Recording Car for the inspection of overhead contact lines

by

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THE WEAR ON OVERHEAD CONTACT WIRES is a problem to which attention had already been directed at an early stage in the electrification of the Swedish State Railways. It was found that the wear occurring was greater than had been anticipated and that the wire was subjected to greater wear at certain points in the contact line span than at others. Exhaustive investigations were therefore put in hand. After experimenting with various forms of line suspension, a uniform system of suspension was finally evolved which, with the train speeds and traffic density common at that time, was found to meet reasonable demands both for limiting the amount of wear and obtaining satisfactory current collection in general. Experience showed, however, that the requirements were not met merely by installing the new contact wires in a suitable manner, but that it was also necessary to inspect them at regular intervals so that any appreciable changes in their position could be corrected in time. It was an obvious step, therefore, to arrange for annual inspections covering the whole of the contact wire network.

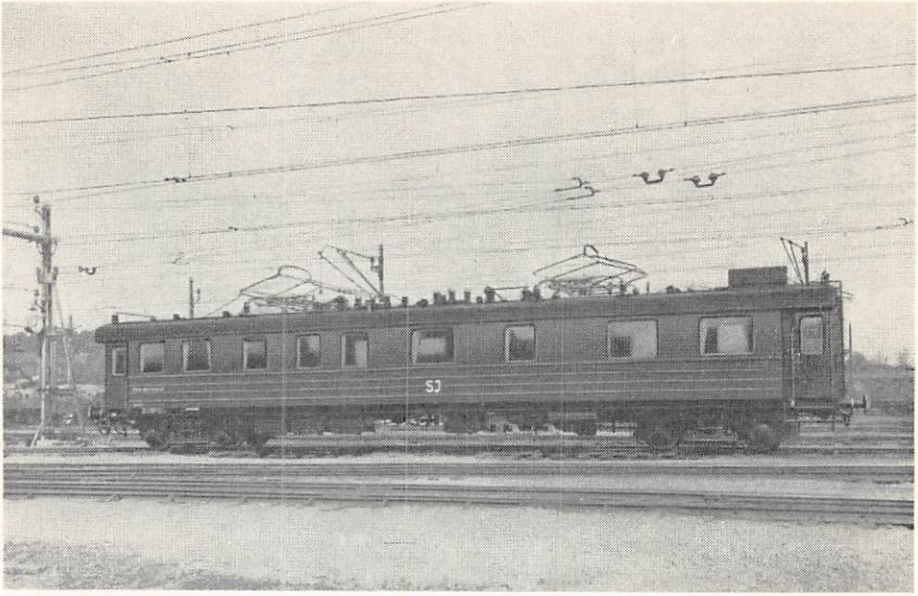


Fig. 1. Exterior of the recording car.

The electrification of our railways has now been carried out over a track length exceeding 8 000 km. Both the traffic density and train speeds have increased, and at the same time greater demands have been made with respect to precision in the operation of the service. This provides well-justified grounds for the adoption of time-saving and objective methods of inspection insofar as the contact wires are concerned.

The wear on the contact wires also represents an economic problem. It has been found from experience that the contact wire over main lines has an average life of approximately 12 years. Under present conditions it is necessary to reckon with costs for replacing worn wire amounting to about 1 Mkr per annum. Thus, good reasons existed and still exist for seeking methods which would permit the properties of the contact wire to be defined and improved.

A conception of the contact wires' properties and condition can best be obtained by studying and recording the movement of the pantograph along the conductor. Here, it is the vertical movement of the pantograph which is of primary importance. In the year 1938, therefore, the Railway Board purchased an apparatus which was mounted on a locomotive for the purpose of recording these movements. It was soon realised, however, that it would be necessary to add to and improve this equipment in order to obtain quicker and simpler methods of measurement.

The shortage of materials, particularly copper, which prevailed during the war contributed in no small degree towards rendering the matter urgent. The Railway Board consequently decided that a specially designed recording car should be purchased for carrying out contact-wire measurements. This car could only be delivered in 1947 after certain manufacturing difficulties had been overcome. A certain time necessary for the adjustment of the instruments subsequently elapsed before the car could be placed in service for the intended purpose. A brief description of the car and its equipment and employment is given below.

The recording car, Fig. 1, does not differ appreciably in its external appearance from the ordinary type of modern steel coach, apart from the apparatus mounted on its roof. The equipment on the roof comprises two pantographs, two current transformers, isolating switches and throw-over switches together with a high tension connection at each end of the roof the purpose of which is to transmit the electric energy collected by the pantograph on the recording car to the locomotive. In addition an observation cab is built up on the roof from which the current collection process can be studied directly.

The available space inside the car, Fig. 2, has been so arranged that the actual workrooms have been located at one end of the car, the other end comprising a conference room, Fig. 3, together with combined seating- and sleeping compartments.

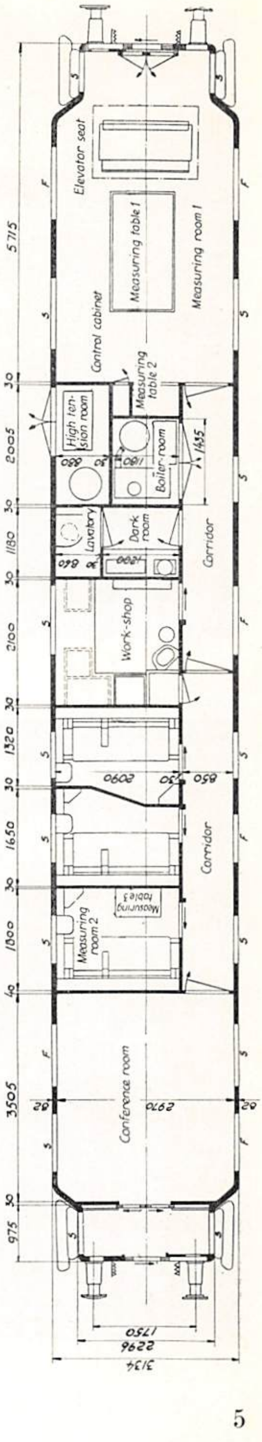


Fig. 2. Plan view.

