this mid-rib enables one to change these connections to the whole series of boxes for motion in one or the reverse direction; but such reversal cannot be accomplished except by opening the switch-trough and pulling this bar. Fig. 114 shows this mid-rib and one box in position.

The contacts are made by carbon blocks mounted upon a lever in such a way that, in coming together, the one face slides a short distance over the other, the object being to keep the surfaces clean by abrasion.

These two systems have different inherent faults, the Vedovelli in that it will not reverse, and the Claret-Vuilleumier in that the

Fig. 113.

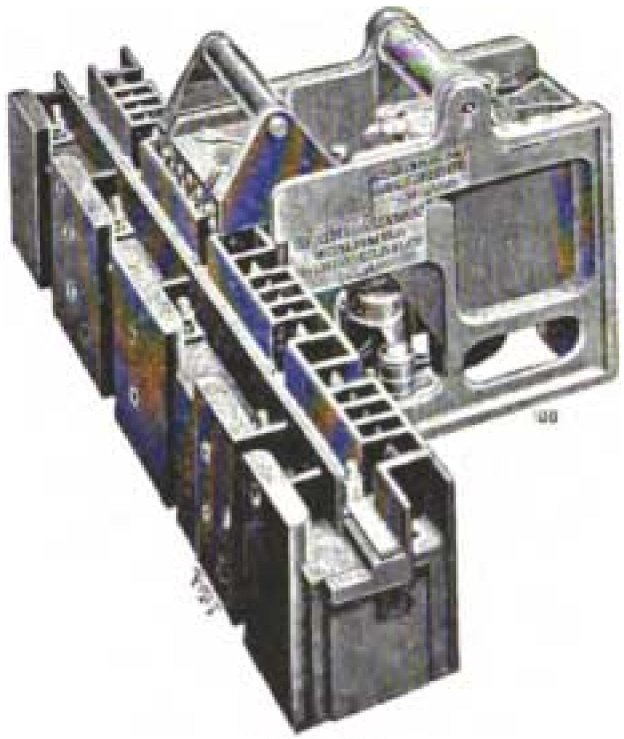

Fig. 114.

whole group of switches is served by one moving arm, so that one car only can be served at a time, and so that, if the car and the one arm get out of touch, there is no means of bringing them together again without great loss of time.

26. Both these defects are avoided in what is known as the Schuckert system, invented and patented by Mr. Paul. They are avoided at the expense of greater complication and greater cost, but in the result the working appears to be economical and very safe. It has been subjected to very prolonged experimental test in Munich, but has not yet found the opportunity for the commercial success which, in the writer's opinion, its technical merits deserve.

The trial line, as first laid down in Munich in 1896, gave trouble. Some of the switches stuck, and, during a thaw following a snow-storm, a stud, which was left charged owing to such sticking, led to the killing of a horse. This accident induced the authorities to prohibit further trials in their streets until the whole system had been rearranged, with the introduction of new safeguards.

Before this the electro-magnets which operated the switches were excited by the main working current; they are now operated by a shunt off the main current. The difference is obvious, and extremely important. The main working current taken into a tram-car is very variable. It is not only quite different during the starting period to what it is during uniform running, but it also changes as the load, the gradient, and the weather changes. During a portion at least of the braking it further becomes zero, as also when the car stands still. But the current, through a shunt of definite resistance, remains constant so long as the P.D. between the terminals of the shunt is unchanged. Switches operated by the main current taken into a car are thus of necessity subject to uncertain and unreliable action. Certainty and uniformity of action in the whole line of switches is of the essence of success; and a much greater chance of attaining it is afforded by the use of shunt currents, the shunt P.D. being from the full voltage of the main supply to earth.

From April 1 to November 27, 1899, daily trials were made in the Goethestrasse on the improved system, and, these proving satisfactory, on December 1, 1899, regular all-day running over the 2000-feet stretch was begun. Since then it has worked daily without accident. In outward appearance the change of system has been recognizable only by experts, firstly, because only a small proportion of the cars running over the trial length have been built for the new system, the others taking current by overhead line, which line, therefore, still runs over the 2000-feet stretch of contact studs; and, secondly, because the new cars themselves are fitted with trolley and pole, since they run long distances in either direction beyond the trial length.

Other minor improvements have been introduced since 1900, and it is sufficient to describe here the perfected form which the design now takes. Fig. 115 shows the scheme of the electrical arrangements.

In this diagram G is the generator at the central station; PP is the insulated supply main; e, e, e are the running rails—that is, the earthed return. If P and e be also taken as symbols for the potentials in the supply main and in the earth respectively, then $(P - e)$ is the available potential difference for driving the cars. S, S are the series of contact studs, from which working current is picked up by the collecting skate C; s, s, s are the switch terminals directly connected to S, S by copper leads.

27. Each of these leads requires such section as enables it to carry half the maximum current ever taken by a single car. In the diagram the switches are spaced uniformly along the line, they having the same spacing as the contact studs S. In reality, however, they are grouped, from twenty-five to thirty being brought together in one switch-box, placed at the side of the road away from the rail-track and the traffic. The spacing of the studs being about 10 feet, each switch-box serves a length of, say, 300 feet of tramway. The box is placed, of course, in the centre of the length it serves. Thus the length of copper lead from switch to stud varies from, say, 5 feet to 145 feet, not counting the transverse lengths due to the switch-box being placed at the side of the road and not between the rails on the line of the studs. The average length of these leads is thus 75 feet, and the total length of thirty of them is 2250 feet. Each, however,

