DISCUSSION ON "LINE CONSTRUCTION FOR HIGH-PRESSURE ELECTRIC RAILROADS," AND "HIGH-PRESSURE LINE CONSTRUCTION FOR ALTERNATING-CURRENT RAILWAYS."

PRESIDENT LIEB: I am sure it is gratifying to all interested in this class of work to learn from Mr. Varney's paper the character of the electrical engineering construction that is being done in connection with heavy traction on steam railroads, and that it is comparable with the civil and mechanical engineering construction of railroads, as represented in track and bridge construction. It would be most unfortunate for the development of electric traction on our great steam railroad systems if the character of construction followed in the pioneer days of electric traction at comparatively low voltages were continued in pioneer high-pressure traction work. It is apparent from the details laid before us that in attempting to solve the problems of important trunk-line traction, electrical engineers are alive to the necessity of avoiding anything that savors of flimsy or cheap construction, and are seeking to devise equipments based upon such sound engineering principles as will ensure safety in operation and permanence under the strain incident to heavy work.

The papers of Mr. Varney and Mr. Damon are now open for discussion, and I think they can be profitably discussed together. The suggestion in connection with protection by guard-wires, referred to in Mr. Damon's paper, is a reminder of the danger that sometimes follows an attempt to add a safeguard to a system, whereby an element of danger may be introduced even greater than the trouble which it is desired to guard against. In one of the earlier installations of the synchronous converter system, it was important to prevent the high-pressure current from getting over to the low-pressure system through contact between the primary and secondary windings of transformers. To that end, some of the earlier transformers were equipped with ground-shields between primary and secondary windings. In the first two years all the troubles encountered with the system as a whole were due to the presence of the ground-shields; they were an element of danger rather than of protection, as in the case cited by Mr. Damon.

F. N. WATERMAN: The papers of the evening have very fully covered the limited field of actual experience in this kind of engineering work. But some observations in the way of further details and as to the results of use may be worth adding even if somewhat incomplete.

The longest experience with the problem of conveying energy at high pressure to a moving vehicle has been that of the Ganz Co., which has now extended over about five years. This has all been with three-phase currents at 3000 volts and low frequency, and, therefore, two trolley wires were employed. The preliminary trials on the experimental line at Budapest lasted for something over a year, and the system has been operated

in Italy altogether nearly four years, of which two and one-half years represent actual practical service. The original line erected at Budapest was practically reproduced at Valtellina, except for a few minor details.

During the experimental work at Budapest both single- and double-catenary suspension were tried, the construction being essentially similar to that used on the Spindersfeld line. The cross-suspension type, however, was adopted, the system of double insulators and double supports, shown in Mr. Damon's paper, being used. A considerable sag was allowed in span-wires, and every effort was made to give an elastic and uniform suspension. The insulators, as installed, are extremely heavy, and certainly do not aid in securing this result. Dry wood, impregnated, as suggested by Mr. Damon, forms an important feature both of the old and new construction.

For long spans and at switches an arrangement similar to that of Fig. 20 of Mr. Damon's paper is employed, and a very interesting special type of span-wire construction is also used, particularly where the trolley wires are lowered to pass under bridges, and for this reason undue rise and fall with the passage of the trolley would be objectionable. This consists of a catenary type of cross-suspension connected at intervals by suspension wires with an upwardly arched span-wire, which carries the insulators, thus making a construction that does not sacrifice the substantial elasticity of the line, but holds it accurately in place, permitting a limited rise and fall with the passage of the trolley.

During the experimental period some difficulty was experienced with the overhead construction, and in one or two cases the wire broke. But the chief difficulty was encountered in the tunnels; it was both mechanical and electrical in its nature; the accumulation of deposits from the steam locomotives continually running through the tunnels during the experimental period, and the leakage of tunnel roofs, caused insulation troubles; while owing to the very small clearance of the tunnels, difficulty was experienced in keeping the wire from grounding between supports. This was overcome by shortening the distance between supports, and weighting the conductors by clamping small iron rails upon them, which were put on in sections several feet in length in the same manner as a mechanical clip.

Although the construction is not by any means heavy, and the workmanship shows the effect of inexperience on the part of the linemen, it has successfully withstood the wear and tear of use, and so far as I have been able to learn is still in place. In one or two instances at the beginning of the experimental operation the trolley caught in the suspension-wire, owing to the improper location of curves and turnouts, the result was to break some portion of the trolley mechanism, but to leave the rest of the line unharmed.