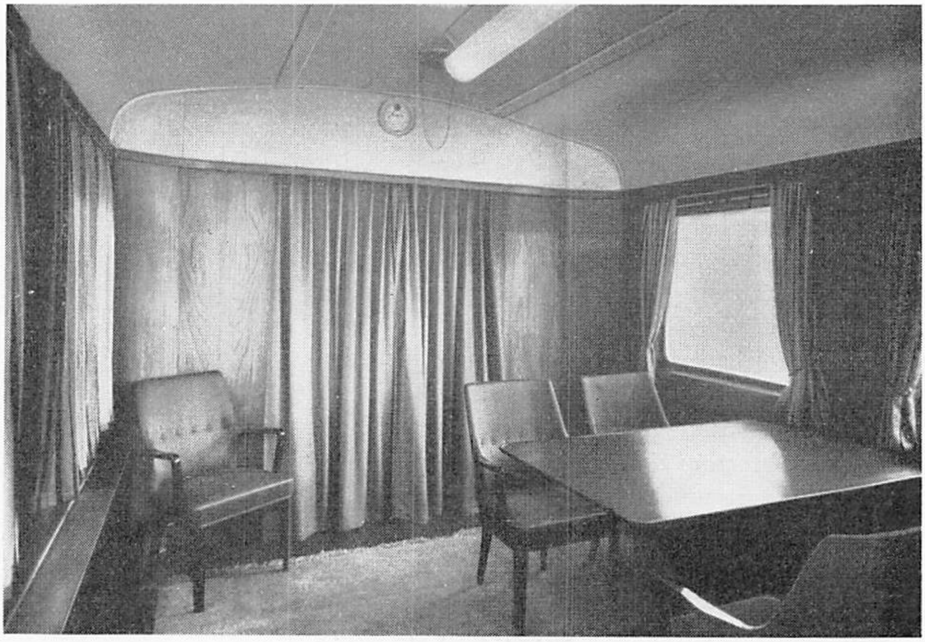


Fig. 3. Conference room.

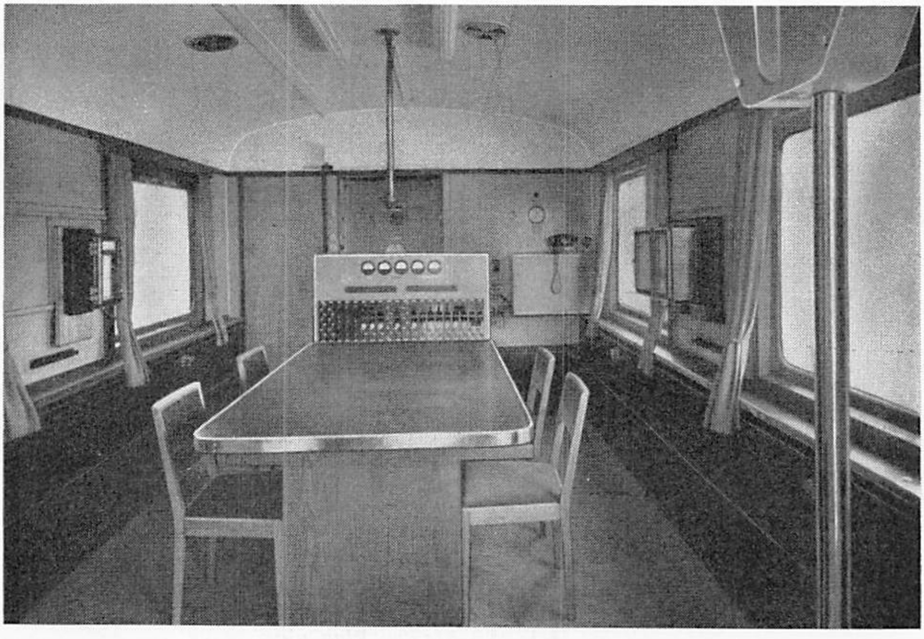


Fig. 4. Measuring room 1.

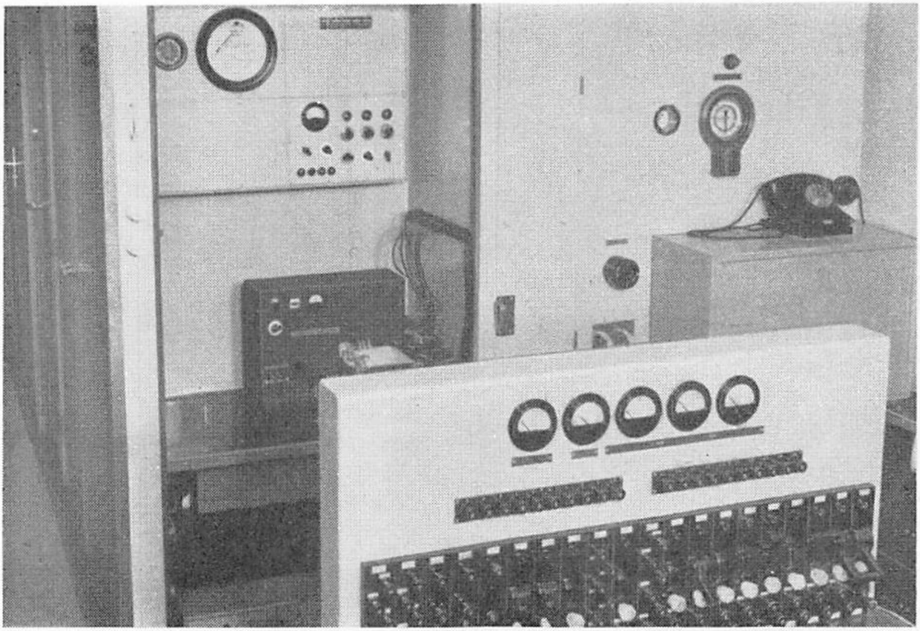


Fig. 5. Measuring table with switch panel.