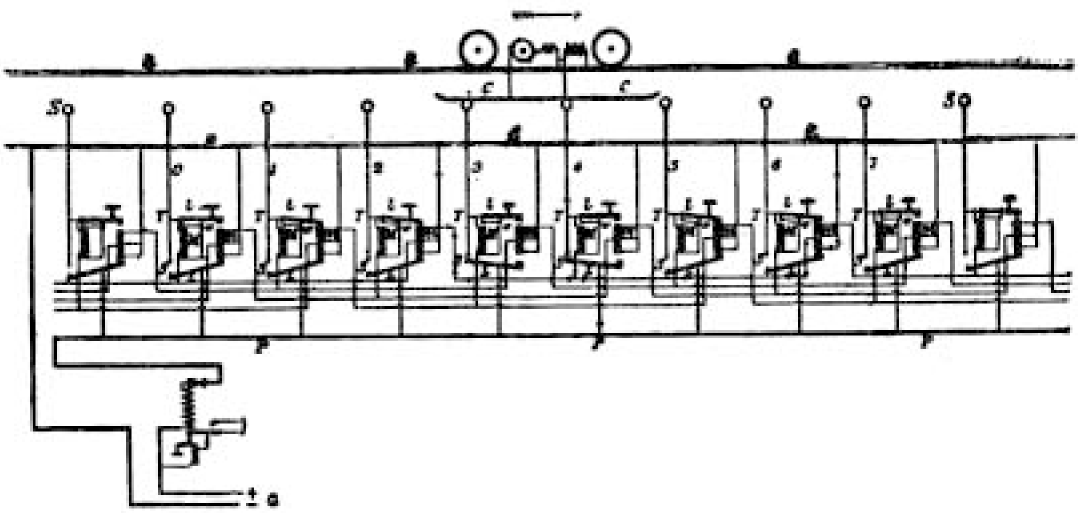

FIG. 115.—Diagram of Schuckert Contact Tramway System.

carries only half the current needed per car, so that the copper thus spent is equivalent to 1125 feet of the section needed for the whole current taken per car. This length 1125 feet = 300 feet × $\frac{30}{8}$; that is, the extra length of leads introduced by the system of grouping the switches equals the whole length of track multiplied by one-eighth of the number of studs served from each switch-box. As previously explained, however, the current density in these leads may be legitimately much higher than in the main supply cables, because the current passing through them lasts only a minute time during the passage of the car over the stud which is the terminal of each lead. Thus the leads are exposed to practically no heating, while the ohmic loss of power in them should be compared with the capital cost of the whole group of leads, and not with that of one lead only, in order to calculate the economical section.

The balancing advantage obtained from this system of grouping to set off against the extra expenditure in copper leads is the reduction of the number of switch-boxes to keep under supervision and repair. The time and cost of examining a switch-box to see if it be all right is practically the same whether the box contain one, three, or thirty switches. The number of switches getting out of order and needing repair per year, and the cost of such repairs, will be the same whether these be placed in 100 or in 3000 boxes along the line. Rather it will be less on the grouping system, because the one box containing thirty switches will certainly be of much better construction and be better set than would thirty boxes. Practically the thirty boxes can get no periodical inspection; they are almost necessarily placed so that they cannot be inspected except when such inspection becomes a necessity, that is, when it is found that one of them has got out of order. The inspection then taking place not only stops the traffic; it consists in a tedious search from box to box to find the switch that causes trouble. When thirty are grouped in one box so that the whole are exposed at once to view upon the unlocking of a single hinged door, the locus of the trouble is instantly detected, since it must be always apparent within which stretch of 300 feet of tramway the switch-sticking occurs; only rarely can there be doubt in locating it as between one switch-box and its next neighbour.

These advantages of grouping the switches increase with the number grouped together up to a certain limit, and at a less rate as this number becomes greater; that is, the extra advantage of grouping twenty instead of ten is greater than that derived from grouping thirty instead of twenty, while that from grouping forty instead of thirty is very much less. The extra copper expense of the branches increases in simple proportion to the number grouped together. Thus there is established a limit to the economy gained by increasing the number brought together in one group. The experience with the system is not yet sufficiently extended to supply data for determining this most economic limit.

It is to be noted that this extra expense in branch-leads depends on the spacing of the contact studs. Thus, if the length of line operated from one switch-box be 300 feet, and if the spacing be 10 feet, there must be thirty branches grouped together, and the factor explained above will be $\frac{30}{8} = 3\frac{3}{4}$. If, however, the spacing be 15 feet, only twenty will be grouped in one box, and this factor will be diminished to $\frac{20}{8} = 2\frac{1}{2}$. The possible spacing depends mainly on the length of the car, but it also depends a good deal upon the construction of the collecting skate hung underneath the car. Lower down are mentioned the improved skate constructions used by the Schuckert Company.

With a given length of collecting skate, the spacing required for the system now used by Schuckert, in which the skate always touches two, and intermittently three, studs, is just half that permissible with the system they used at an earlier date, in which the skate was always in touch with one, and intermittently with two, skates. But as in the new system the current carried by each lead is only half that carried by each on the previously followed plan, the change has made no alteration in the total necessary copper expenditure on the branch leads connecting switches with surface studs. It, however, doubles the number of studs built into the track, and also doubles the number of switches.

28. Returning now to Fig. 115, the design of the connections and the mode of action of the switches may be explained. Each switch is worked by two electromagnets, M which makes contact to the surface-stud, and *m* which breaks this contact. The reference letters are seen on the larger scale diagram, Fig. 116, of one of the switches. There are two moving parts, diagrammatically represented by the two levers L and *l*. L is pivoted at its centre, while *l* is hinged at its left-hand end. Each forms a soft-iron armature, the opposite ends of L being alternately attracted by the magnets M and *m*; while the right-hand end of *l* is intermittently attracted by *m*, and, when current ceases to flow through *m*, is drawn back to normal position by a spring. L has permanent electric connection with the supply main P. The lever *l* is connected to the surface-stud S at T, this connection being also permanent.

