

the cost of the motor cars at \$10,000 each; the cars cost about \$3,500 each.

Then 22 motor cars will cost.....\$220,000
and 44 ordinary cars..... 154,000

Cost of electrical rolling stock..... \$374,000
The station building could probably
be erected for..... \$60,000

For steam locomotion there would be about 11 steam trains in service at any one time, each of 5 cars, which will be taken as the length of a steam train, as in New York they are frequently of that size.

We should reckon on about 15 locomotives and say 70 cars, as the steam equipment.
Steam locomotives, of the size required, cost about \$5,000 each.

15 locomotives would cost..... \$75,000
70 cars "..... 245,000

Total cost of steam plant..... \$320,000

For the electrical plant:

22 locomotives :
44 cars :
Rolling stock.....\$374,000
Line copper..... 16,115
Power plant..... 127,500
Station building..... 60,000
\$578,000

To this must be added the cost of the iron needed for the overhead work, at 50 pounds per running foot of double track, and at 3.65 cents per pound..... \$33,000

\$611,000

The items for the West Chicago system are reckoned up in the same way.

Steam plant :
20 locomotives at \$5,000... \$100,000
100 cars at \$3,500..... 350,000
\$450,000

Electrical plant :
33 locomotives at \$10,000..... \$330,000
66 cars at \$3,500..... 231,000

Cost of rolling stock..... \$561,000
697,061 feet of No. 0000 copper, weighs
445,650 pounds, cost..... 78,500
3,000 horse power at \$85..... 255,000
Iron overhead work..... 53,000
Building accessories, etc..... 90,000

Total cost..... \$1,037,000

In this plant, 500 horse power was added for contingencies.

The following are the estimates for the Lake Street road, allowing for 6,500 horse power at the station. Allowance is made for 20 steam trains, or 35 electrical trains as a maximum:

Steam plant :
25 locomotives at \$5,000..... \$125,000
125 cars at \$3,500..... 437,500

Cost of steam equipment..... \$562,500

Electrical plant :
40 electric locomotives at \$10,000..... \$400,000
75 cars at \$3,500..... 262,500

Cost of rolling stock..... \$662,500
1,689,600 feet of No. 000 wire weighs
856,750 lb., cost..... \$150,000
6,500 horse power at \$85..... 552,500
Overhead iron construction..... 96,000
2 buildings, etc..... 180,000

Total first cost..... \$1,641,000
562,500

Excess over steam plant..... \$1,078,500

Now let us see whether enough can be saved by the use of electricity to pay the interest on this excess of first cost. This will be worked out only for the Lake Street road, which requires the largest outlay of the three.

We have seen that the average expenditure of power, on this line, is about 140.8 units of 33,000 foot pounds each, for every station passed, assuming a three-car electrical train weighing 65 tons.

For the steam trains, which weigh, including a 23-ton engine and five 20-ton cars, 122 tons in the aggregate, we must make a new determination of the power expenditure.

In order to bring our train up to a speed of 30 miles per hour, there must be expended, in overcoming inertia,

$$\frac{244,000 \times 44}{64 \times 32} = 7,177,100 \text{ foot pounds.}$$

The resistance, which is $122 \times 8 = 976$ pounds, must be overcome through 1,410 feet, making the energy expended in traction

$$1410 \times 976 = 1,376,160 \text{ foot pounds.}$$

The total is 8,553,260 foot pounds.

$\frac{3,553,260}{33,000} = 259.2$ units of 33,000 foot pounds, per train per station.

There being 60 stops, and the running time having been assumed at not less than 60 minutes.

$$\frac{259.2 \times 60}{60} = 259.2 \text{ horse power the average expenditure}$$

per train per round trip. On the Sixth Avenue line of the Manhattan Railway the maximum number of trains dispatched from both termini, in one hour, is 68, while the average for the 24 hours is about 38.

On the Lake Street road, we have assumed the maximum as the equivalent, in steam trains, of twenty per hour.

If we assume the relation of average to maximum as the same for the two railroads, we obtain about 11 as the average number of steam trains per hour on the Lake Street road. The total number of trains for the 24 hours would therefore be $24 \times 11 = 264$ trains of 5 cars each. Assuming the coal expenditure at 6 lb. per hour, we have, since the time of a round trip is just one hour,

$$259.2 \times 6 = 1,555.2 \text{ lb. coal per round trip.}$$

$1,555.2 \times 264 = 410,572.8 \text{ lb. coal consumed in 24 hours.}$
This is, in round numbers, 205.3 tons.