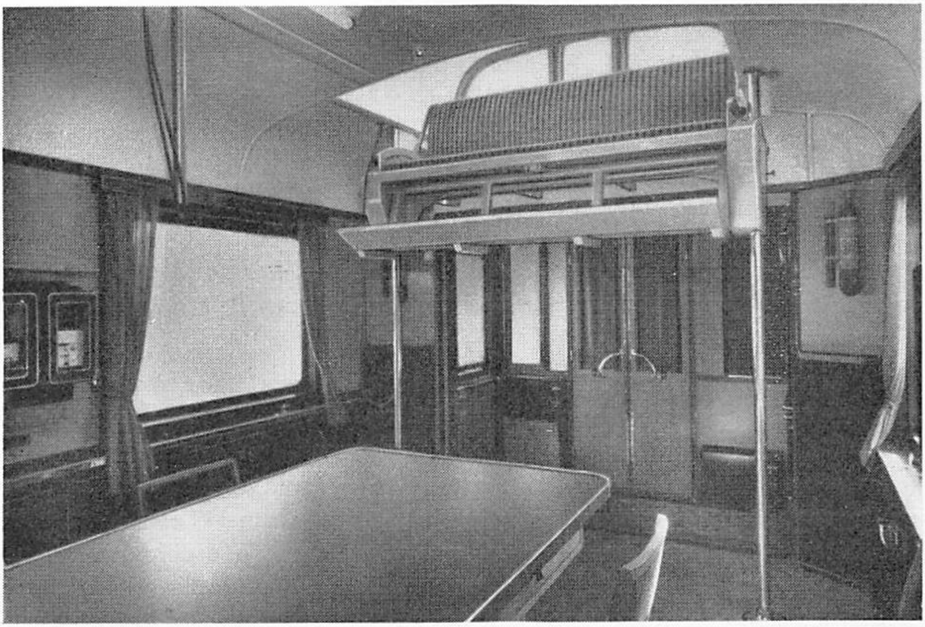


Fig. 6. Elevator seat.

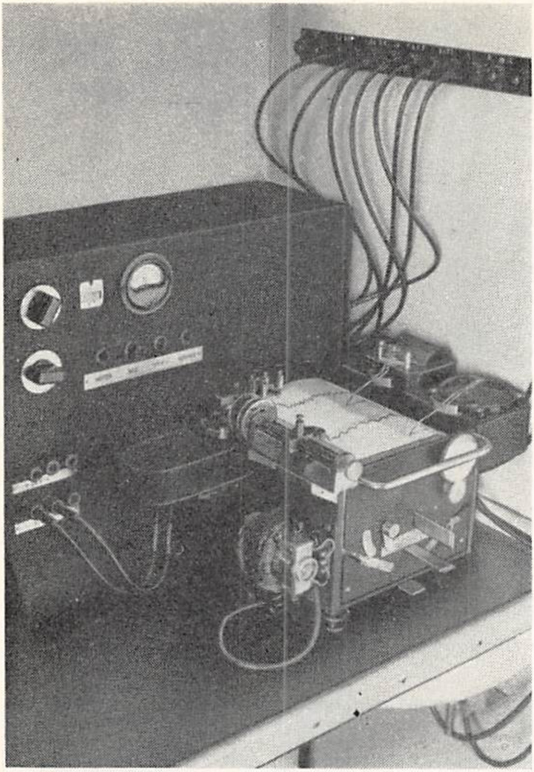


Fig. 7. Photo of the recording equipment.

The workrooms consist of a large measuring room, a high tension room, a heating plant, a dark room and combined workshop and pantry. Furthermore, a small measuring table is installed in one of the compartments so that the measuring apparatus can be transferred to this point if necessary.

The measuring room, Fig. 4, contains instruments for recording the movements of the pantograph, a measuring table with a terminal panel, Fig. 5, arranged at one end, to which connections can be made for measuring the contact wire voltage and the current transmitted by the pantograph to the locomotive, amongst other things. Terminals from batteries and a converter are also available to which oscillographs and the like can be connected. The measuring room also contains an elevator seat, Fig. 6, by means of which a person can be raised to the observation cab.

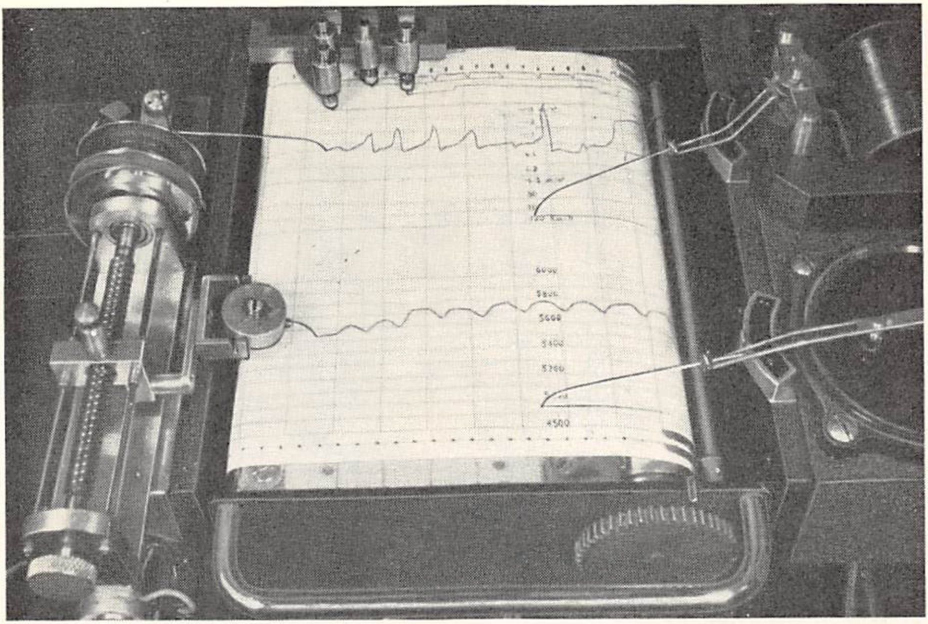


Fig. 8. Close-up view of the recording equipment.

