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Paper 21

Effects of Dynamic Performance of Rolling Stock on Current Collection

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1 Introduction

Tests have been carried out on pantographs and overhead wire under 'live' wire conditions with special vehicles for measuring the pantograph pressure and interruptions (if any) occurring, see Paper 33 for example, but that another useful approach would be to establish a method of measuring what happens under actual conditions not only with 'live' wire but with the actual locomotive or motor coach with all its actual springs and movements. The results shown in this Paper are the first answers to this problem of measurement and considerable development is still necessary in the measuring technique to obtain a complete co-ordination of the relationship between wire movement, pan head movement, pantograph frame movement, vehicle movement and track displacement, so that having a true knowledge of all the factors involved, optimum current collection can be assured.

2 Factors which affect Pantograph Movement

Some of these have already been mentioned in Paper 20 but before reporting the testing technique it is useful to consider these further. They may be considered under three headings, namely, mechanical, electrical and aerodynamic.

3 Mechanical

3.1 Variation in the height of the overhead contact wire above running rail level. The constructional wire levels are between 13 ft. 5 in. and 19 ft. 6 in. above running rail level, but lift and oscillation of the overhead system follow from the passage of pantographs under the wire, causing change of height locally as distinct from any constructional gradient. Positive measurement of wire movement at the structures were made during the test by the method described in Paper 11.

Variation in the elasticity of the overhead contact system causes local change of gradient in the wire, as the pantograph passes underneath the wire.

3.2 Variation in the height and level of the vehicle roof above running rail, due to the action of the body and bogie springs mainly following deviation of track level or its direction.

3.3 Any of the foregoing factors may be encountered singly or in combination. They may occur simultaneously either in addition or opposition.

3.4 Springing of the vehicle is necessary to achieve comfortable riding qualities which can be expressed in terms of Ride Index Values embracing frequencies and accelerations.

The effectiveness of rail vehicle suspension can be expressed in terms of Ride Index Values based on an evaluation of extensive tests carried out under controlled conditions.[1] It should be mentioned that the higher the index value, the worse the ride and that good carriages ensure a value of 2·5, current steam stock vehicles can rise up to 3 whilst bogie locomotives can attain values of 3·5 to 3·75, all at speeds of up to 90 – 100 m.p.h. The index values are determined as a function of frequency and acceleration and the significance of the Ride Index Values will be gathered from the table, the main accelerations being given as function of the gravitational accelerations: g.

Reference

[1]J. Koffman, 'The Riding of Bogie Vehicles', The Railway Gazette, Nov. 27, 1959. 'Vertical Oscillations of Bogie Vehicles', The Railway Gazette, July 15, 1960.

Ride Index Values as a Function of Frequency and Mean Acceleration in terms of g.

Ride Index	Frequency (c.p.s.) 0·5	1	1·5	2	2·5	3
Vertical						
2·5	·055	·044	·039	·035	·032	·031
3·	·1	·08	·07	·064	·06	·056
3·25	·135	·105	·092	·085	·078	·073
3·5	·175	·135	·12	·11	·1	·092
3·75	·21	·17	·145	·135	·125	·115
4·	·27	·21	·185	·17	·155	·145
Lateral						
2·5	·04	·035	·029	·0265	·0245	·028
3·	·075	·06	·053	·048	·044	·042
3·25	·098	·078	·068	·063	·058	·064
3·5	·125	·1	·088	·08	·074	·07
3·75	·16	·125	·115	·1	·095	·086
4·	·2	·16	·138	·125	·115	·11

With the new locomotives the body bouncing and pitching frequencies are 1·5 to 2 c.p.s. Nosing is at about 1 c.p.s., whilst the natural frequency of swaying is about 0·7 c.p.s. In addition, the locomotives are subjected to swaying at frequencies of 1·5 to 2·2 c.p.s., but even these are too low to excite the natural frequencies of the pantograph structure. The highest frequencies usually encountered in service are caused by bogie pitching at 5 to 8 c.p.s., depending on design. The resultant amplitude can be sufficiently pronounced to excite body oscillations of up to 0·5 in. Without adequate damping, particularly at the primary springs, these oscillations can be responsible for increasing the lateral pantograph displacement by 1 in. and more.