At \$5 a ton, this will cost \$1,026.50.

Let us now determine the coal consumption of our electrical system for 24 hours. As we have seen before, the number of 33,000 foot pound units required, by each electrical train, per station passed, was 140.8, while the amount available for recovery was 84.7 units, of which 60 per cent. was actually saved, or 50.8 units. The net consumption per train per station is therefore the difference, or 90 units.

$$\frac{90 \times 60}{60} = 90 \text{ horse power, the average rate of expenditure per train.}$$

If the ratio of average to maximum number of trains, per hour, is as 38 to 68, having assumed 35 trains as the maximum, we will obtain 19 per hour as the average. The total number of trains in 24 hours will then be $19 \times 24 = 456$.

If the efficiency of the system be 55 per cent., $90 \div 0.55 = 163.6$, the average horse power expended for each train at the central station. The running time being one hour; there will be used for each round trip,

$$163.6 \times 2 = 327.2 \text{ lb. coal.}$$

$$\frac{327.2 \times 456}{2,000} = 74.6 \text{ tons coal, consumed in 24 hours.}$$

$$74.6 \times \$3 = \$223.80.$$

24 hours' operation of steam plant costs..... \$1,026.50

24 hours' operation of electrical plant costs..... 223.80

Difference..... \$802.70

If, during 365 days, there be saved \$802.70 per day, we will have, at the end of a year, \$292,985 saved in the matter of fuel.

The difference in first cost was \$1,078,500.

The deduction is, therefore, that an electrical plant will pay for its extra first cost in less than four years, and this, too, with an efficiency of only 55 per cent.

Even if it cost twice as much as has been mathematically estimated, to run the electrical plant, or \$453.60 per day, there would still be a daily saving of \$572.90, amounting at the end of the year to \$209,100.

This is on a coal basis alone. As to employees, there would in all probability be a slight increase in their number, which will to a small extent offset the decrease in fuel expense. But it does not seem as if the necessary increase in the number of employees would very greatly diminish the remarkable rate of interest on increased first cost, which would follow the use of electrical motive power.

For smaller plants, the difference might not be so markedly in favor of electricity as on a large scale, but so many are the advantages it offers in any case, that it would undoubtedly be worth while to adopt it, even if it took several times four years to pay off its increased indebtedness.

A tabulation of costs, etc., is herewith presented as a summary of what precedes.

RECAPITULATION.

Steam.

Line.	Locomotives.	Cars.	Cost of Rolling Stock.
South Chicago...	15	80	\$320,000
West Chicago ..	20	100	350,000
Lake Street.....	25	125	562,000

Electricity.

Locomotives.	Cars.	Cost of rolling stock.	Pounds copper.	Cost of copper.	Cost of buildings, plant, and overhead cond.	Total cost.
S. C. 22	44	\$374,000	144,030	\$16,115	\$220,500	\$611,000
W. C. 33	66	501,000	445,650	78,500	398,000	1,037,000
L. S. 40	75	662,500	856,750	150,000	828,500	1,641,000

DIFFERENCE IN FIRST COST.

S. C. Railway..... \$291,000
W. C. "..... 687,000
L. S. "..... 1,078,000

The saving in fuel for the Lake Street road has been calculated at about \$800 per day, or nearly \$293,000 annually. An electrical system would thus pay for its extra first cost in less than four years.

These general results seem to me to be not at all unreasonable.

In closing, I desire again to express my gratitude to all the engineers to whom I am indebted, for their uniform kindness, courtesy and encouragement. While the general adoption of the electric motor on the railway may yet be a long way off, I have accomplished my purpose if I have shown that the obstacles to be encountered are by no means beyond the capabilities of electrical engineers.

A PRACTICAL ELECTRIC RAILWAY CONDUIT.

By STEPHEN D. FIELD.

THE subject of conduits for electrical railroads has occupied considerable space in this journal of late, and is one which is seemingly beset with many difficulties, judging from the elaborate constructions described,

and the poor success attending their installation. The various details of conduit construction have been thoroughly worked out by cable railway engineers, and it only remains for the electrical engineer to supply the necessary insulating conductors and contacts to secure a sure and lasting installation for electric traction.

