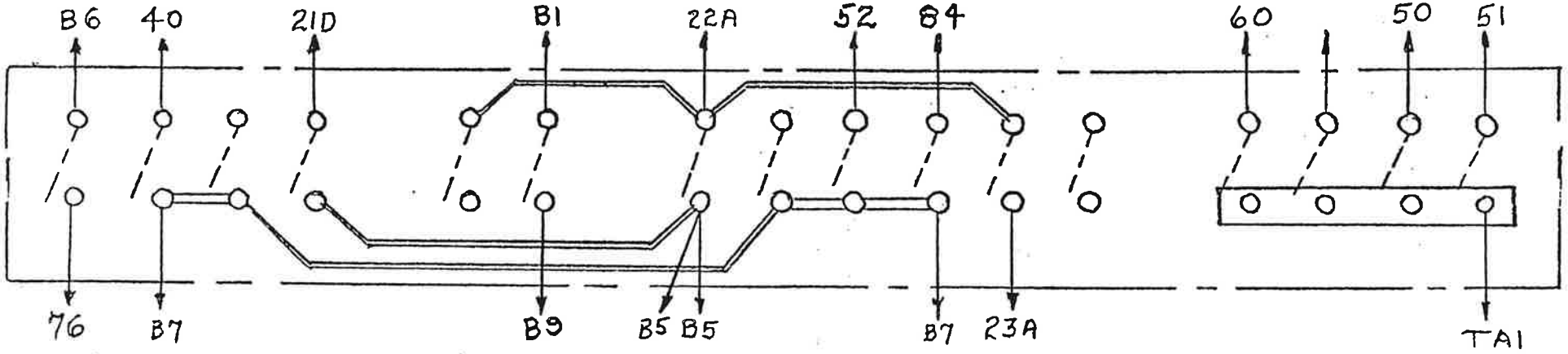
4.00-4747



SEPT·3·65·

E.E.S.

1	2	3	4	5	6	7	8	9	10	11	12	13	14		15	16	17	18
GONG (SPRING RETURN)	SANDER (SPRING RETURN)	SPARE (SPRING RETURN)	DOORS (TOGGLE)	SPACER	SPARE (SPRING RETURN)	M.G. SET (TOGGLE) ADD SHUNT	SPACER	EXIT CONTROL (TOGGLE)	SPARE (TOGGLE)	HEADLIGHT (TOGGLE)	DEFROSTER FAN (TOGGLE)	CENTRE ENT. (TOGGLE) REMOVE HALF OF HANDLE.	SPARE (SPRING) CUT OFF HANDLE	SPACER	CAB HEAT (TOGGLE) 600 VOLTS	CAB HEAT (TOGGLE) (UNDER FLOOR) 600 VOLTS	BODY LIGHTS (TOGGLE) 600 VOLTS	BODY LIGHTS (TOGGLE) 600 VOLTS



NOTE : CONTROL SW. AS VIEWED FROM BOTTOM.

→ CAR WIRING ○—○ CONTROL SW. WIRE JUMPER ═══ COPPER JUMPER

A13 - P.C.C. CARS - 4700 - 4747 CONTROL SWITCH A6603/1



260–6® VOLT–OHM–MILLIAMMETER

SPECIFICATIONS

RANGES

DC MILLIVOLTS

0 - 250 MV
Sensitivity: 20,000 ohms per volt

DC VOLTS

0 - 1 - 2.5 - 10 - 50 - 250 - 500 - 1000
Sensitivity: 20,000 ohms per volt

AC VOLTS

0 - 2.5 - 10 - 50 - 250 - 500 - 1000
Sensitivity: 5,000 ohms per volt

DC MICROAMPERES

0 - 50	250 MV Drop

DC MILLIAMPERES

0 - 1 - 10	250 MV Drop Approx.
0 - 100	280 MV Drop Approx.
0 - 500	400 MV Drop Approx.

DC AMPERES

0 - 10	250 MV Drop Approx.

OHMS

R X 1	0 - 2,000	12 ohms center
R X 100	0 - 200,000	1,200 ohms center
R X 10,000	0 - 20 megohms	120,000 ohms center

Range	Nominal Open Circuit Voltage	Nominal Short Circuit Current
R X 1	1.5	125 MA
R X 100	1.5	1.25 MA
R X 10,000	9.0	75 µAmps

OUTPUT VOLTS (AC)

0 - 2.5 - 10 - 50 - 250

DECIBELS

With zero DB power level equal to 1 milliwatt across a 600 ohm line

-20 to +10 DB
-8 to +22 DB
+6 to +36 DB
+20 to +50 DB

BATTERIES

One 1.5 volt, NEDA 13F battery and one 9 volt alkaline, NEDA 1604A battery.