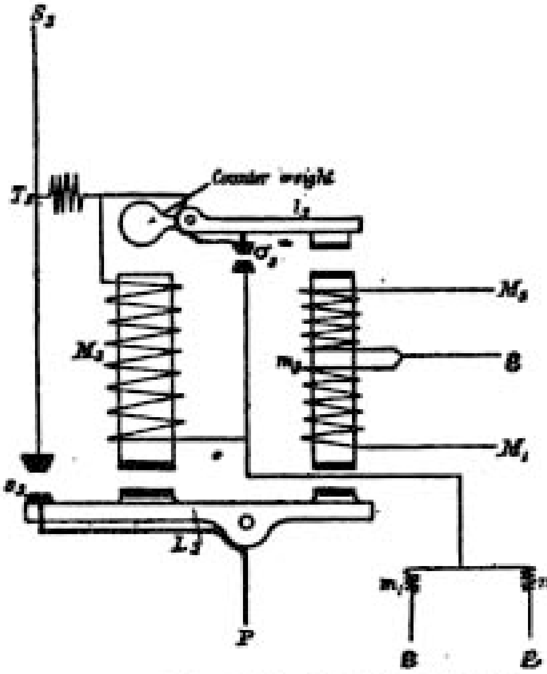

FIG. 116.—Detail of Switch.

M is magnetized by a solenoid current, which is a shunt from the terminal T between *s* and S to the earth *e*. Such current flows only when the connected surface-stud S is charged to the high potential. This charging of S takes place either through the closure of the lever L upon the switch contact *s*, or else through the collecting skate C and the other stud in contact with the skate.

The current magnetizing M may, however, be short-circuited through σ, the auxiliary switch contact closed by the depression of the lever l. When this short circuit is established, M is demagnetized, or remains so feebly magnetized that a magnetic pull from m on the other end of L easily draws L away from M and breaks contact at s.

Beyond this short circuit the shunt current proceeds to earth, not directly, but through two branches, one of which runs backwards to the switch second behind, and the other forwards to the switch second in front of, the switch from which the shunt current flows. At these two switches, four steps apart in the series, the two halves of the shunt current run through the solenoids magnetizing the magnets m. Thus, the shunt current which magnetizes the main magnet M_3, after leaving this magnet, splits and magnetizes the two auxiliary magnets m_1 and m_5; while that passing round M_4 also magnetizes the magnets m_2 and m_6. From these auxiliary magnets the two branches of the shunt run straight to earth. Although the studs 1 and 5 are $4 \times 10 = 40$ feet apart, the fine, well-covered wires making these connections stretch only a few inches in the switch-box, so that the copper expense of making these connections is immaterial. Thus each auxiliary magnet m is wound with two coils, one in series with a main switch magnet two stud-spacings behind it, and the other in series with a main switch magnet two spacings in front of it. The magnet m is excited by current through either of these coils. It never receives excitation from both at the same time. Since its function is to attract either of two simple soft-iron armatures, it is not material that either excitation should give it a prescribed polarity; but if the two coils give it alternately opposite polarities, this will prevent all risk of its acquiring residual magnetism.

29. It is to be noted that all these connections are entirely symmetrical forwards and backwards. It results from this symmetry that the automatic action is continuously equally ready for either direction of car movement, and this without setting over any reversing lever. The only reversal needed is that of the motor.

30. At the instant, represented in the diagram, the skate C is in contact with the two studs S_3 and S_4, and the car-motors are taking current through both of these and the switch contacts s_3, s_4, which are closed, the magnets M_3, M_4 being both excited, and the magnets m_3, m_4 both idle, so that the levers l_3, l_4 are raised by their springs or weights, and the short circuits σ_3, σ_4 both opened. The shunt from T_3 through M_3 magnetizes the auxiliary magnets m_1 and m_5, holding the levers L_1 and L_5 securely in the positions which keep s_1 and s_5 open, while the levers l_1 and l_5 are held down, so that contacts are made for the short circuits σ_1 and σ_5. No current, however, flows through these short circuits, the terminals T_1, T_5 being neither of them connected to high potential.

The shunt from T_4 through M_4 acts in precisely the same way upon the apparatus at 2 and 6, which are at this instant in precisely the same condition as those at 1 and 5. All four, the pair 1 and 2 behind the car and the pair 5 and 6 in front of it, are now in the same condition.

When the car has advanced so that C touches S_5, there is still contact between the C and S_3, the skate being made a little longer than two stud spacings. On touching S_5 this stud is raised to high potential through the skate, and therefore from T_5 there flows a current through σ_5 to the auxiliary magnets m_3 and m_7 and thence to earth. M_5 is, however, for the moment still unaffected, the shunt current 5 being almost wholly passed through the short circuit. The magnet m_7 being now excited, the lever l_7 is drawn down and the short-circuiting contact σ_7 is made, thus preparing the switch apparatus 7 and bringing it into the same state of readiness as that to which 6 has already been brought.