I have endeavored in the accompanying illustrations to point out one design which I think will answer the purpose.

The two factors most required in electrical conduits for railroads are perfect insulation and accessibility of parts. The conduit shown has fittings so designed that all electrical attachments can be removed and renewed without disturbing the integrity of the conduit. The insulation may be so high that leakage will be inappreciable in any kind of weather.

The conduit frame, A, is made of cast iron, capped with steel at the slot. Insulation is provided by means of the well known Brooks insulator, B, set at intervals

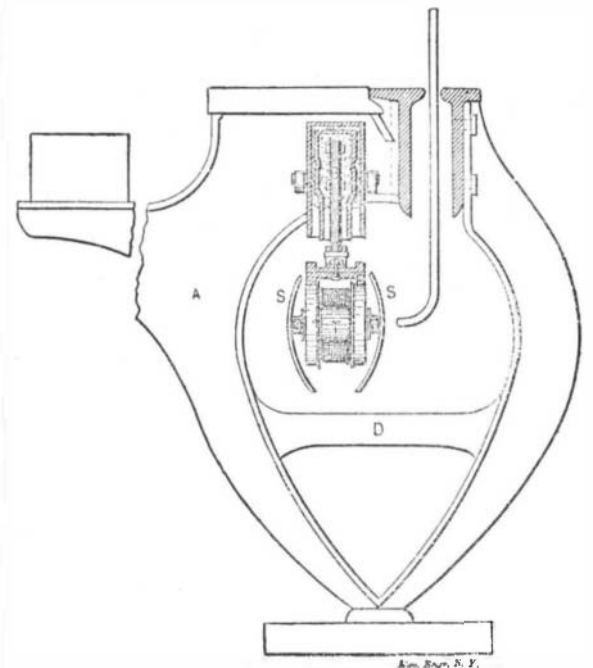


FIG. 1.—FIELD'S ELECTRIC RAILWAY CONDUIT.

of ten feet along the line of the conduit. The working conductor, F, is made in sections of twenty foot lengths, arranged to "break joints."

Contact with the working conductor is obtained by what is termed a "magnetic trolley," T, which consists of two soft iron wheels fixed rigidly on a core which turns within a fixed coil, C. A current of 0.1 ampere passing through the coil causes the trolley wheels to adhere firmly to the iron working conductor. A spring is provided, just sufficient in strength to keep the trolley lightly against the conductor when no current is passing through the coil.

Immediately above each insulator a trap is provided through which the conduit may be cleaned and the insulators changed.

A brace, D, passes from side to side of the conduit at about one-third of its height. This secures rigidity of construction and allows of a lighter and less expensive yoke than is used in cable construction where no such device is permissible.

The switching is accomplished on the working conductor in precisely the same manner as on the surface track.

The outer wall of the conduit may be used as one of the rails by allowing the flanges of the car wheels to run in the slot.

The lower portion of the conduit is so shaped as to provide adequate drainage, and it will be seen that water entering the slot falls clear of the working conductor and trolley. An insulating shield, S, encircles all the exposed metallic parts of the trolley, thus guarding against accidental contacts. Connection between the trolley and car is obtained by a hollow arm

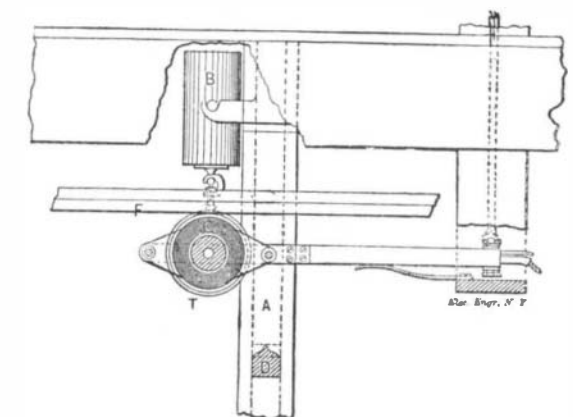


FIG. 2.—FIELD'S ELECTRIC RAILWAY CONDUIT.

passing down through the slot, through which insulated conductors pass from the trolley to the car motor. The trolley is connected mechanically with the arm by a hollow wooden shaft hung in a gimbal.