The measuring equipment, Figs 7, 8 and 9, consists of a number of instruments which, together with recording pens and paper feeding mechanism, constitute the unit which records the current collecting process and the factors affecting it. The instruments included in the equipment record the pantograph's (pantograph pan's) height and acceleration, the train speed and the wind velocity relative to the recording car. In order to identify the diagram recorded and facilitate the work, poles and section points and also station buildings and road bridges are marked out on it. In addition, a time interval is recorded every tenth second.

The movement of the pantograph is transmitted to the recording mechanism by means of a nylon- or silk cord which is kept stretched by a cord-tensioning device with a force of about 500 g, which is substantially independent of the pantograph pan's height (above the edge of the rails). The cord thus executes the same movement in a vertical direction as the pantograph pan on the pantograph. That part of the instrument which records this vertical movement consists of a device which is controlled by a screw actuated by the cord, and which has such a pitch that the movement is reduced to the scale of 1: 20.

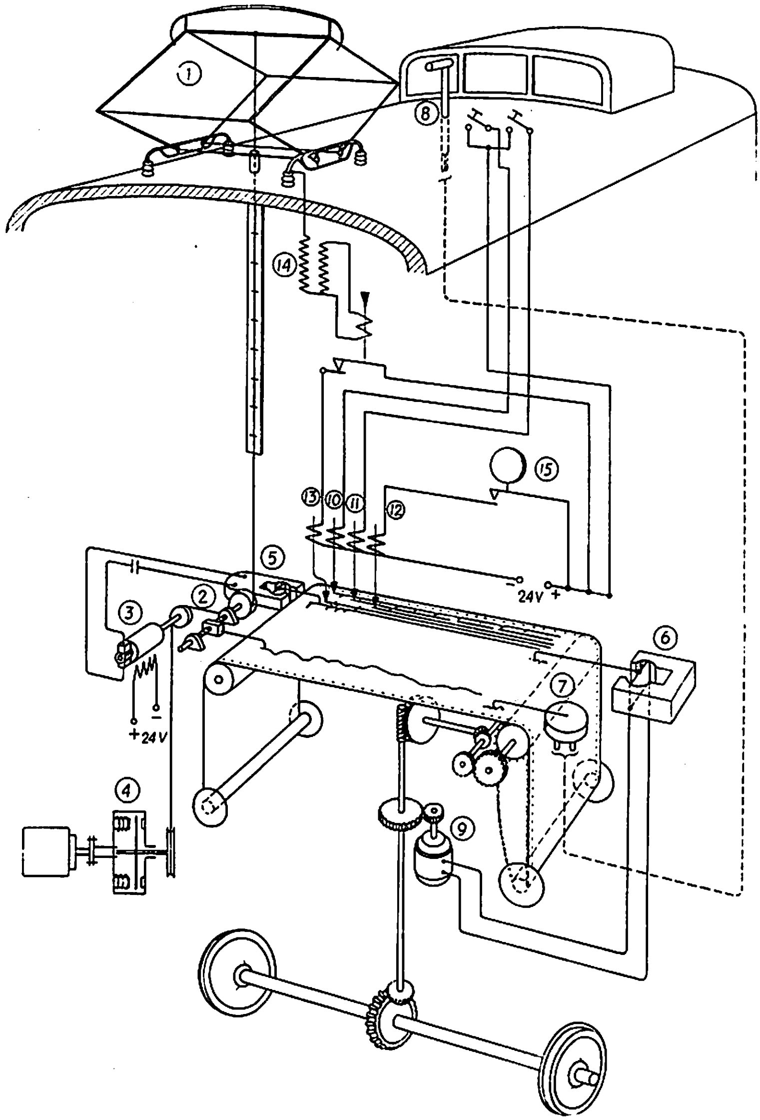
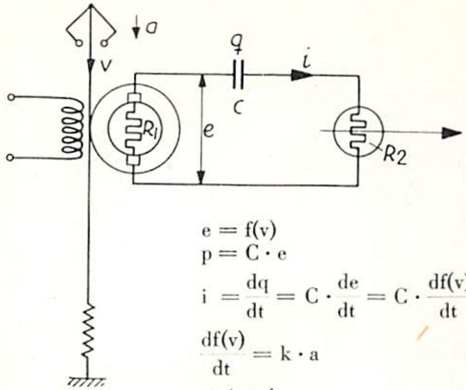


Fig. 9. Diagrammatic view of the measuring equipment.

1. Pantograph.
2. Height recording meter.
3. Generator for acceleration meter.
4. Cord tensioning device.
5. Acceleration meter
6. Train speed meter.
7. Wind velocity meter.
8. Venturi tube.
9. Tachometer generator.
10. Pole recording pen.
11. Station building recording pen.
12. Time recording pen.
13. Recording pen for interruptions in contact.
14. Voltage transformer.
15. Clock switch.

Fig. 10. Lay-out for acceleration meter.



$$e = f(v)$$
$$p = C \cdot e$$
$$i = \frac{dq}{dt} = C \cdot \frac{de}{dt} = C \cdot \frac{df(v)}{dt}$$
$$\frac{df(v)}{dt} = k \cdot a$$
$$\therefore i = k \cdot a$$

The cord likewise transmits the movement to the accelerometer, Fig. 10, a separately excited direct current generator which, in series with a condenser, is connected to a moving coil instrument, the latter recording the acceleration values.