At the same time, the magnet m_3 being now excited, this draws down the lever l_3 and closes the short circuit σ_3. This deprives the magnet M_3 of current, which thus gives up its grip of lever L_3 and allows m_3 to pull over L_3 and break the main contact s_3. At the instant of this break current ceases to flow from S_3 to the skate C. But there is no spark at S_3 in the switch-box, because both carbons are kept at the same 500-volt potential by the continued contact of the skate with stud 3, the skate being charged from stud 4. It is important that the skate should not leave stud 3 before the switch contact S_3 is opened. The potential gradient is now reversed, and for the next small fraction of a second current flows from C through S_3 to T_3. From T_3 it flows in the same direction, and of the same magnitude, as before through σ_3 and thence to m_1 and m_5, the levers l_1 and l_5 being still held magnetically. This ceases, however, as soon as the skate end leaves the stud S_3. As it does so, the above reverse current, which is small because it passes through considerable resistances, is broken, the break occurring at the surface stud.

As soon as the surface break takes place the magnets m_1 and m_5 are demagnetized, and the levers l_1 and l_5 are raised. This throws switch 1 into wholly neutral condition. It at the same time breaks the short circuit σ_5 and throws the whole down current from S_5 to T_5 through the main magnet M_5, which, becoming now excited, pulls over the main lever L_5, since the magnet m_5 no longer holds this back. Thus the main contact s_5 is closed, and current now flows from the supply main P up to S_5, and thence through the skate to the car-motors. The current through C S_5 to T_5 which is at this instant reversed, is a small one, because of the fine wire resistances inserted in the shunt circuit. Contact is made at the surface stud before any main current runs through it. The main current contact is made in the switch-box, but the two carbons are already at the same high potential before the contact is made.

The six switches 2 to 7 are now in every respect in the same condition as were the six from 1 to 6 at the beginning of the period considered above. By repetitions of the process described, this condition advances automatically with the progress of the car along the line. The progression may be in either direction along the line without any alteration of the switch apparatus. Each switch apparatus has inserted in it a resistance which makes the shunt current operating it ½ ampère under 500 volts; that is, the power needed to work each active switch is ¼ kilowatt, and as two are taking current at each instant, the power thus spent per car is ½ kilowatt.

A minor criticism upon the system may be here stated. The above explanation of the action makes it clear that the supply of current to the motors through stud S_3 has ceased a measurable interval of time before the supply through S_5 begins. Throughout this small interval the whole working current passes through S_4. The criticism

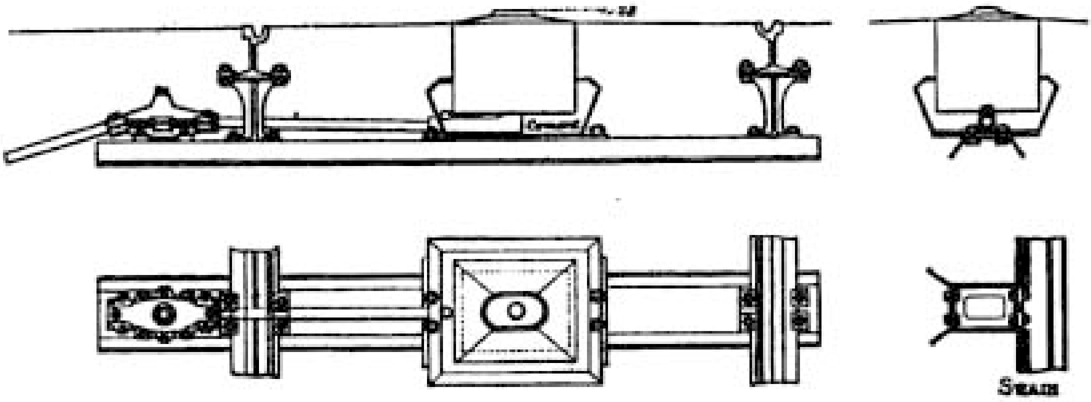

FIG. 117.—Surface-contact Stud.

is a small and non-damaging one. The overloading of a wire with current refers to the risk of over-heating. The heating takes time—it is a matter, not of ampères, but of watt-seconds—and if the overload lasts only for a fraction of a second, it requires an enormous overload to create risk of damage.

31. Certain safety appliances embodied in the Munich design will be mentioned lower down.

Fig. 117 shows in transverse and end sectional elevations, and in plan, one of the surface-contact studs with its setting. The stud is of hardened cast steel. It is let into a granite block, measuring 10 inches by 13½ inches wide and 10½ inches deep. This block rests on a cement bed in a sheet-iron box trough. This is bolted to a transverse steel sleeper which is hung by I-section distance pieces of the proper depth from the longitudinal rails. On the end of the sleeper is bolted a coupling muff, from which the lead is taken to the centre and up to the stud through a vertical hole bored in the centre of the stone. The block, sleeper, muff, and connections are all finished and finally fixed together in the workshops, the only work done *in situ* being to clamp the whole to the underside of the two rails. The binding to the rails is very solid, and keeps the stud rigidly in its true central position and at its true relative level, which is about $1\frac{1}{8}$ inch above rail surface. Fig. 118 shows one of the switches partially dismounted, and Fig. 119 shows it in completed form. The magnets M and *m* are both horseshoes, and are mounted on the wall-plate so that the pair of poles of each magnet lie at diagonally opposite corners of a square. The cores stand horizontally, and the armature lever L, which is shown detached in Fig. 118, is pivoted on a horizontal pin at the centre of the square. Its pole-pieces are attracted alternately to one and the other pair of diagonally placed cores. These cores project beyond the solenoids, and the lever lies between them, oscillating between them by a throw-over through quite a small angle. The main contact is made by a couple of carbon blocks, one fixed in an upward horn extension of the lever, the other fixed in a bracket from the wall-plate. The auxiliary lever *l* is acted on by one pole only of the magnet *m*. It lies horizontally under the square of four poles, and is drawn out of contact by its own weight instead of by a spring, as represented in the diagram Fig. 115.