3.5 The unbalanced lateral force encountered in service can attain values equivalent to 0·1g. With an effective swing link length of about 20 in. employed with some of the locomotives, the lateral displacement will be about 2 in., thus leaving another 2 in. for displacement due to body rolling on the springs, the remaining 1 in. out of a total of 5 in. allowed, being reserved for wear. To allow for the value claimed by roll, the lateral displacement with most of the vehicles concerned was limited to 0·7 to 1·75 in. depending on design.

3.6 Since the desire for good riding qualities in the vertical plane called for a relatively soft suspension, it was essential to increase the spring base as far as possible. Consequently the distance between the bolster springs with most of the locomotives is 7 ft. and even 7 ft. $5\frac{3}{4}$ in., although in one case, special design features limited this dimension to 5 ft. 3 in. The distance between the primary springs varies between 6 ft. 3 in. and 6 ft. $9\frac{1}{2}$ in. As a result of these measures, the body roll on the springs does not exceed about 1° whilst the total displacement at pantograph pan level does not exceed 3·25 in. to 3·75 in. depending on design.

4 Electrical

The electrical requirements imposed on the current collection are peculiar in so far as two distinct voltage levels are used thus resulting in the necessity of dealing with currents varying between 270 and 1000 amps. In addition, the conversion to A.C. of some lines already running at 1500V D.C., further complicates the requirements. With the locomotives and new M.U. stock built for A.C. lines, the power demand rises gradually with speed, whereas with the old D.C. stock connected to work from A.C. overhead, the power is at two distinct levels up to the end of the notching-up period due to the series/parallel D.C. connections which have been retained.

5 Aerodynamic

At speeds in excess of about 60 m.p.h. the aerodynamic forces tend to affect the stability of current collection. Because of this, great care must be devoted to the correct shaping of the pantograph structure, to the shape of the vehicle roof, the location of the pantograph and position and shape of roof mounted equipment adjoining the pantograph.

However, with the vehicles concerned, wind tunnel tests with simulated roof shapes carried out at air speeds of up to 100 m.p.h. have shown that the increase in upward pressure for both directions of vehicle motion did not exceed 5 lbs.

6 Road Tests

A number of test runs have been made over a section of track specially prepared to induce lateral and swaying oscillations of vehicles. The track was modified by introducing sinusoidal elevations spaced at 60 ft. intervals at alternative sides. The vertical deviations were of a sinusoidal pattern, the rails being raised to a height of $\frac{1}{4}$ in. and subsequently to $\frac{1}{2}$ in.

The overhead equipment at this place consists of single stitched catenary now used for the electrification on lines restricted to 75 m.p.h., but it was considered interesting to obtain the results with this construction at 100 m.p.h. As shown in fig.1, there are certain gradients in the wire at this site and the measurements having been made over *four* span lengths, the effect of register arms at the structures is apparent.

The locomotive E3006 used throughout the tests was of A.E.I. – Rugby manufacture, full details of the springing being given in Paper 15. The vertical displacements of the primary and secondary suspension as well as the lateral displacement of the body relative to the bogie frame, were recorded with the aid of resistance transducers. In addition, the vertical and lateral accelerations of the locomotive body were recorded with the aid of recording inductance accelerometers, capable of responding to all the motions involved. The motion of the pantograph head relative to the pantograph base and the contact wire was recorded with the aid of a high-speed cine-camera (about 130 frames per second), permitting continuous recording under normal operating conditions and eventually of measurement of displacement by analysis of consecutive frames. The equipment is described in Paper 11.

Fig.1 is an example of records obtained by this technique. Many more such tests will be needed and will be made to permit useful comparisons and hence the needful conclusions. One inference from this chart is that the pantograph can absorb the movements imposed by the vehicle and track.

It must be mentioned that at the time of the tests, only a limited number of electric vehicles had run over the section concerned, whilst the normal through services were maintained mainly by steam locomotives, diesel railcars being used for local traffic. In spite of these circumstances, the standard of current collection was quite satisfactory, particularly if it is borne in mind the overhead equipment is not of the type now considered desirable for the highest speeds involved.