For the latest construction the double-catenary type is used; no span-wire supports whatever being employed, and two messenger wires serve to carry both contact conductors. The spacing of the conductors is maintained by wooden insulator-bars upon which the insulators proper are carried, and to which supports from the messenger wires are attached. The insulators have been very much lightened by the substitution of pressed steel for malleable-iron castings. The messenger wires are carried on iron girders, spanning the track, and placed 130 ft. apart; the distance between points of attachment to the wire is 65 ft., there being two supports between girders and none immediately under them.

The block-signal system is interconnected directly with the contact conductors, and the entrance of a train into a section in face of a danger signal disconnects the section. I was unable to learn the details of this system. In addition, the conductors within the limits of the stations, and for a definite distance on each side, are dead at all times, save when a train is actually approaching or starting from a station. These sections can only be thrown in by the signal operator. It is customary for express trains to coast over the dead parts of the conductors with trolleys down, and it is the usual practice for trains moving at full speed to lower the trolleys at all switches, excepting such trains as are off schedule and are making up time.

The feature of double insulation, which is used throughout, has proved particularly useful in rendering possible the breakage of a single insulator without causing interference with traffic until repairs can be effected. This feature, while, of course, not a novelty, seems particularly worthy of perpetuation in high-tension lines where special liability to mechanical breakdown exists. The idea of cutting out sections at stations, and the extension of the same idea carried out on the Spindelfeld line, of cutting out sections under bridges where the right of way passes under highways, seems also worthy of consideration, at least for special cases.

The Valtellina system seems to have been free from trouble with the overhead construction to a remarkable extent, notwithstanding the fact that two overhead wires are required; and this fact emphasizes the importance of using a trolley contact-device that cannot get off from the wire and thus either break insulators or pull down the construction.

The trolley itself is a single apparatus and not two independent devices. It requires, however, two separate bases and poles, the same as if there were two single trolleys. The outer ends of the two poles are connected by a continuous bar of impregnated wood, the centre portion of which for a distance of about eight inches is the full diameter of the rolling contacts. On either side the diameter is reduced to receive two contact-cylinders, which are slipped over and sup-

ported on insulated ball-bearings, the current being taken off by carbon contact-rings at the ends and carried by flexible jumpers to the trolley poles.

The cross-bar, with its contact-rollers, is flexibly connected to the ends of the arms by horizontal spiral springs, permitting simultaneous contact with the two wires even where they are at widely different heights. The rollers originally used were of copper, which gave trouble by elongation under the hammering incident to service, and a resulting binding of the bearings. Ganz & Co. now send out copper-plated steel rollers, and claim for them a service of 10 000 km. per roller, or 20 000 km. per vehicle before replating becomes necessary. The copper rollers gave a life of 30 000 to 40 000 km. per vehicle, but then had to be entirely renewed. The operating company prefers bronze, and finds no trouble from elongation.

The trolley poles are supported by spiral springs in tension, the tension being put on from within the vehicle by compressed air. With this device the slow-moving trains take 300 amperes without sparking or burning the wire. The normal speed of passenger trains is 40 miles per hour, and the maximum current that has been taken off at that speed is about 240 amperes, under which conditions the collectors worked satisfactorily. The highest speed at which the device has been tested is 62 miles an hour, taking off a current of about 100 amperes. This test was made without alteration of springs or line construction and gave entirely satisfactory results. The plan of construction employed has therefore demonstrated its effectiveness at moderate speeds in spite of the handicap of the extreme weight of the insulators.

After two years of use the trolley wires show practically neither wear nor evidence of burning. Very little sparking is perceptible at night when running at full speed; but, as would naturally be expected, such flashing as does occur takes place at the points of suspension. The type of trolley used seems therefore to combine the advantages of the wheel- and bow-forms. It cannot leave the wire, and, as at present constructed, cannot catch. The rolling contact practically eliminates the wear on the wire and contact conductors. The only serious objection to the overhead construction raised by the local engineer was to the location of the wires over the track, necessitating much of the work being done at night, or else conducted under serious disadvantages. During the entire period of operation no one has been injured or killed by contact with the overhead construction, but an engineer of the Ganz Co. was killed in one of the sub-stations.

The organization for the maintenance of overhead construction is very interesting. The line is 66 miles long, and for the purpose of controlling is divided into five sections for each of which five men are required. Their duties include patrolling the line and visiting the sub-stations at regular intervals. When

not otherwise engaged one man is always on duty at the sub-stations. In general charge of all sections is a superintendent who reports to the electrical engineer.