FUSE

2 amperes, 600 volts. Type KTK
1 ampere, 250 volts. Type 3AG. quick acting

TEST LEADS

One red and one black test lead, each approximately 48 inches long. Two screw-on type alligator clips supplied.

SIZE

5 - 1/4" X 7" X 3 - 1/8"

WEIGHT

3 pounds

ACCURACY

Calibrated at $77^{o}F$, $\pm$ F $\pm$ $2^{o}F$.

		260/260-6P	270
DC VOLTAGE			
All ranges		2% F.S.*	1.25% F.S.
AC VOLTAGE (See Note)			
All ranges		3% F.S.	2% F.S.
DC CURRENT			
0 - 50 microamperes		1.5% F.S.	.75% F.S.
Other ranges		2% F.S.	1.25% F.S.
RESISTANCE RANGES			
R X 1	0 - 2000 Ω	2.5^{o} of arc	1.5^{o} of arc
R X 100	0 - 200,000 Ω	2^{o} of arc	1^{o} of arc
R X 10,000	0 - 20 megohms	2^{o} of arc	1^{o} of arc

FREQUENCY RESPONSE

Referenced to response at 100 Hz when making level measurements.

NOTE: Responds to the average value of an A.C. current and is calibrated to indicate the R.M.S. value of a pure sine wave.

* F.S. = Full Scale Accuracies specified are for the 260/270 in a horizontal position.

GENERAL DESCRIPTION

FRONT PANEL

The instrument has a large easy to read 4 1/4" indicating instrument at the top of the front panel. Below the indicating instrument are three operating controls and eight circuit jacks. All switch positions and circuit jacks are marked with white characters on black background to insure long lasting, easy readibility.

RANGE SWITCH

The range switch is located in the center of the lower part of the front panel and has 12 positions. It may be turned in either direction. There are five voltage positions, four direct current positions and three resistance positions.

FUNCTION SWITCH

The function switch is on the lower left of the front panel. It has three positions: - D.C., +D.C. and A.C.. To measure current, D.C. voltage or resistance, set the function switch at -D.C. or + D.C. according to the polarity of applied current or voltage. The function switch permits reversal of the test lead connections without removing the leads from the circuit under test.

ZERO OHMS

The control at the lower right on the panel is marked ZERO OHMS. It is a variable resistor in the ohmmeter circuit that compensates for variations in the voltage of the internal batteries.

CIRCUIT JACKS

There are eight jacks, two in each corner of the front panel. These are the connectors for the test leads. Plug the elbow prods of the test leads into the proper jacks to obtain the circuit and range desired for each application.

At the lower left are -COMMON and +jacks. Connect the black test lead to -COMMON for all circuits and ranges except 10 amperes D.C. Connect the red test lead to the +jack for all circuits and ranges except those designated by the other circuit jacks.

Across the top of the panel are jacks marked -10A, +1V, dual marking of +50 μ Amps and +250 MV at a single jack and +10A. For the 50 microampere or 250 millivolt D.C. range, connect the red test lead to this dual marked jack. For the 10 ampere D.C. range, use the black test lead in the -10A jack and the red test lead in the +10A jack.

At the lower right are OUTPUT and 1000V jacks. For all audio frequency output ranges, connect the red test lead to the OUTPUT jack. For 1000 volts A.C. or D.C., connect the red test lead to the 1000V jack.

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OPERATING INSTRUCTIONS

ADJUST POINTER FOR ZERO

With the volt-ohm-milliammeter in operating position, check that the pointer indicates zero at the left side of the scale when there is no input to the meter. If pointer is off zero, adjust the screw located in the case below center of the dial. Use a small screwdriver to turn the screw slowly clockwise or counterclockwise until the pointer is exactly over the zero mark at the left side of the scale. With the indicating pointer set on the zero mark, reverse the direction of rotation of the zero adjuster. Rotate the zero adjuster a sufficient amount of introduce mechanical freedom or "play" but insufficient to disturb the position of the indicating pointer. This procedure will eliminate disturbances to the zero setting from subsequent changes in temperature, humidity, vibration and other environmental conditions.

POLARITY CORRECTION

When making D.C. measurements with the test leads connected to the + and COMMON jacks, polarity can be reversed with the function switch without reversing the test leads. When making measurements on the 50μamps/250 MV range, 1 volt D.C. range or 10A range, polarity can be corrected only by reversing the test leads.