The working conductor is of such a shape that it can be passed through the street slot and removed when necessary through the same opening. The joints in this conductor are bridged by strips or wires riveted to their adjacent ends, while current is supplied from an insulated trunk line laid parallel to the conduit, the working conductors being laid down in sections of five hundred feet and attached to the trunk line by branches containing cutouts. As the trolley runs on the under side of the working conductor, it is obvious

that it always finds a clean surface to travel on. No dirt from the street can find lodgment there. Magnetic adhesion provides an intimate contact, with scarcely any weight and little resistance to progressive rotation.

In any cold climate the conduit may be kept open

side of the armature as coil 1, adjoining coil 2 on that side, but leaving a space between it and coil 1 on the opposite side of the armature for coil 4, which is to be started and finished on the same side of the armature as coil 2. Coil 4 will adjoin coil 3 on the side of the armature opposite that on which the coil is started and

wood. It is provided with journals which revolve in bearings in a wooden frame attached to the top of the field magnet. On the ends of the wooden cylinder are mounted copper rings, C D, which are pressed by springs, A B, connected with the commutator brushes as shown in Fig. 6. Between the rings, C D, are arranged four se

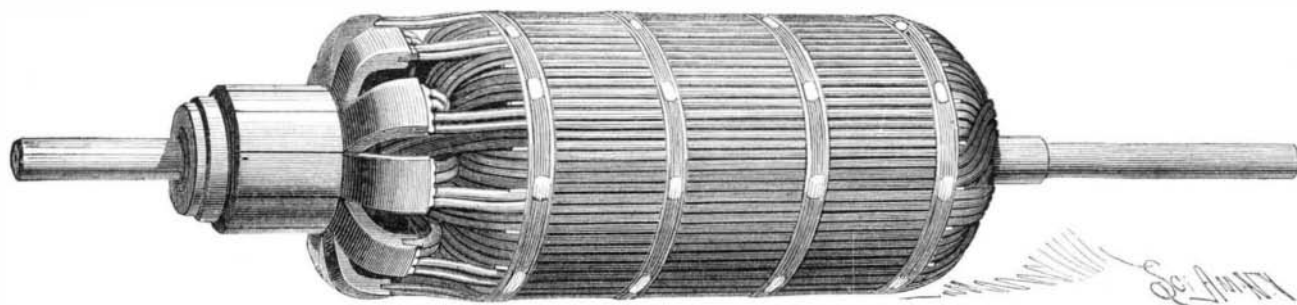


FIG. 1.—PERSPECTIVE VIEW OF ARMATURE.

by means of a pipe laid on either side of the slot, through which hot brine can be pumped from the engine house.

A very few degrees of artificial heat communicated from the pipe to the conduit is required to effect this result, while the efficiency of this device may be greatly extended by having relays of heating stations at proper intervals along the track. As this heating system is only in operation during the prevalence of extremely cold weather, it is probable that a few days per year will cover its total time of operation, and it would seem that the expense attendant upon its operation is too trivial for consideration.

I am of the opinion that a road equipped as indicated will be found to be far more reliable in operation and unobstructive in installation than is the case where the working conductors are carried in the air. This system can be introduced for less than the cable system, and worked with greater speed, freedom from interruption and at a less cost of operation.—*Electrical Engineer.*

AN EFFICIENT PLATING DYNAMO.

By GEO. M. HOPKINS.

To convert the 8 light dynamo described in SUPPLEMENT 600 into a machine for electroplating, it is necessary to replace the armature with one wound with very coarse wire and to provide a switch which will connect

finished. The armature is proceeded with in this manner until all the spaces are filled up and the coils are all in place with their ends projecting as shown.

There are ten coils, and the same number of bars in the commutator cylinder. Each commutator bar receives the end of one coil and the beginning of the next, so that the coil is closed as in the case of the Siemens armature described in SUPPLEMENT 600.

If desired the coil may be wound according to the Siemens (or Heffner-Altneck) method, provided a commutator cylinder has an odd number of bars and the armature an odd number of coils. The Siemens method thus modified is, in fact, the Edison winding.

The only material difference between the commutator cylinder here shown and that described in connection with the 8 light dynamo in SUPPLEMENT 600 is in the provision for heavy connections between the bars and the coils. In the present case each bar has formed integrally with it a radial arm which is bent toward the armature core, and slots, R, are made in the end to receive the terminals of the coils, which are soldered in the slots. The arrangement of the terminals of the coils is the same as in the Siemens armature, i. e., each commutator bar receives the end of one coil and the beginning of the next.