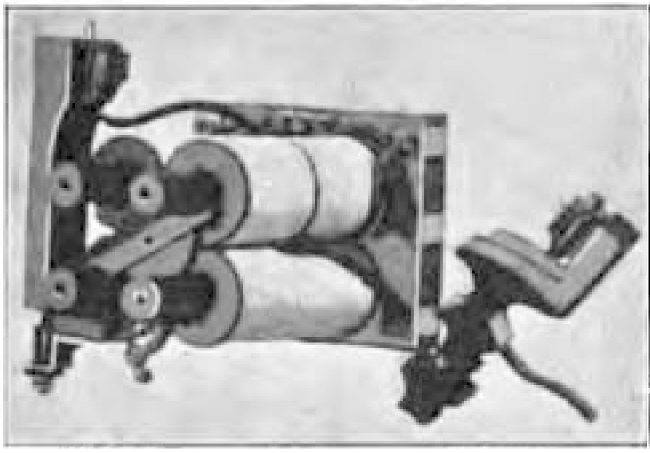

FIG. 118.—Part of Switch.

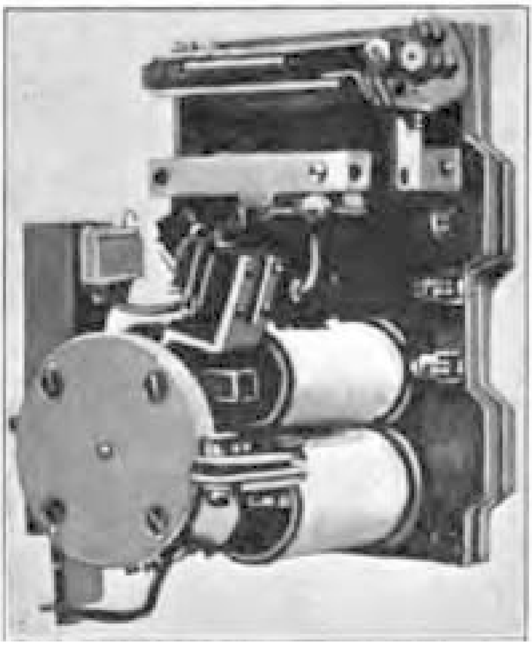

FIG. 119.—Complete Switch.

Test apparatus rigged up in the Schuckert works at Nürmberg kept a series of the switches constantly making and breaking contact under full current for many months. After between 50,000 and

60,000 makes and breaks, the carbons and all the apparatus were reported to be still in very good condition.

The wall-plate of each switch is pushed into and held by a spring clamp on the wooden inside lining of the cast-iron switch-box, which

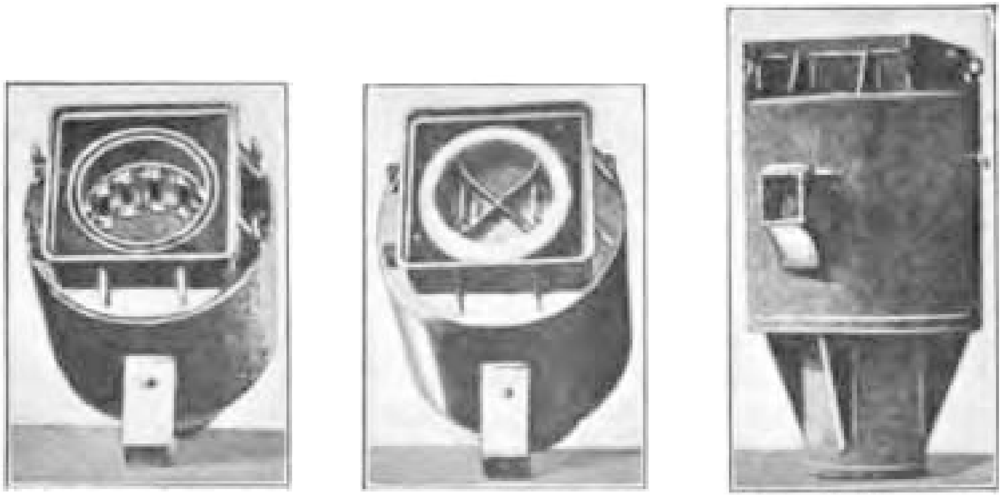

FIG. 120.—Switch-box.

is shown in Fig. 120. This box, holding thirty switches in three tiers, is of considerable size, especially as a hollow space is left between its outside walls and its wooden lining. It is large enough for a man to stand in it. It has a double-top cover, designed to make the

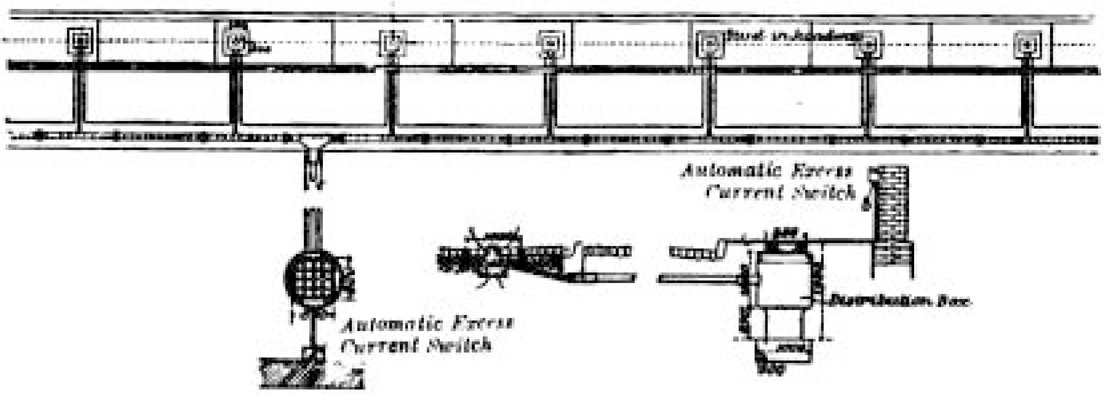

FIG. 121.—Distribution Box and Studs.

interior absolutely water and damp proof. Fig. 121 shows in plan and section the disposition of this box with regard to the tram-line and the leads to the surface-studs. The box in this case is sunk below the level of the foot pavement. Another form of box, allowing it to stand above ground and giving access by a hinged side door, would, in permissible situations, have superior advantages.