The total cost of maintenance of primary and secondary lines, care, attendance and maintenance of sub-stations, and patrolling of the line on this plant is about \$102.00 per mile, per annum. This force is not kept fully occupied, but it is held that no smaller force would be allowable. The engineers of the operating company, and of the Rete Adriatica, seem to agree that the exigencies of trunk-line railway service demand that a sufficient force should be maintained to insure the prompt resumption of service in case of accident, and that the cost of maintenance and repairs, and of the supervision of sub-stations is not determined by the actual labor involved, but by the necessity for prompt action in emergencies. The difference in cost of maintenance between a three-phase and a single-phase line on trunk-line railways is, therefore, according to this view, simply the difference in the cost of material and hence a negligibly small quantity. This point of view is interesting, and, so far as I know, has not been mentioned in just the same form in this country; but in view of the higher cost of labor here it is questionable how far the plant could be adopted.

Regarding the Huber system, the practical difficulties are not fully brought out in the papers of the evening. The contact device itself is carried on a rectangular framework hinged to the car-roof, and leaning outwardly for contact with the conductors when at the side of the line, but requiring to be moved inward when the line passes the centre of the track in entering tunnels and bridges. This movement is not automatic, and does not follow from mere change of position, but must be caused by special actuating devices, which must be operated from within the train, or by means of a contact-rail laid along the side of the track and operated by a contact-shoe. Any failure of this auxiliary contact would mean the tearing of the structure from the roof of the locomotive. The actual contact-maker is a light brass tube which, as seen on the experimental line, showed deep cuts, indicating rapid wear from use; and wherever it showed the effects of wear the damage was considerable. As used on the experimental line last spring, the device gave the impression of being still in the early experimental stages.

CALVERT TOWNLEY: The only changes in the overhead construction for trolley service have been those of improvements in detail, whereas the proposed departure in the direction of using high-pressure current is an extremely radical one. The advantages of high-pressure trolleys are not to be disregarded, but a considerable amount of caution should be observed in the immediate adoption of very high pressures.

I disagree with Mr. Damon's recommendation that it is now time to standardize trolley pressure and the location of the

trolley wire, on the ground that although it will be essential to standardize with reference to these points ultimately. Enough is not yet known about the matter from practical experience to enable standards to be selected without the danger of making very serious mistakes.

Regarding Mr. Damon's suggestion that 15 000 volts should be adopted for steam railroads, it is doubtful if so high a pressure would be warranted by any railroad problem now in sight, either on the ground of first cost or of operating advantage. I am inclined to think that a system for such a high-pressure would be more expensive to install and maintain than one for a lower pressure.

A. H. ARMSTRONG: It would seem advisable that the trolley line pressure shall be kept as low as possible under the operating conditions involved. A trolley wire suspended from a steel catenary can be insulated for 15 000 volts or more, as Mr. Damon says, but because a construction has been found capable of withstanding higher pressure, and because a motor system has been found that can use high pressure, that is no justification in using higher trolley pressure than the operating needs of the road requires. The apparatus is increased in cost; the liability to breakdown is increased, and the 3000 volts ordinarily in use upon our suburban lines seems to be high enough to secure all the economic advantages of higher trolley pressure.

There is another way of looking at the matter. With 3300 volts at the sub-station, it is possible to operate heavy suburban cars at speeds approaching 50 miles an hour on from one-half-hour to one-hour headway, with sub-stations placed fully 20 miles apart, assuming, of course, that the sub-stations are tied together. It is a question in the operation of the road how much trolley line is liable to be disabled in case of accident. Twenty-mile blocks seem too long for satisfactory operation; and a higher trolley pressure, permitting of greater distance between sub-stations, is an undue refinement, unnecessary expense for the apparatus, and presents a refinement that entails disadvantages which outweigh any possible saving in feeder copper.

In considering the operation of heavy freight trains of 2000 or 3000 tons, where the output of the locomotive must reach 1500 h.p. or more, it is proper to consider trolley potentials higher than 3000 volts suitable for single-car suburban work.

Long blocks upon steam railroads are much more objectionable than upon suburban roads, and consideration of the operating conditions involved will show that 5000 or 6000 volts upon the trolley is amply able to provide an electric system having a cost as low as the conditions will warrant, while a higher trolley pressure in many cases offers no reduction in first cost, and carries with it the additional chance of breakdown.