The magnitudes of locomotive body motion in the vertical plane suggests that the accelerations do not exceed the limits required to ensure effective operation so far as current collection is concerned.

The results of these tests, amplified by the visual inspection of the cine-camera records obtained so far for both locomotives and multiple-unit trains operating over a number of track sections on both the Styal and the Colchester – Clacton line by day and by night, show that after initial operation which has cleaned and 'bedded in' the contact wires, collection is practically sparkless.

7 Future Tests

The preliminary tests carried out so far and briefly dealt with in this Paper, have confirmed that with suitably designed vehicles and overhead equipment, current collection does not present difficulties at speeds of up to 105 m.p.h. However, since the track conditions are likely to vary within the normal limits set by maintenance, weather conditions will be intermittent and the consistency of vehicle riding will be affected by tyre etc. wear, whilst on the other hand, the desire to keep vehicle weight to a minimum will pose new problems in terms of oscillations, it will be necessary to continue the tests in order to obtain additional information. In this manner it will be possible to acquire under service conditions sufficient data to enable vehicle and overhead designers to appreciate fully the effect of design variables and to make use of the knowledge thus obtained to ensure completely satisfactory operation of the current collection equipment at all speeds and under all conditions likely to be encountered in the future.

Because of this, tests will be extended to each type of locomotive and multiple-unit train utilising either photography or displacement meters mounted on the pantograph frame or, alternatively, using a wireless link to transmit the movement of the pantograph to the vehicle, thus maintaining the principle of carrying out the measurements under normal service conditions, which has already been found to be of appreciable value. This is not to say that the recording vehicles described in Paper 33 can be superseded, nor that the model techniques described in Paper 33A are unnecessary. All three methods and indeed others have their special advantages and only good results can follow from study of the record of each of them.

SUMMARY

Satisfactory current collection demands that the pantograph should overcome the factors which are likely to cause either unduly high pressure or loss of contact under all conditions encountered in service. These factors are grouped under three headings, (*a*) Mechanical, (*b*) Electrical, (*c*) Aerodynamic. The Paper discusses these factors, stressing that good riding qualities of the vehicle are an obvious prerequisite so far as passengers and crew are concerned. The riding qualities can be expressed in terms of Ride Index Values which, for passenger-carrying vehicles should not exceed the magnitude of 3 to 3·25, whilst for locomotives 3·5 to 3·75 can be permitted.

It then describes tests recently made of vehicle and pantograph movements deduced from acceleration recording and high speed cine-camera films in operation at speeds of up to 105 m.p.h. on level and on disturbed track. They are of considerable value for assessment of the current collection performance of the pantograph. The interaction of the pantograph with the overhead was found to be generally satisfactory.

Results of preliminary tests are briefly considered and related to other work in progress on this matter.

RÉSUMÉ

Le captage satisfaisant du courant exige que le pantographe puisse éviter sous toutes les circonstances de service, les facteurs qui peuvent causer soit une pression excessivement élevée, soit une perte de contact. Ces facteurs sont étudiés sous trois groupes: (*a*) mécaniques, (*b*) électriques, (*c*) aérodynamiques. L'exposé discute ces facteurs et souligne que la bonne qualité de roulement de la voiture est une condition nécessaire évidente en ce qui concerne les voyageurs et l'équipe de conduite. La qualité de roulement peut être exprimée avec les valeurs de la cotation de roulement. Elle ne dépasse pas 3 à 3,25 pour les voitures de voyageurs, tandis qu'une valeur de 3,5 à 3,75 peut être permise pour les locomotives.

L'exposé décrit ensuite les essais effectués récemment sur les mouvements de la voiture et du pantographe. Les mouvements sont étudiés à partir d'enregistrements d'accélération et de films de caméra à haute vitesse pris à des vitesses atteignant 105 m.p.h. sur voie régulière et sur voie rendue irrégulière. Ils sont d'une valeur considérable pour l'évaluation des performances du pantographe en ce qui concerne le captage de courant. La réaction réciproque du pantographe et de la caténaire s'est avérée généralement satisfaisante.