32. It will be noticed that it is unnecessary that the car-motor should take any current in order to keep the switch apparatus working. This results from its being operated by a shunt taken to earth from a point outside the car. Thus the car may stand still or may run down hill or against the brakes without current, and it will still find the surface-studs automatically prepared to supply current to the motors. The use of a shunt also makes the correct working of the switches independent of leakage from the electrified studs to the rails, or even of any absolute short circuit between these.

When the car, however, is run from a place where the studs and switches have not been established—as, for instance, from an overhead line on to a contact-stud line, as in Munich, or after a cessation, from any cause, of supply to the main—the contact studs under the car must be energized from an external source. For this purpose the car carries a small accumulator battery, which, when it is connected to the skate, sends current through the two studs in contact to the magnets M, and thence to earth by the four magnet coils *m*. The magnets M pull over the two levers L, and communication with the main is thus established. The battery requires very small capacity, and in order to obtain the voltage needed in small bulk, the battery is made up for 20 volts, and this is transformed to 400 or 500 volts by a small rotary transformer mounted on the car and driven by the battery itself.

33. At Munich two new forms of collecting skate have been used. One consists of a chain having long, flat links and close joints. The other is a wire-brush collector of the proper width, and about 24 feet long. Both, and more particularly the latter, are reported to have given good results. Further improvements in this part of the construction of surface-contact trams are by no means improbable.

34. At the two ends of the car beyond the ends of the collector are fixed two "short-circuiting" brushes which sweep the studs as they pass. When either of these brushes touches a stud it establishes direct conducting connection between the stud and the rails, so that, if through failure of a switch a stud remains electrified after the collector has left it, a short circuit from supply main to rails is established. This short circuit is made to operate an automatic safety cut-out switch which cuts out the whole section. One of these cuts-out is attached to the section commanded by each distribution box. It becomes locked on coming into action, so that the section cannot be connected again until the whole of the distribution switches on the section have been opened. It is placed in a wall box, above ground, opposite the distribution box, as seen in Fig. 121, and can be opened only by a special key.

Independently of these safety brushes, the same magnetic cut-out is brought into operation if three successive switch main contacts (s) are at any time simultaneously closed. It has been explained that, in normal working, s_3 is opened before s_5 is closed. If, through imperfect action, s_3 remains closed when s_5 is also closed, the whole section is disconnected from the supply main. If, on the other hand, the imperfect working, while leaving s_3 closed, also fails to close s_5, the successive working of the series of switches is interrupted, and the car ceases to receive current and comes to a stop, unless it be on a down grade sufficient for running by gravity alone.

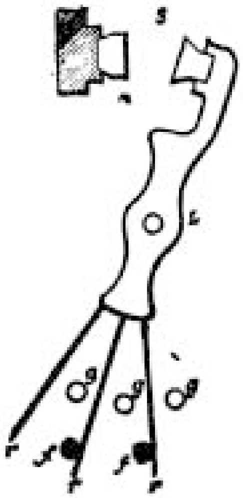

FIG. 122.

The automatic cut-out is double-wound, a current through either winding bringing it into operation. The one comes through the action of the short-circuiting brushes; the other through that of the last described safety appliance.

With these safety appliances the system is reported after two years' regular working at Munich, in a street that is said to be particularly muddy and badly paved, to be immune from danger through studs being left charged behind the car.

The *modus operandi* of these appliances may be simply explained by help of Figs. 122, 123, and 124. In Fig. 122 is sketched separately the main lever L, which closes and opens the main switch contact s. The spindle of this lever carries three small spring arms, r, r, r, in metallic contact with each other through their fixture on the spindle.

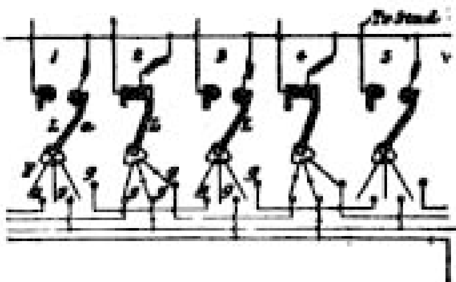

FIG. 124.

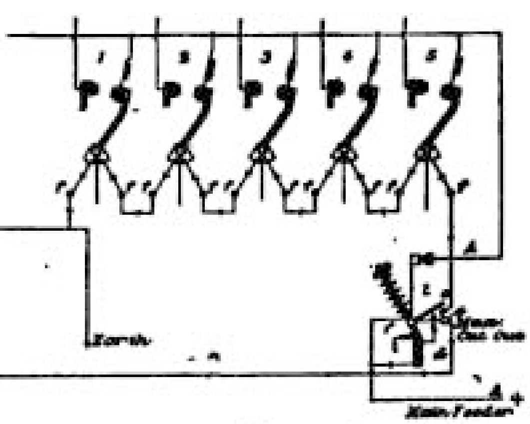

FIG. 123.