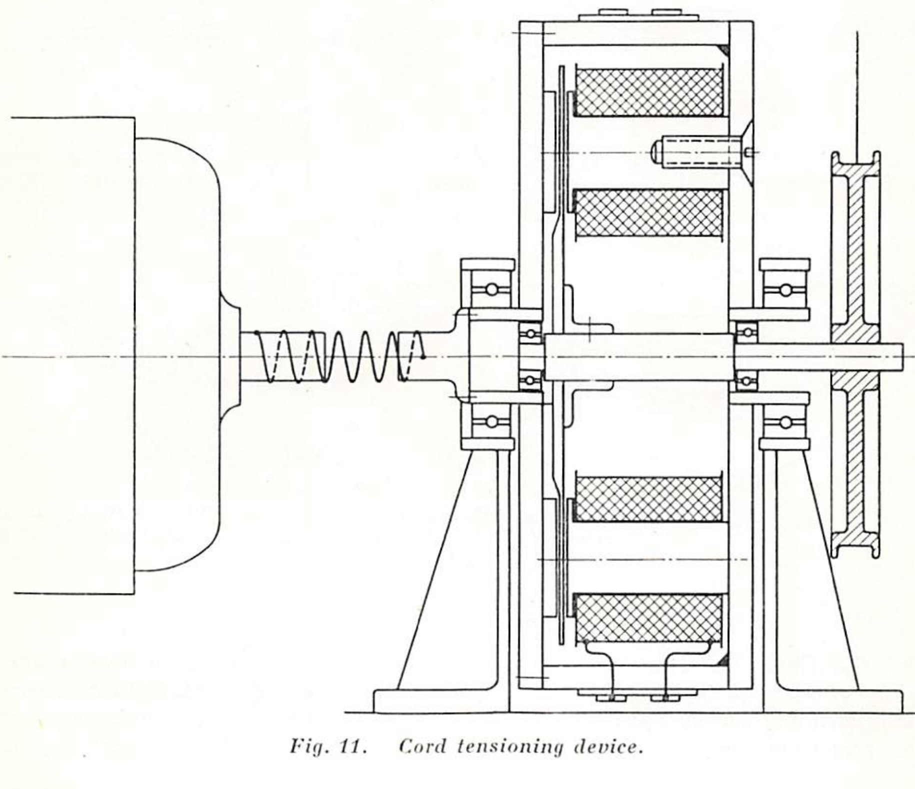


Fig. 11. Cord tensioning device.

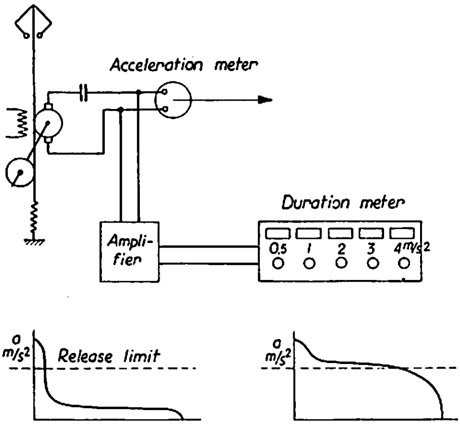
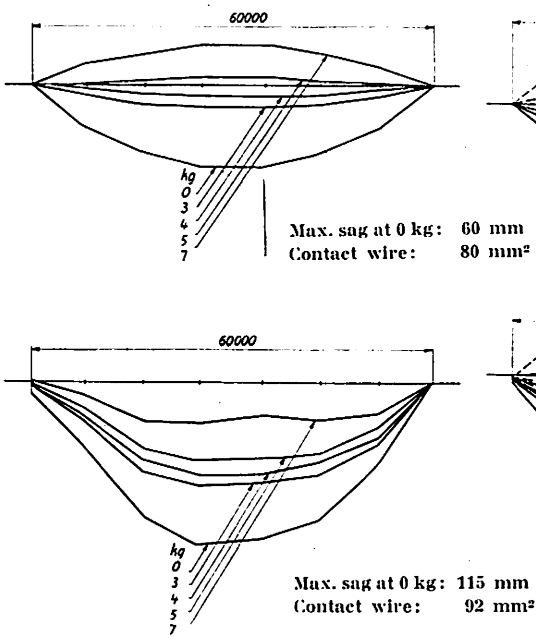


Fig. 12. Acceleration meter and duration meter.



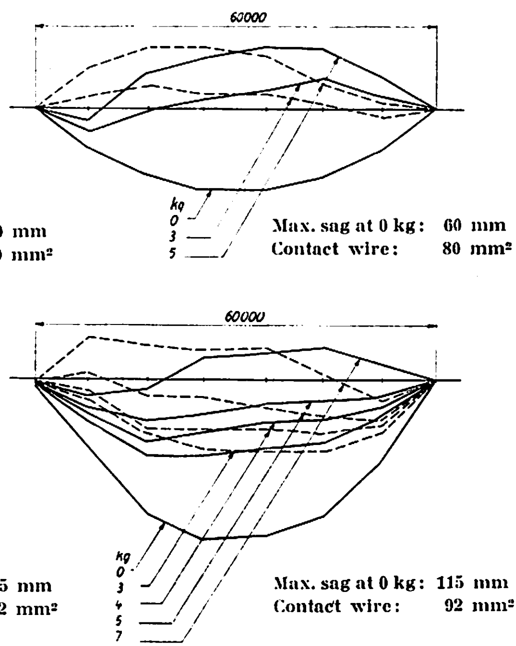


Fig. 13. Curves showing the raising of the contact wire under the influence of varying upward pressures from one pantograph.

Fig. 14. Curves showing the raising of the contact wire under the influence of varying upward pressures from two pantographs.