The commutator cylinder is built up on a flanged sleeve, M, fitted to the armature shaft. The flange of the sleeve is grooved in the side to receive the lugs projecting from the commutator bars, P. A tube, O, of insu-

ries of plates which may be brought into contact with the series, a b, of springs secured to the wooden switch frame and connected with the terminals of the separate coils of the field magnet—the terminals 1, 2, 3, 4, 5, 6, 7, 8, of one-half of the field magnet being connect-

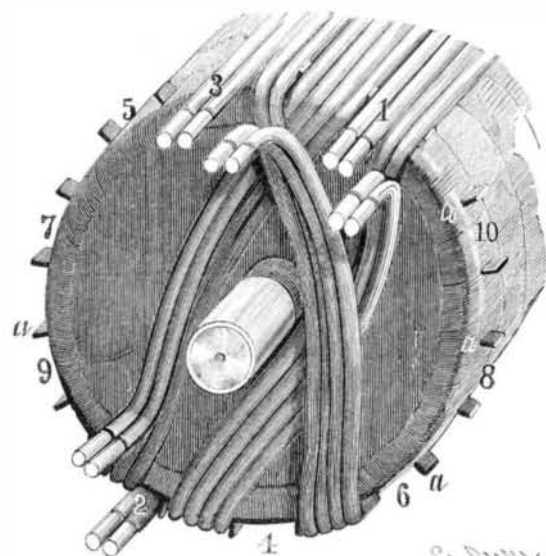


FIG. 3.—COMMUTATOR END OF ARMATURE.

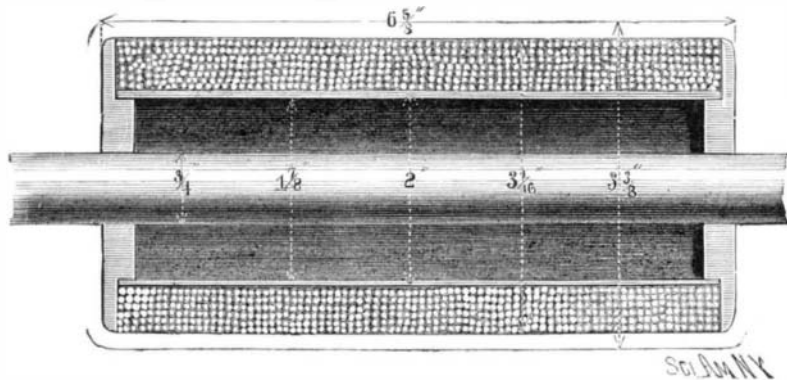


FIG. 2.—LONGITUDINAL SECTION OF ARMATURE.

up the sections of the field magnet wire in parallel or in series as may be required.

The armature for plating has but a single layer of wire with two convolutions to each layer. To facilitate winding, two parallel wires, No. 10 B. and S. gauge, are used in each coil instead of using a single larger wire. Fig. 1 shows the armature complete, and Fig. 2 shows the armature core in section with the dimensions marked on.

It consists of an iron spool filled with No. 18 or No. 20 very soft iron wire either rusted or varnished to prevent Foucault currents.

The heads of the spool are provided with twenty

lating material, such as hard rubber or vulcanized fiber, is slipped over the sleeve, M, and the groove in the flange of the sleeve is lined with insulating material. A countersunk nut, N, is screwed on the end of the sleeve, M. Between the nut and the beveled ends of the commutator bars is placed an insulating washer, Q. The bars, P, are separated from each other by mica.

The commutator brushes used on the 8 light dynamo will answer for this armature, but wider ones would be preferable.