The position of the trolley wire has been alluded to; there are arguments in favor of both the center trolley and the offset

trolley. Of the three alternating-current lines now in operation in this country, two have center trolleys, and the third is equipped with a trolley wire placed over the edge of the car; in all three roads the trolley wire is suspended from a steel catenary. The advantage of using a center trolley is that it permits the use of the same trolley-pole for both city and suburban tracks. Suburban service, however, may be carried on by means of sliding-bows, or rollers, for which the city overhead construction is not adapted, thus in some measure destroying any argument in favor of the center trolley for suburban service. It is possible that our suburban lines will adopt a trolley-bow, or roller, best adapted for high-pressure trolley operation, in which case it will be necessary to provide an extra trolley-pole, with wheel, for city operation. With four trolley-poles upon the car, there is no objection to considering a trolley suspended at the side of the track, while the adoption of this construction offers certain advantages not enjoyed by the center suspended trolley. In changing from alternating current to direct current, and vice versa, the side-suspended trolley permits contact being made with both alternating-current and direct-current lines at the same time, thus facilitating changing over. We are hardly in a position as yet to standardize in any way the location of the trolley-wire, and the operation of the different lines now constructed and in process of construction will be watched with considerable interest as affording operating data in this connection.

The frequency of hangers between the supporting cable and the trolley itself is also an open question. The Pontiac and Ballston lines are both operating with a single connection between trolley and catenary, placed midway between poles, while the Indianapolis & Cincinnati line provides for supports every 10 ft. The latter line is not yet running at full speed, and we cannot say how much inconvenience is caused by the frequent supports, but it would seem hardly necessary to provide supports more frequently than once or twice between poles.

Mr. Damon has suggested the use of a separate transmission line to each sub-station, as an improvement upon a trunk transmission line feeding all sub-stations in multiple. From experience in transmission systems I am led to believe that any trouble experienced with them is proportional to the number of miles of wire in operation, and separate transmission lines to each sub-station is open to criticism on this score. Separate transmission lines offer the possibility of operating the sub-stations without labor, but while such a system of operation is possible it would seem advisable to have an attendant within call of a sub-station, although the proportion of his time taken up in sub-station duties is negligible.

A road operating from a high-pressure trolley is new to this country, and as yet we are hardly in a position to attempt any standardizing either in type of apparatus, or in the construction of overhead lines.

PRESIDENT LIEB: I will now call upon Mr. Babcock, the consulting engineer of the Southern Pacific Railroad, and Secretary of the San Francisco Branch of the INSTITUTE.

A. H. BABCOCK: On the Pacific coast the conditions are such that the first and third classes of construction mentioned in Mr. Damon's paper will probably be the ones that will be encountered first, namely, comparatively inexpensive lines over a country not very well settled between points where there is a large movement of freight and over which the freight traffic must form the large proportion of the earnings. Then there will come the steam roads, of which we have hopes. But the natural prejudices of railroad men to radical innovations must first be overcome.

The question of line pressure and installation is one that is very vital along the ocean front. It has been demonstrated that transmission lines of very high frequency can be operated in the interior and in the southern portion of California with comparatively little insulation, but on the coast the fogs make the conditions entirely different.

As to operating above 3000 or 6000 volts, it becomes at once a question not only as to whether it is worth while from the standpoint pointed out by Mr. Armstrong, but whether it is worth while in view of the leakage. The construction, as detailed in Mr. Varney's paper, certainly has the appearance of fine workmanship; but the leakage that he gives, if that is to be carried throughout the length of the line in bad weather, I think it is a question how far we may go even with the best developed form of construction. For example, on page 139, he states that five miles of single catenary construction showed under test a leakage of one ampere at 6000 volts. Now, on a 40-mile line of double track this would be equal to 96 kw. constant loss. In 500-volt direct-current work the loss-constant is not great. The greatest loss is while the cars are moving. It appears that this constant loss would pay for a whole lot of line loss while the cars are moving.

C. O. MAILLOUX: The subjects discussed and suggested for discussion in the papers presented this evening are, undoubtedly, of great importance at the present time. If the statement be true that the question of the hour, in electric railroad engineering, is the extension of electric traction into the field that has been hitherto occupied exclusively by steam, then the first question to answer is of necessity that of conveying electrical energy in large amounts safely and conveniently from a stationary conductor to an electric locomotive or motor-car. I have had the conviction for some time that material progress in the direction of a general supplanting of the steam locomotive by the electric locomotive must wait for progress in methods adequate for the purpose just stated.