On considère brièvement les résultats des essais préliminaires et leur relation avec les autres travaux en cours sur cette matière.

ZUSAMMENFASSUNG

Zufriedenstellende Stromabnahme erfordert, dass der Stromabnehmer fähig ist, unter allen im Betrieb vorkommenden Bedingungen die Einwirkungen unschädlich zu machen, die entweder unnötig hohen Kontaktdruck oder Unterbrechung zur Folge haben könnten. Diese Einwirkungen werden in drei Gruppen zusammengefasst, (*a*) mechanische, (*b*) elektrische, (*c*) aerodynamische. Der Bericht erörtert diese Einwirkungen und betont, dass gute Laufeigenschaften des Fahrzeugs eine selbstverständliche Vorbedingung mit Rücksicht auf Fahrgäste und Zugpersonal sind. Die Laufeigenschaften können durch den 'Laufgüte Index' bewertet werden, der für Personenfahrzeuge 3 bis 3,25 nicht überschreiten sollte, während bei Lokomotiven Werte von 3,5 bis 3,75 zugelassen werden können.

Weiter werden vor kurzem durchgeführte Untersuchungen von Fahrzeug- und Stromabnehmerbewegungen beschrieben, die aus Registrierungen der Beschleunigung und aus Zeitlupen-Filmaufnahmen abgeleitet werden, bei Geschwindigkeiten bis zu 105 Meilen je Stunde auf gut unterhaltenem oder künstlich gestörtem Gleis. Sie sind von grossem Wert für die Beurteilung der Güte der Stromabnahme. Das Zusammenarbeiten von Stromabnehmer und Fahrleitung war im allgemeinen zufriedenstellend.

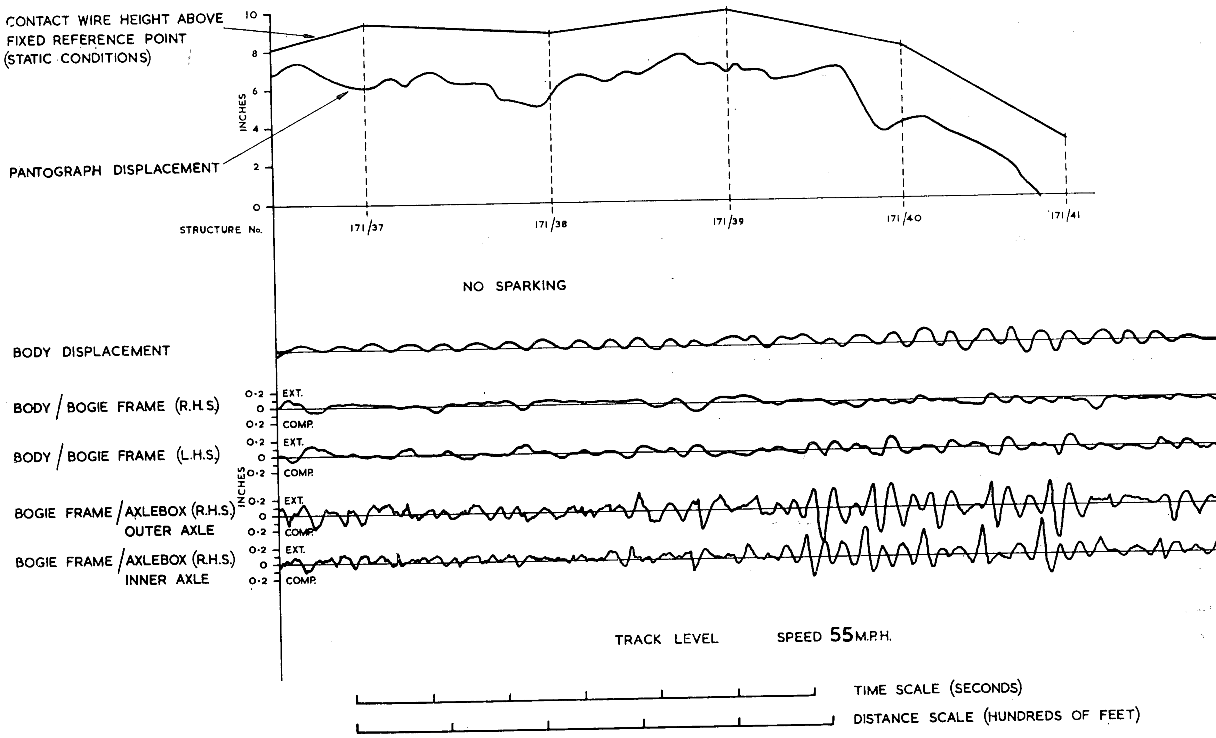
Die Ergebnisse vorläufiger Versuche werden kurz besprochen und mit weiter laufenden Untersuchungen in Beziehung gebracht.