The field magnet of the 8 light dynamo above referred to is used in connection with the armature here

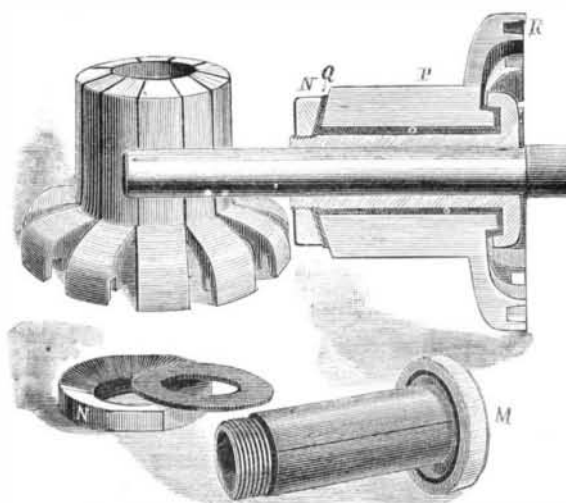


FIG. 5.—DETAILS OF COMMUTATOR.

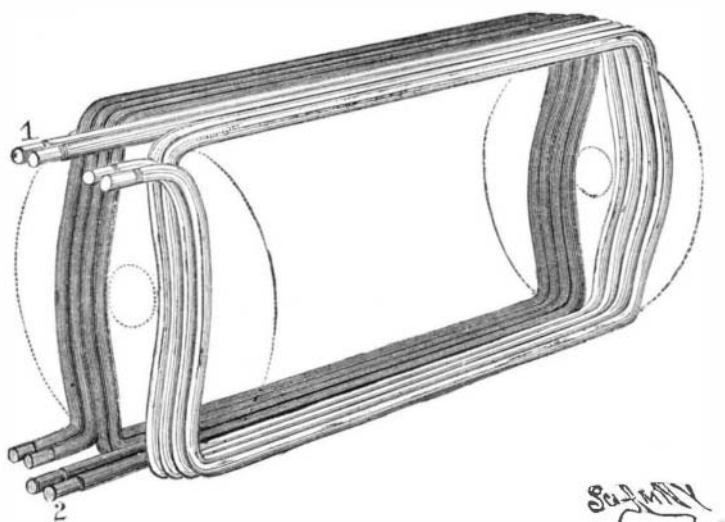


FIG. 4.—TWO ARMATURE COILS SEPARATE FROM CORE.

radial slots in which are inserted the small wedges, a, separating the coils of the armature. The wires forming the coils are each about twenty inches long. The winding is according to the Froelich method. Coil 1 (consisting of two parallel wires as described) is placed entirely upon one side of a diametrical line of the armature and begins and ends upon the same side of the armature. Coil 2 is placed on the opposite side of the same diametrical line, and begins and ends on the opposite side of the armature. Coil 3 begins on the same

shown and described, but a switch is required by means of which the current may be sent through all the coils in series, or all in parallel, or with any intermediate arrangement, so that the current can be controlled at will.

The switch is made in cylindrical form with metallic plates and connections as shown in Fig. 7, in which the surface of the cylinder is spread out flat to permit of easy explanation.

The cylinder forming the body of the switch is of

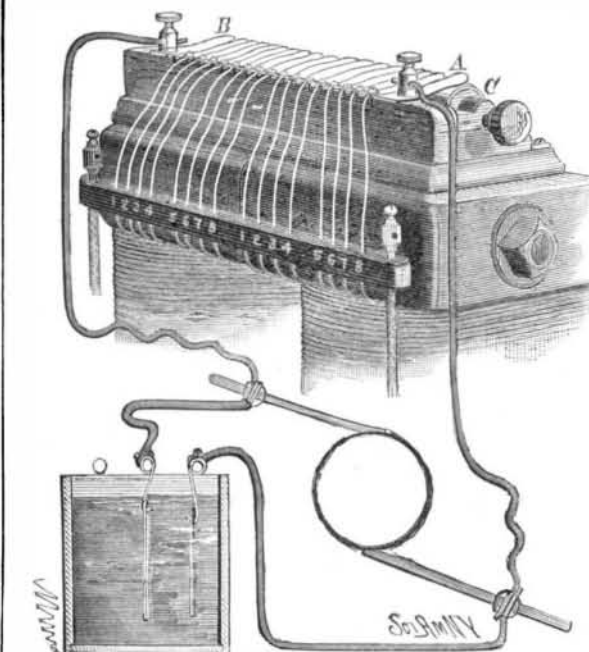


FIG. 6.—TOP OF F. M., WITH SWITCH AND DIAGRAM OF CONNECTION FOR PLATING.

ed with the series a, those of the other half being connected in the same way with the series b.

With the switch in the position shown in Fig. 7 the current arrives at the spring, A, from the armature