Before making, last year, a personal inspection and study of experimental and commercial alternating-current traction sys-

tems in Europe, I was somewhat skeptical in regard to the feasibility of raising above 3000 volts the difference of pressure applied direct to the motors, in spite of the fact that 3000 volts had been used successfully in this manner for a year or more on the Valtellina line in Northern Italy. Doubts on this point were dissipated by what I saw, especially on the Spindersfeld line near Berlin, and the experimental line built in Switzerland by the Oerlikon Company near Zürich, which has since become a working line. I am now a firm believer in, and a strong partisan of, high-pressure contact lines, whether overhead trolley or third-rail conductors.

Mr. Damon's view, expressed on page 116, in favor of higher contact-line pressures for alternating-current railway motor cars is in the right direction; and as between 3300 volts and 6000 volts, I am inclined to favor 6000 volts as the standard which should be adopted for interurban lines. As Mr. Damon says, for steam railroad conditions a line contact pressure of at least 15 000 volts is desirable. Its feasibility is borne out by tests and experiments that I made abroad.

The contact line with catenary suspension has been recently introduced here, and, judging from the data contained in Mr. Damon's paper, has already reached a high stage of development. The catenary contact line on the Spindersfeld line, with 6000 volts pressure difference, appeared to work satisfactorily in every respect. Nevertheless, it would seem that either on account of municipal restrictions or for other reasons not readily apparent, the catenary contact lines for other projected alternating-current single-phase roads, that came to my notice, were limited to 2400 volts. I surmise that notwithstanding the fact that so few breakdowns of the contact line have occurred at Spindersfeld, and that none of these breakdowns caused any accident, there is still some feeling of unrest associated with the thought of a contact line of 6000 volts placed directly over the car or locomotive; and even though the *probability* of accident is very remote, yet, so long as the *possibility* thereof still remains, the objection will doubtless persist.

The double catenary, as Mr. Damon states, has the advantage of keeping the contact wire from swaying, but its increased cost does not appear always to justify its use. With the tower method of construction, using long spans, probably the double catenary would be indispensable. With the ordinary trolley-line form of suspension, where the distance between poles is not excessive, the single catenary would seem adequate and satisfactory for all purposes. At Spindersfeld, the poles are placed about 39 metres apart. Both the single- and the double-catenary suspension have been tried, and both have proved satisfactory.

The reference made by Mr. Damon to spectacular sparking, when the contact line was coated with ice or sleet, emphasizes

a very serious and, in my opinion, radically inherent, defect in any contact line arranged to deliver current from its lower side. The fact that the sparking increases with the frequency of the trolley supports, in the cases observed by Mr. Damon, proves conclusively that ordinary trolley-line construction, using a trolley-wheel, is wholly unsuitable for high-pressure contact lines. With the catenary suspension, even with a trolley-wheel, the sparking should be independent of the number or frequency of the line supports.

The necessity of employing higher pressures for the transmission lines will obviously depend on the pressure of the contact line. When this pressure difference is as low as 3000 volts, undoubtedly it would still be necessary to employ higher transmission pressure in most cases for interurban lines; but if the pressure difference at the contact line is raised to 6000 volts, there are many cases where this pressure would be sufficiently high for both transmitting and distributing purposes. When the contact line pressure is raised to still higher values, say, for instance, to 15 000 volts, the same pressure difference will suffice in a large number of cases for both transmitting and distributing purposes. Indeed, if it were not for the convenience of subdividing the total line into blocks or sections the contact line itself could serve as the feeder.

Mr. Huber, of the Oerlikon Company, mentioned a project for the equipment of a steam line in Switzerland, where it was proposed to supply 50 miles of track, in both directions from a central station, without feeders, simply by using duplicate contact lines, one on each side of the track. This method has the advantage of providing a duplicate line equipment, which can still answer the purpose at lower efficiency and without materially crippling the service in case of defect or derangement in either of the two contact lines.

Mr. Huber has kindly furnished me with a set of slides and photographs showing interesting details of his system, which I will now show.

(COMPLETION OF DISCUSSION AFTER ADJOURNMENT.)

The slides and photographs referred to illustrate the characteristic features of the high-pressure, single-phase, alternating current electric railroad equipment of the Seebach-Wettingen line, in Switzerland. This line, which is a branch of the Swiss National Railroad system, is about 20 kilometers long, with single track of standard gauge. It has been operated by steam since it was first built, and will continue to be partly operated by steam for some time to come. When visited by me last summer, a portion of the line situated a short distance from the works of the Oerlikon Co., was equipped electrically, and was used by the Oerlikon Co. for making experiments with electric locomotives and various forms of contact lines and line supports.