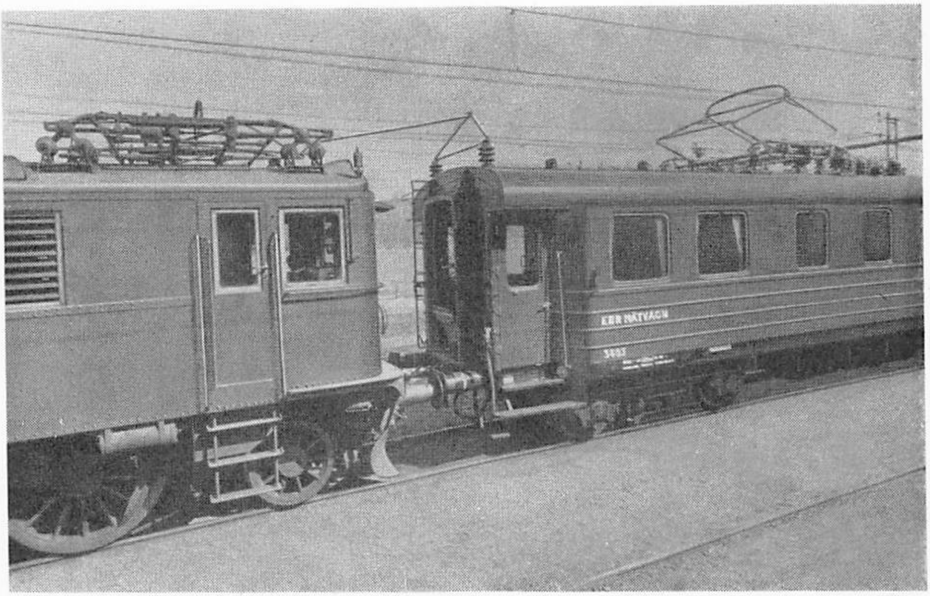


Fig. 15. Flexible high tension coupling.

The occasions on which the pantograph leaves the contact wire are registered on the diagram by one of the recording pens. This pen receives impulses from a no-voltage relay which is connected to the pantograph through a voltage transformer. Recording takes place when the top of the pantograph has moved away from the wire for such a distance that the arc formed between the wire and the top of the pantograph is blown out by the wind caused by the movement of the train.

The paper feeding mechanism can either be driven at a constant speed by a motor or through a mechanical connection from one wheel axle. The latter form of drive possesses the advantage that the diagram strip is fed forward at a speed proportional to the train speed.

The cord tensioning device, Fig. 11, consists of a circular aluminium disc located in a rapidly rotating magnetic field. A drum is mounted on the disc spindle which winds up or unwinds the cord, according to whether the pantograph rises or falls. The magnetic field imparts a practically constant torque to the disc.

The diagram is supplemented by data of a purely numerical nature relating to the condition of the contact wires. For example, a counting mechanism records the number of times the acceleration reaches or ex-

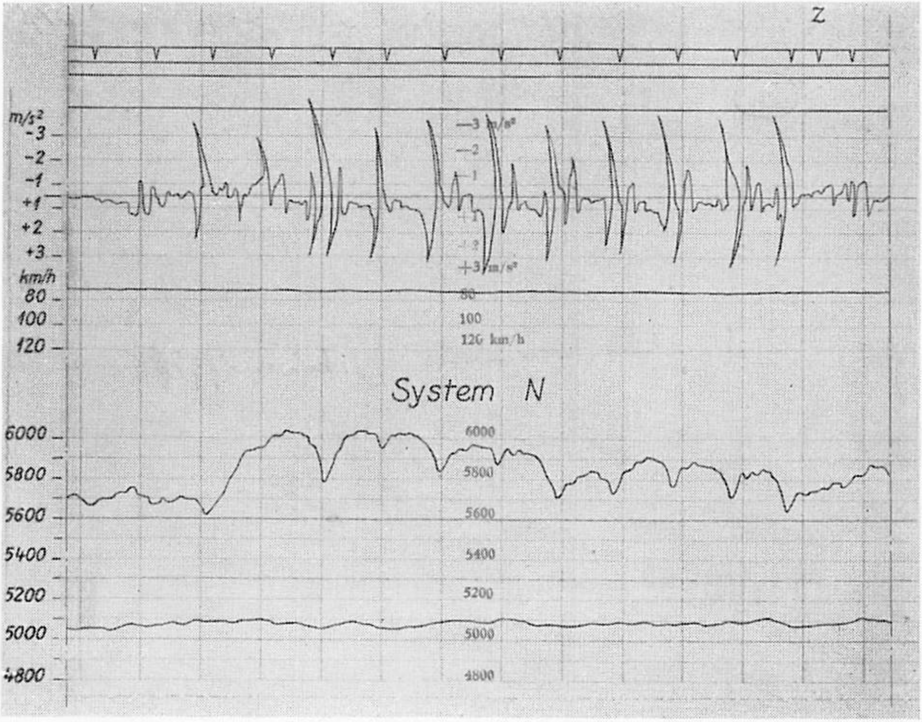


Fig 16. Diagram showing the contact line before adjustment.

ceeds certain values. The lay-out for the arrangement may be seen in Fig. 12. The amplified acceleration values are fed into a duration meter which sorts out the different values so that all those between 0.5 and 1 m/s² are recorded by the first counter whilst those between 1 and 2 m/s² are recorded both by the first and second counter, and so on. From these recorded values, constancy curves can subsequently be plotted.

Of the two examples of these duration curves shown in Fig. 12, the first shows that the contact wire on which the measurements were carried out permits satisfactory current collection except at a few points. The other curve shows, on the contrary, that the contact wire lies badly throughout.