When contact s is open two of these arms press against two metallic pins, f, f. As shown in Fig. 123, the pairs of pins f belonging to the whole series of switches in one distribution box are joined up so that when all these switches are open and all their arms, r, pressing against the pins f, a continuous circuit for a feeble current is formed from end to end of the series. When contact *s* is closed the three small spring arms *r* press against three other metallic pins, *g*, *g*, *g* (see Fig. 122). The front pin *g* of the set on switch 1 is wired to the back pin of the set on switch 3, the front pin of 2 to the back pin of 4, and so on—as shown in Fig. 124. The middle pins of the switches 1, 2, 5, 6, 9, 10 are wired to earth; while the middle pins of switches 3, 4, 7, 8, 11, 12 are wired to the positive or out-lead of a shunt circuit leading through the safety cut-out switch. This connection is clearly shown in Fig. 124, the successive switches being taken in alternate pairs in this connection to the positive wire and to earth.

It will be remembered that the main contact *s* in switch 1 ought to be opened just before that of switch 3 is closed. If it remains closed after 3 closes, the automatic action is disturbed, and, in order to prevent the danger of leaving a charged surface-stud behind the passing car, there is need to call into action the safety switch. In Fig. 124 the arrangement just explained is shown to effect this result, the two switches 2 and 4 being drawn as simultaneously closed, and the effect being that shunt current passes from the positive lead through the middle and back spring arms of 4, and through the front and middle spring arms of 2, to earth. The shunt current, thus permitted to flow to earth, actuates the magnetic cut-out and stops the supply of main current to the whole section controlled from this one distribution box. It will be noted that this action will be unaffected by switch 3 being either closed or open, and that the simultaneous closure of any two following switches, such as 3 and 4, does not call it into play. The ingenuity and simplicity of the device are admirable.

When the cut-out has acted, the car-motors cannot obtain current again until the conductor has proceeded to the safety switch-box and closed the switch. For this purpose he carries a key enabling him to open the box, but this does not give him access to a hook-pawl which holds the switch open until the hook is released by a small electro-magnet energized by shunt current passing by the circuit shown in Fig. 123 and already explained. Any break in this circuit prevents him reclosing the safety switch. Such a break occurs until *all* the switches in the distribution box have been thrown over to the open position, as in Fig. 123. By this means it is made impossible to restart the car without ensuring that all the surface-studs upon the section are reduced to earth potential. After this is done and the safety switch reclosed, the employment of the accumulator battery carried on the car permits the motor to be restarted.

35. Figs. 125 and 126 are reproductions of autographic records taken in the Goethestrasse, of Munich, of the current supplied to a car worked by this system. Fig. 127 gives a similar record of current

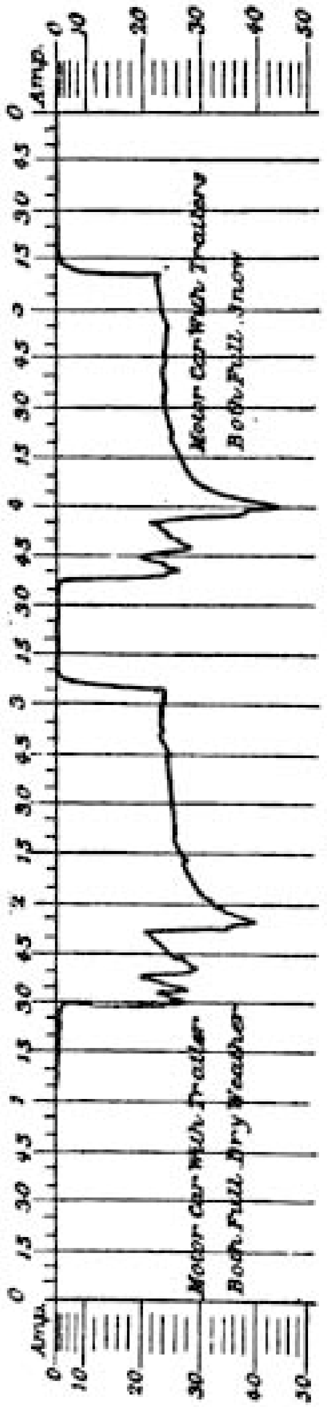

FIG. 125.—Surface-contact System.

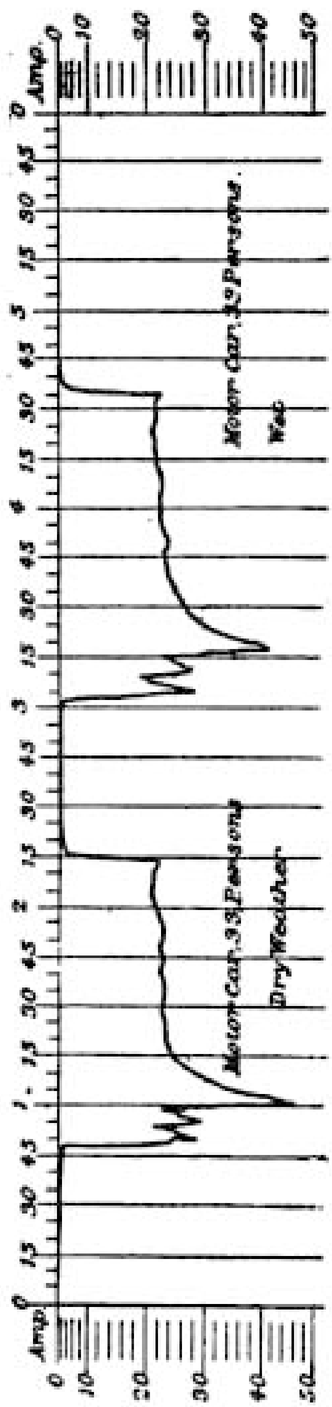

FIG. 126.—Surface-contact System.