It was then expected that the entire branch-line would be equipped and operated electrically by November or December, 1904; but it seems that sufficient allowance had not been made for official procrastination and obstruction. The plans for the equipment of the Seebach station, for instance, were only approved some time last January.

The portion of the road equipped and the electric locomotive intended to be used were both inspected by the Federal authorities, on November 18, 1904. As Mr. Huber states, it would have been difficult to select worse weather, there being a thick, wet fog, which lasted all day. The results were entirely satisfactory, however; not the slightest defect being observed as the result of a great diversity of very severe tests of the line and of the electric locomotive.

This case is interesting as being the first in which the Huber contact-line system, referred to by Mr. Damon and illustrated in Figs. 9 to 17 of his paper, has been adopted. It is particularly interesting and important as a pioneer movement toward the electrification of steam railway lines in Switzerland; for apparently both the Swiss government and the Oerlikon Co. are as much interested in the ulterior possibilities as in the immediate results; and in endeavoring to produce a satisfactory "sample" of electric traction as a substitute for steam traction for the specific conditions, both parties are evidently desirous, the former of testing, the latter of demonstrating, the general fitness of the system for all kinds of steam roads. This may account, in a large measure, for the careful and time-consuming scrutiny which has been given by the authorities to every detail of the proposed equipment. The further development of the line is to proceed apparently in the same conservative and cautious manner. It has been decided that the regular daily trips for which the official time-table has been issued shall be made, for a certain time at least, on the short portion of the line already equipped, before proceeding further with the electrification of the rest of the line.

The following is a quotation from remarks by me before the New York Electrical Society, last November, as published in the *Street Railway Journal*, Nov. 26, 1904:

"The electric train service proposed for this line will require eight trains, or four trains in each direction, per day. It is expected that this service can be done with one single electric locomotive. Each train will carry both freight and passengers, mostly freight. The estimated average train loads, not including the weight of the locomotive, are: 180 to 200 tons for trains running west, in which case the up-grades average about 0.8%, and 150 to 170 tons for trains running east, in which case the up-grades average about 1.0%. The average speed will be about 40 km. per hour. There are seven stations in the line including the two terminal stations. One of the present steam locomotives will be retained in service, at first, to run at least two more trains per day, one each way. This will be done partly to avoid the necessity of a second locomotive, but principally to enable the comparison between steam and electricity to be made under substantially the same operating conditions."

The members interested will find in this article a brief reference to the electric locomotive which is passed by here as extraneous to the subject under discussion. The following para-

FIG. 1.—Single Wire Held by Wire-Holders Rigidly Supported.

graph, which is a quotation from a reference made by Mr. Huber to the slides and photographs, contains interesting details regarding various forms of contact-line supports experimented with by him:

FIGS. 2 AND 2A.—Single Wire Held with Clamps with Lever to Secure the Wire Horizontally.

“ From the photographs you will see that we are experimenting with different methods of carrying the trolley or contact-wire over the poles. You will find (Fig. 1) the single wire held by wire-holders rigidly sup-

FIG. 3.—Pair of Wires Interconnected by Loose Links.

FIG. 4.—A Specimen of " Inverted " Catenary .

ported in the way which you know from our short experimental line inspected by you when here. Next, you find (Figs. 2, 2A) a single wire held with clamps to which a kind of lever is attached for securing the wire horizontally, while a spring made of steel wire, having some play vertically, supports the weight of the wire and takes up the hypothetical 'blows,' or the downward pressure, of the current collector. You will also find (Fig. 3) a pair of wires carried over the poles with the two wires interconnected by loose links. The inside wire is intended as the contact-wire for the current-collector, the outside wire as a reinforcement of the cross-section or conductivity of the line. The outside wire, having a somewhat greater sag, is less likely to break and will therefore constitute a safety-suspension for the inside wire in case the latter should

FIG. 5.—Another View of the " Inverted " Catenary Suspension.

break near a support, it being then held above the ground by the inter-connecting links just mentioned. The same principle of mutual safety-suspension has been adopted for road crossings of small importance (Fig. 6). You will also find two different forms of 'inverted' catenary suspension, which have so far given excellent results (Figs. 4 and 5). This suspension has been used on about $5\frac{1}{4}$ kilometers of length. During these last days, when the weather was very cold, the trolley or contact-wire, supported on these catenaries, was so straight that the current-collector showed no appreciable up-and-down motion. We have, however, come to the conclusion that this suspension, although it costs only

about 200 francs per kilometer more for erection, and hardly as much for material, will not be desirable for ordinary purposes. With two current-collectors on the car there has never been any appreciable sparking in passing over the supports of the contact-wire at the poles, with line construction of the types shown in Figs. 1 to 3."