RESÚMEN

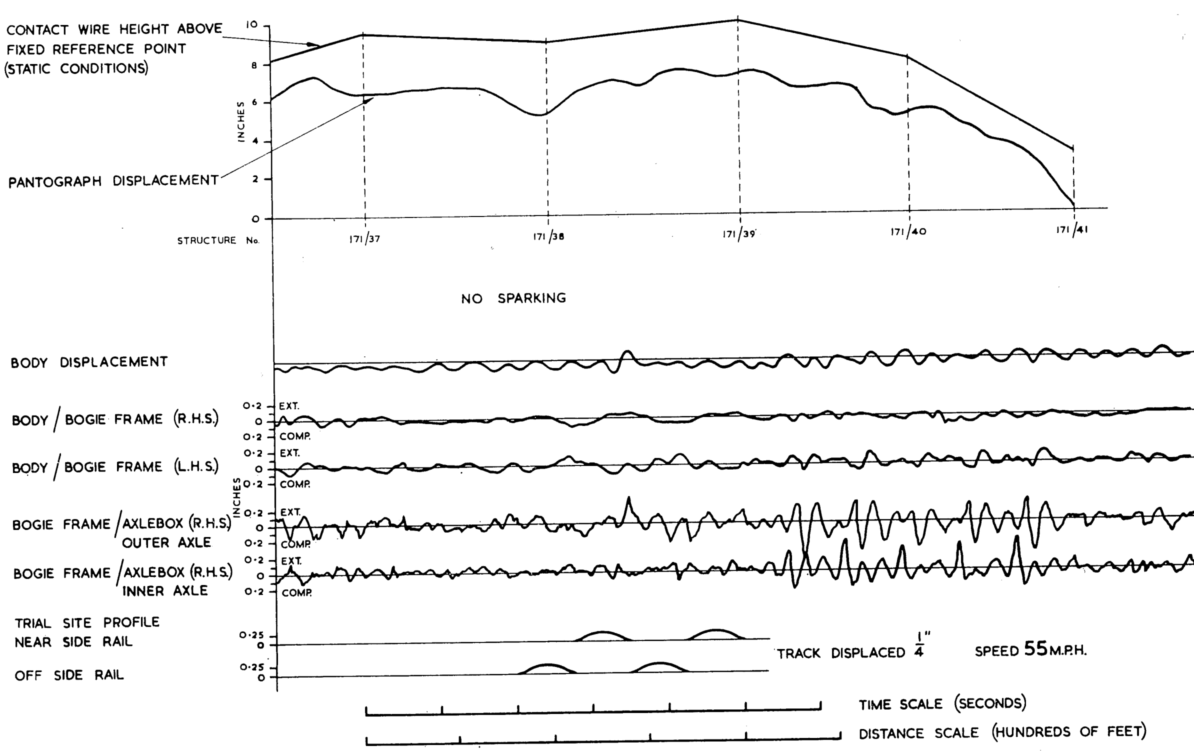
Por las exigencias de la colección perfecta de corriente, es menester que el pantógrafo, en todas condiciones de servicio, pueda vencer los factores que crean eventualmente una presión demasiado alta o destruyen el contacto con la catenaria. Estos factores se clasifican en tres grupos, á saber: (*a*) mecánicos, (*b*) eléctricos, y (*c*) aerodinámicos. El folleto presenta una discusión de estos factores, señalando que una marcha estable del tren o locomotora es evidentemente una necesidad tanto por los pasajeros que por el personal de servicio. La estabilidad y suavidad de marcha pueden expresarse en términos de los valores del 'Ride Index' (Índice de Marcha); en cuanto á los vehículos de pasajeros el valor del Índice no debería pasar los limites de unos 3 á 3.25, mientras para las locomotoras es posible permitir valores de 3.5 á 3.75.