The measurements are usually carried out with only one pantograph in operation so that as correct a picture as possible of the contact wire's condition is obtained. When two or more pantographs are in use, oscillations are generally set up in the contact wire system. Furthermore, the upward pressure of the pantographs against the wire is combined and

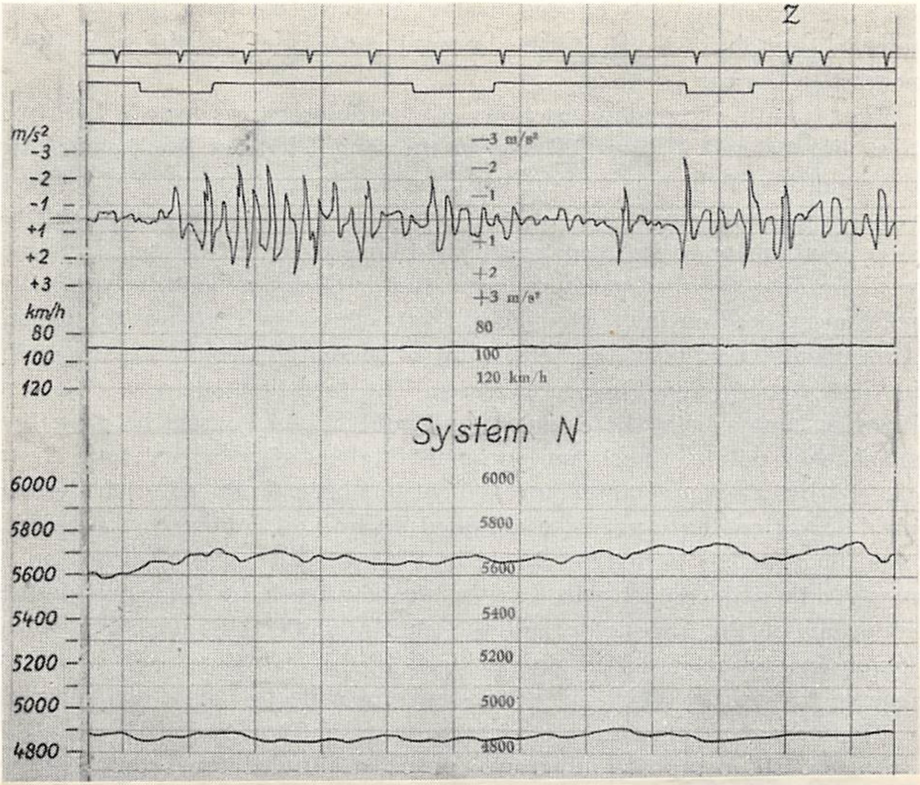


Fig. 17. Condition of contact line after temporary adjustment. Residual increased acceleration values are partly due to inequalities in the track and partly to deformation of the contact wire resulting from delayed supervisory work.

may lead to the raising of the line between the suspension points to a position which is above that of the suspension points, even though the line may have the correct sag when there is no load on it. This condition is still more pronounced if pantographs are used, the upward pressure of which increases considerably under the effect of the wind at high train speeds. These factors give measuring results which are inaccurate to some extent. The diagram reproduced in Figs 13 and 14, showing the raising of the contact wire under the effect of different upward pressures exerted by one and two current collectors respectively mounted on a stationary locomotive, give some conception of the shape of the path followed by the pantographs.

To enable the measurements to be carried out when only one pantograph is in operation, energy must be supplied to the locomotive through the pantograph on the recording car. This is arranged in such a way that the recording car's bus-bar system is connected by a flexible high-tension coupling, Fig. 15, to the lowered pantograph on the locomotive nearest to the car.

Figs 16—19 show some sections of the diagrams recorded. The two first, Figs 16 and 17, were taken over the same length of track and show the condition of the contact wire before and after adjustment. The reasons why the contact wire occupied such a high position between the suspension points prior to its adjustment are found partly in the fact that the wire lies on a so-called pressure curve, that is to say, a curve in which the poles are placed on the same side of the track as the centre of the curve. This usually results in the setting up of increased tensile stresses both in the catenary and the contact wire. The fact that the wire is worn likewise causes both the catenary and contact line to rise between the suspension points. Check measurements taken after adjustment show clearly that an appreciable improvement has been produced, even though ideal conditions have not been obtained. By way of comparison a section of a diagram has been reproduced in Fig. 18 which was recorded on a newly adjusted contact wire over a straight track, and for which the condition of the conductor and the current collection associated with it may be characterized as almost ideal. In this case the track was also located favourably which influences current collection in a high degree.

The measurements on the contact wire are not made solely for control purposes. By using the diagrams recorded on different contact wire systems for comparative purposes, the most suitable system for the particular section of the track in question can be determined. For example, Fig. 19 is a diagram showing the condition of the contact wire over a pressure curve of relatively short radius, where two different systems have been installed side by side under conditions that are as nearly similar as possible. In this special case the two systems exhibit relatively marked differences. As the acceleration values indicate, current collection was smoother when the contact wire was installed in accordance with a system bearing the designation NYT. The most characteristic feature of this system consists in the fact that the contact wire has a relatively large freedom of vertical movement even at the suspension points. This result is obtained both by attaching a supplementary tube to the lower bracket-arm, consisting of a light tube which guides the wire laterally and at the same time partly supports it, and also by the wires forming a Y which supports the lower bracket-arm. In the system designated by N on the other hand, the contact wire is directly suspended from the lower bracket-arm. In this case the dead suspension points are more noticeable.