Fig. 6 shows the arrangement of the contact-line at an ordinary crossing. The arrangement is based on the form of contact-line construction illustrated in Fig. 3; there being a pair of wires, which are interconnected by loose links. The object is, obviously, to make provision for supporting the ends of one of

FIG. 6.—Arrangement of the Contact Line at an Ordinary Crossing.

the wires in case it breaks, and to prevent the ends from reaching the ground.

Fig. 7 shows a more elaborate form of road crossing. In this case a bridging structure made of angle-iron is placed over the road and under the wire, and serves both to catch and to ground the ends of the broken line wire. In order to make the protection more adequate, a short section, or "block," of the contact-line itself, varying in length from 40 to 70 meters,

according to the width of the crossing, has its connection with the source of electricity controlled by the gates in such manner that this short section is connected with the line-wire only when the gates are closed and a train is passing; it is entirely disconnected and "dead" when the gates are open, at which time the current passes through a short auxiliary line which is specially installed over the street crossing. The cost of an

FIG. 7.—Angle-Iron Bridging Structures at Important Crossing, to Catch Broken Wires.

ordinary street crossing, such as shown in Fig. 6, is estimated at 600 francs. The cost of a street crossing such as shown in Fig. 7 is estimated at 1300 francs.

Fig. 8 shows the line-contact construction at a station, and over switches and side-tracks. In this case, the line construction is such that the current-collector makes contact partly above, partly at the side, and partly under the contact wire. It is proper to emphasize, at this point, the fact that while the Huber system is designed to permit the collector to take current from the contact-wire by touching it either below, on the side,

or above, the top contact is preferable and is the normal method.

The collection of current from the side or from below the contact-wire is to be regarded as, in reality, only an expedient called for by certain conditions, especially by the limited space usually available for trolley supports, in railroad tunnels, under bridges, and at switches and side-tracks. On steam railroad lines only a comparatively small percentage of the contact-lines would require other than top-contact current collection.

Where a sufficient width is available, under bridges and gh-ways, the shifting of the pivot of the current-collector can be readily eliminated. This has been done in the case illustrated

FIG. 8.—Line Contact Construction at a Station, over Switches and Side Tracks.

in Fig. 9. It does not follow, therefore, that the shifting of the current-collector, which has been criticised as one of the objectionable features of the Huber system, would be required in every case. Moreover, this device has now been brought to such a degree of perfection that its use is no longer a serious objection.

Referring to the large photographs, attention is called to the thin wire carried on ordinary insulators on the side of the pole away from the track. This wire forms part of a "block" system devised by the Oerlikon Co. The entire length of the

Seebach-Wettingen line is to be divided into 13 sections. The contact-wire at or near each station will form a section or block, and the portion extending from one station to another will also constitute a section; hence, there being seven stations, including the terminal stations, there will be 13 electrical sections or blocks in the entire distance of 20 km. The small wire shown in the photographs, which is called the "cut-out" wire, or the "feeling" wire, is connected with a weatherproof fuse to each *insulator pin*. If the insulator begins to leak excessively, or if it actually breaks down, current flows through its pin, and through the fuse, and is conveyed by the cutout

FIG. 9.—Illustrating an Instance where a good Bridge Clearance makes Unnecessary the Shifting of the Current-Collector Pivot.

wire to the operating solenoids of certain line switches located at the ends of the sections. Thus, any section or block on which there is a leaky or faulty insulator is automatically cut out. When the fuse is blown there is an explosive sound like that of a gun-shot, serving to attract the attention of the guardmen or station-men, even at a considerable distance. After the fuse has blown, the fuse-holder hangs from its support in such a position as to make it visible even from a considerable distance. Some of the switches controlling the blocks or sections are placed on poles. Figs. 10 and 11 show one of the switches open and closed, respectively.

Another form of section switch is shown in Fig. 12. The

FIGS. 10 AND 11.—Block Controlling Switches Closed and Open.

FIG. 12.—Another Form of Section Switch.

faulty insulator is located, first, by the audible signal produced by detonation of the fuse; secondly, by the visual signal given by the displacement of the fuse holder, and thirdly, by the absence of the fuse from the fuse holder.