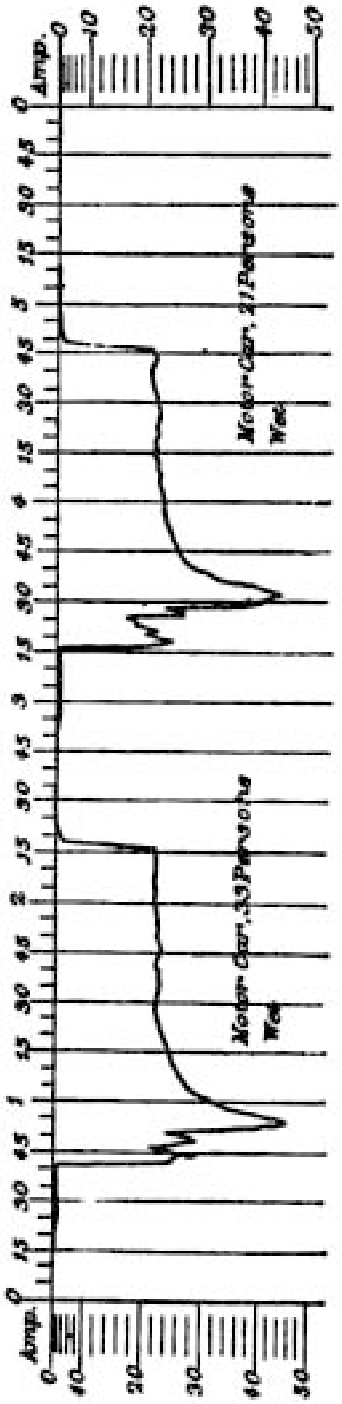

FIG. 127.—Overhead System.

taken by an identical car from the overhead line on the same stretch of street. It will be noted that the passenger loading in Figs. 125 and 126 is heavier than in Fig. 127. Fig. 125 refers to a motor-car and trailer-car together; Figs. 126 and 127 to a motor-car alone. The first two records show that the current consumption is not measurably affected by wet and snowy weather. The addition of the trailer also seems to make little difference in the current, and comparison with Fig. 127 shows the current consumption to be precisely the same whether taken from the overhead wire or from the surface-studs. It should be explained that the current recorded was not taken on the car itself, and includes all leakage in each case.

With thirty-three passengers the maximum current taken during starting and acceleration is 45 ampères. After steadying, it sinks to 23 ampères. In all the six records given the current follows almost precisely the same variations.

Respecting the applicability of the system in more northern countries, doubts have been expressed regarding its suitability for our English climate, on account of the damp of our fogs, mists, etc. Messrs. Schuckert answered this adverse criticism by placing a battery of the switches in a tank of water at the Glasgow Exhibition of 1901, where it was seen daily working regularly and well, fully and permanently immersed in water. Of course a small leakage occurred through the water, but it did not in any way affect the certain action of the mechanism. It must be remembered, also, that these switches are, in practice, ranged in a box that is made quite water-tight and even air-tight.

36. One further remark is needed to do justice to the system. The above description of the automatic progression of the switch action might possibly make it appear that the mechanism of this action is complicated, and therefore liable to derangement. The apparent complication lies, however, mostly in the difficulty in mentally following the action, and the tedious explanation of this action needed to make it clear. The actual mechanism itself is really simple; it has only two moving parts mounted in the most ordinary manner. It should also be remembered that, the switches being grouped in one box, the wire connections between them are all quite short and can all be overlooked as a whole at a single glance.

In conclusion, it may be interesting to give one word of explanation as regards the comparison between the phenomena occurring when the whole of the working current is broken at a switch, and that occurring when, as in the Schuckert system now explained, only half of it is cut off at one switch, to be immediately diverted through another channel, namely, through the switch second in front of that opened. The cause that makes the spark produced by breaking a circuit so much larger than that occurring on closing the same is the self-induction of the circuit. Now, in the diversion of one-half the current from one branch lead to another, the self-induction involved is only that in the small part of the total circuit made up of the two branches in question, or, otherwise expressed, the self-induction only of the sub-circuit, or loop, formed by the joining up of the two branches. The spark caused by this diversion is thus very small as compared with that caused when the current is cut off altogether from the motor.

The usual statement of this explanation is that no spark occurs when the same potential is maintained at the two contact surfaces after they have separated as before the break. This may be taken as a shorthand mode of expression; it is not entirely complete or accurate, but is sufficiently so as to prevent its being misleading. There is no doubt that a spark is a current, and that no current flows except along a down-grade of potential. A spark is a momentary current driven across a high-resistance gap by a large difference of potential. If it were exactly true that the two surfaces of the switch maintained during the instant after separation their previous equal potentials, then no spark would occur. But the self-induction in the loop above referred to, excited by the change in the distribution of current round it, and lasting only while this change is taking place, does produce a momentary difference of potential between the separating switch surfaces; and a spark of length proportional to this self-induction, and therefore proportional to the current itself, must occur. Actual observation, however, shows that the spark so caused in the apparatus now under consideration is so small as to be invisible and entirely harmless.

37. Two systems involving double rows of track-studs have been designed by the Westinghouse Co., and by Stobrawa, of the Helios Co. As these are not much in use, they need no more than mention here. Neither need any description of the Lorain system, which has been installed in Wolverhampton, be given. It is said to have given much trouble in the streets through the number of studs left alive behind the cars.