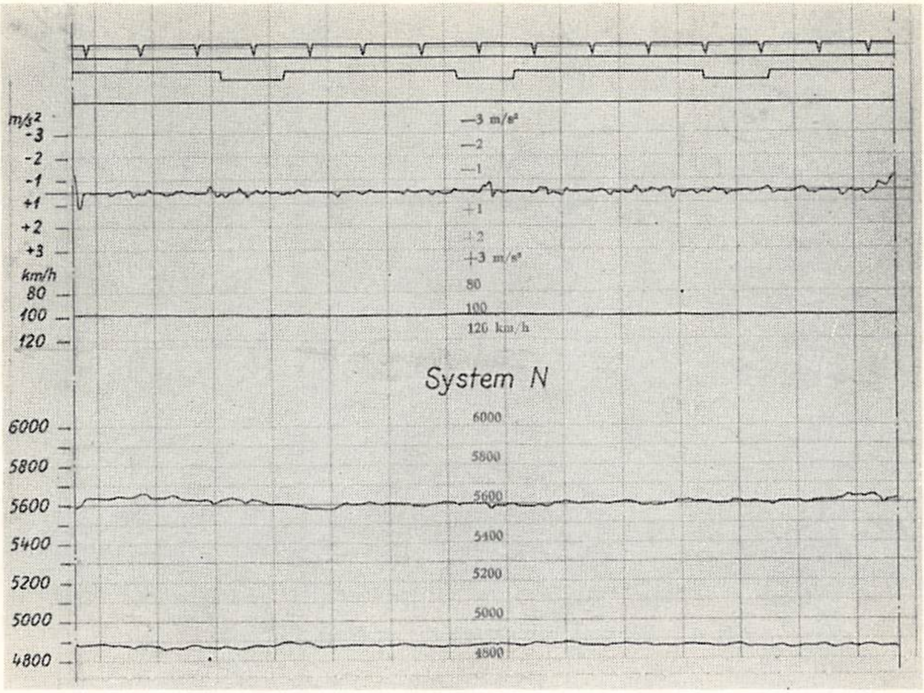


Fig. 18. Diagram for a newly adjusted contact wire.

Hitherto, reference has only been made to the effect of the contact wire and in passing, to that of the track, on current collection. But the part played by the pantograph must not be overlooked, since the latter is of equal importance for the collection of the current to the contact wire itself. It is only intended to mention some of its properties here however, namely, those that exercise the strongest influence on the measurements in the recording car.

First and foremost, the upward pressure (the pressure between the contact strip and the contact wire) must be constant and independant of the train speed and wind velocity. If this is not the case, the wire will be raised too far when the pressure increases with the speed. Under contrary conditions, that is to say, when the pantograph tends to be drawn down by the wind, the wire will be raised insufficiently between the suspension points, and consequently the pantograph will have greater difficulty in following the path of the wire. This results in an increased number of interruptions in the contact. To enable the pantograph to follow the wire as closely as possible, it should have a small mass. Finally,

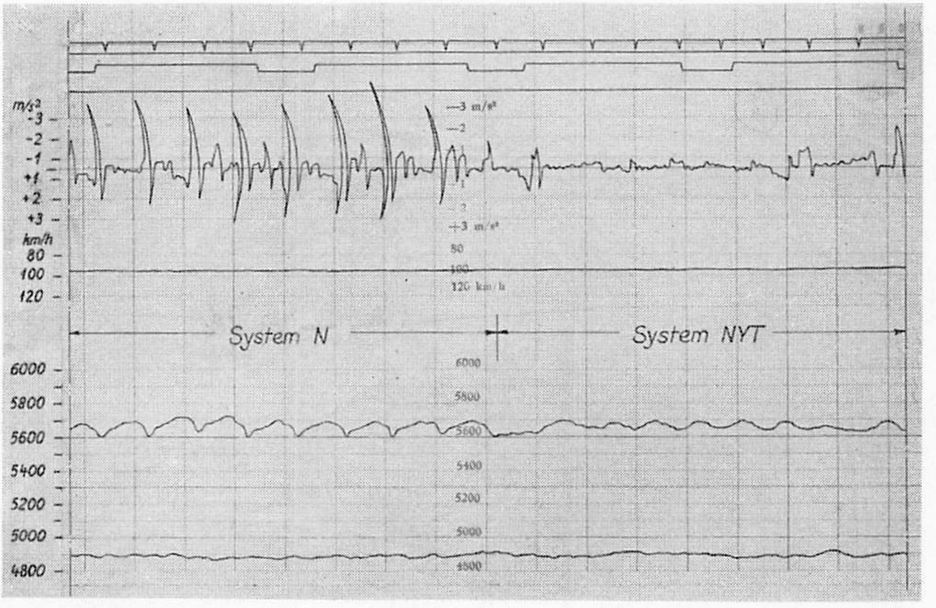


Fig. 19. Diagram comparing the systems NYT and N.

the bearing friction in all joints should be so slight that it does not alter the upward pressure during the up-and-down movement. It may be mentioned here that for pantographs fitted with ball bearings the bearing friction only influences the upward pressure to the extent of a few ounces, whereas the corresponding value for pantographs with sleeve bearings amounts to 4—6 lbs. The pantograph employed on the recording car is specially designed to fulfill the above requirements.

The recording car is also used for a large number of other tests in addition to those mentioned above. For example, the contact wire voltage can be measured and recorded while running, together with the output and energy consumed by the locomotive. For measurements of a more special nature such as the recording of oscillograms under short-circuits and the like, the car affords a convenient and suitable working locality.

The car is further equipped with apparatus for carrying out telephone and radio investigations. Amongst other things, it includes a telephone exchange by means of which connection can be made to all the different types of telephone systems employed on the State Railways. In addition, a frequency-modulated radio station has been installed with which tests relating to range of transmission, interference, etc, can be made.

The routine inspection of the contact wires is carried out twice a year on the main lines and once a year on branch lines. In view of the fact that the main lines, and particularly the contact wires installed on the Stockholm—Gothenburg and Stockholm—Malmö lines, are subjected to greater stresses than the remainder—heavy wear, high speeds—they call for more frequent inspection so that any uneveness in the wire which, owing to the increased wear and impact effect, may give rise to breaks in the wire resulting in serious disorganization of the traffic, may be detected and dealt with in good time.

The diagrams taken in the recording car are copied and sent out to the chief of the track maintenance staff, so that it is possible with their aid to decide directly which sections or points on the line call for immediate attention. This ensures a saving of time and labour as compared with the former method of procedure.

Notwithstanding the short time during which the recording car has been in service much valuable experience has been gained with it in connection with current collection. Much work still remains to be done, however, before the final solutions of the problems referred to above can be found.