As Mr. Huber stated to me, perhaps some of these operating features will be found superfluous, and sufficient reliability in line equipment can be realized without some of them. It was deemed prudent, however, to develop and apply such devices in this case, if only to meet the objection urged by steam railroad men that electrical troubles on a trolley line will be hard to detect, and that their removal would cause trouble and delay. At my request the experiment was tried of making an artificial ground at one of the line-contact insulators, to simulate the case where the insulator breaks down and grounds the contact-line. On making the artificial ground the audible and visual signals were unquestionably such as would attract attention, even though the location of the pole were not definitely known. It took less than three minutes for a lineman to replace the damaged insulator with a new one, and to have the current again turned on to the affected section.

Mr. Huber has paid close attention to the requirements of the contact-rod of the current-collector. After trying different metals, he has found that brass or composition metal tubes answer the purpose very well. He has also succeeded in lubricating the rod, and furthermore, has resorted to the expedient, of zigzagging the contact-line for the purpose of minimizing wear on the contact-rod, and to equalize it along the length of the rod, thereby preventing the rod from being sawed through by the contact-wire.

The top-contact method of current collection is unquestionably superior to all others in sleety and frosty weather. On this point Mr. Huber furnishes interesting evidence in the following comment on the results obtained since the portion of the line electrically equipped was put in regular operation:

"The aggregate number of kilometers run, up to the present time (Jan. 25, 1905), is 450 km. The speed varies between 45 and 50 km. per hour. We have thus far always had to contend with a very large amount of frost on the wire during the first trip, in the morning. The frost, owing to its nature, envelops the wire from all sides, while the sleet, which very often is produced from the frost, clings only to the under side of the wire. For this reason, on one day when the frost was exceptionally heavy, there was a continuous light sparking on the current-collector, which, however, was without any influence upon the volt- and ampere-meters; and, on the next trip, the line was perfectly free from sparking, simply because the frost, as formed on the upper side of the wire, will always be inevitably wiped away by the current-collector, while a cover of sleet will never be destroyed in the same way. It has also been observed that the sparking is very much heavier on those portions where the current-collector touches the wire from the side or from below. It is therefore proved that with regard to frost and sleet on the wires the contact from the top of the trolley wire is a marked advantage."

In conclusion, I may state, that after careful study of the Huber system, I have become a convert to, and a partisan of, the top-contact theory for contact-lines intended for long-distance traction. It possesses constructive and operative features which recommend it as preferable to the under-contact system. Not the least important of its recommendation is that of cost. I am convinced that if a comparison is made on the basis of equal mechanical and electrical results, also including cost of maintenance, the top-contact method is so much lower in cost as to outclass the others. This is the more true, the higher the line-pressure, and consequently the more perfect the insulation demanded.

The impedance of the iron rails of the track on this line has been carefully studied by the Oerlikon Company. The members who are interested in this matter will find an article on this subject in the *Electrotechnische Zeitschrift* for April 1, 1904, by Dr. H. Behn-Eschenburg, of the technical staff of the Oerlikon Company. It has been found that the pressure loss due to impedance of the track rails assumes such importance in some cases as to necessitate a special system of current-return line, with special booster transformers for the track, an interesting form of which is described in the article just mentioned.

THEODORE VARNEY: Referring to Mr. Babcock's remarks concerning leakage, it is important to keep in mind the fact that the entire line was covered with wet snow. Upon another day when the line was clear of snow, although the insulators were black with locomotive and other kinds of smoke which exists in the Pittsburg district, the leakage could scarcely be read with shop instruments. This appears to be the only point requiring especial remark.

GEO. F. SEVER: The remarks of Mr. Armstrong are particularly pertinent as to the continuity of service by having fewer transmission lines, having one trunk line connecting all sub-stations, and having the sub-stations nearer together than is contemplated by the higher trolley pressure suggested in Mr. Damon's paper.

PRESIDENT LIEB: I think it should be said that undoubtedly a great deal of credit is due to the pioneer builders of this high-pressure trolley line, Messrs. Ganz & Company of Budapest; but I think it also might be stated that the road in question could hardly be considered a heavy trunk-line. While it is a branch of the Adriatic Railway system it is rather a spur from the main line. I do not remember the exact conditions as to amount of traffic, but the impression that I got in reading the description of the road, led me to believe that it was not a very heavy line, not at all approaching our trunk-line conditions.