CAUTION

Before making measurements, turn off the power to the circuit being measured. Discharge any capacitors in the circuit undergoing measurement. Connect test leads to circuit being measured and turn on power. When measuring high voltage, never touch the 260/270, the test leads or test probes with the power supply turned on. After making the measurement, turn off power to the circuit being measured before disconnecting the test leads.

The alligator clips provided with the test lead set, screw onto the probe tips. When measuring high voltages, the use of the clips will permit measurement without handling the test probes. Be sure power to circuit being measured is shut off before connecting or disconnecting the clips.

The range switch or function switch positions should be changed only when the power to the circuit being measured is turned off or when the test leads are disconnected. This will eliminate arcing at the switch contacts and prolong the life of the 260/270.

NOTE: In all direct current measurement, be certain the power to the circuit being tested has been turned off before disconnecting test leads and restoring circuit continuity.

The internal voltage drop of the 260/270 on the 50 microampere range is 250 millivolts. The 50 microampere range serves as a dual function. Either 50 microamperes D.C. or 250 millivolts D.C. can be measured at this single jack position.

MEASURING DIRECT CURRENT

0-1 THROUGH 0-500 MILLIAMPERES

1. Set the function switch at +D.C..
2. Plug the black test lead in the - COMMON jack and the red test lead in the +jack.
3. Set the range switch at one of the four range positions marked 1MA, 10MA, 100MA or 500MA.
4. Open the circuit in which the current is being measured. Connect the VOM in series with the circuit. Connect the red test lead to the positive side and the black test lead to the negative side.
5. Read the current in milliamperes on the black D.C. scale. For the 1MA range, use the 0-10 figures and divide by 10. For the 10MA range, use the 0-10 figures directly. For the 100MA range, use the 0-10 figures and multiply by 10. For the 500MA range, use the 0-50 figures and multiply by 10.

MEASURING DIRECT CURRENT

0-10 AMPERES

1. Plug the black test lead in the -10A JACK and the red test lead in the +10A jack.
2. Set the range switch at 10 amps (dual position with 10MA).
3. Open the circuit in which the current is being measured. Connect the instrument in series with the circuit. Connect the red test lead at the positive side and the black test lead at the negative side.

NOTE: The function switch has no effect on polarity for the 10 AMPS range.

4. Read the current directly on the black D.C. scale. Use the 0-10 figures to read directly in amperes.

CAUTION

When using the 10 ampere range, never remove a test lead from its panel jack while current is flowing through the circuit. Otherwise, damage may occur to the banana plug and jack.

TRANSIT

The 500MA range switch position is also the transit position. The additional damping of the movement in the TRANSIT position will reduce pointer swing when the 260/270 is carried.

RESISTANCE MEASUREMENTS

ZERO OHMS ADJUSTMENT

When resistance is measured, VOM batteries B1 and B2 furnish power for the circuit. Since batteries are subject to variation in voltage and internal resistance, the instrument must be adjusted to zero prior to measuring a resistance, as follows:

1. Turn range switch to desired ohms range.
2. Plug the black test lead in the -COMMON jack and the red test lead in the + jack.
3. Connect ends of test leads to short the VOM resistance circuit.
4. Rotate the ZERO OHMS control until pointer indicates zero ohms. If pointer cannot be adjusted to zero, one or both of the batteries must be replaced. For battery replacement, see Section III, MAINTENANCE.
5. Disconnect ends of test leads and connect to component being measured.

MEASURING RESISTANCE

CAUTION

Before measuring resistance be sure power is off to the circuit being tested. Disconnect the component from the circuit before measuring its resistance.

1. Use R x 1 for resistance readings from 0 to 200 ohms.
2. Use R x 100 for resistance readings from 200 to 20,000 ohms.
3. Use R x 10,000 for resistance readings above 20,000 ohms.

Set the function switch at either -D.C. or +D.C. position. Operation is the same in either position. Adjust ZERO OHMS control for each resistance range.

4. Observe the reading on the OHMS scale at the top of the dial. Note that the OHMS scale reads from right to left for increasing values of resistance.
5. To determine the actual resistance value, multiply the reading by the factor at the switch position. (K on the OHMS scale equals one thousand).

If there is a "forward" and "backward" resistance such as in diodes, the resistance should be relatively low in one direction (for forward polarity) and higher in the opposite direction. Rotate the function switch between the two D.C. positions to reverse polarity. This will determine if there is a difference between the resistance in the two directions.

The resistance of such diodes will measure differently from one resistance range to another on the same VOM with the function switch in a given position. For example, a diode which measures 80 ohms on the R x 1 range may measure 300 ohms on the R x 100 range. The difference in values is a result of the diode characteristics and does not indicate any fault in the VOM .