El folleto describe después unas pruebas hechas hace poco, sobre los movimientos de los vehículos y de los pantógrafos, con auxilio de medidas registradas de la aceleración y de películas de cine de alta velocidad, hechas á velocidides de tren hasta casi 105 m.p.h. sobre líneas bien allanadas y líneas desiguales. Tales pruebas tienen un valor apreciable en la determinación del funcionamiento del pantógrafo como colector de corriente. Se halló que la acción recíproca entre el pantógrafo y la catenaria daba en general amplia satisfacción.

Finalmente, unos detalles de los resultados de pruebas preliminares son brevemente considerados y relacionados á otros trabajos hechos en el asunto.

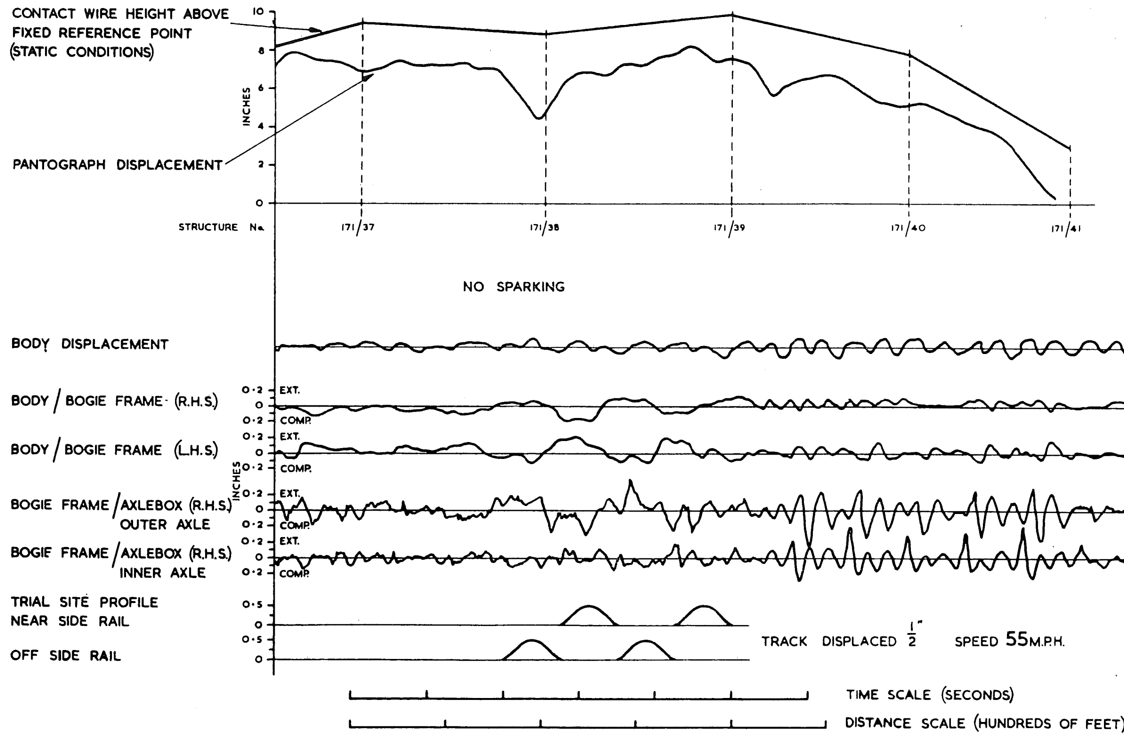


TEST A



TEST B

Fig.1 Locomotive and Pantograph movements



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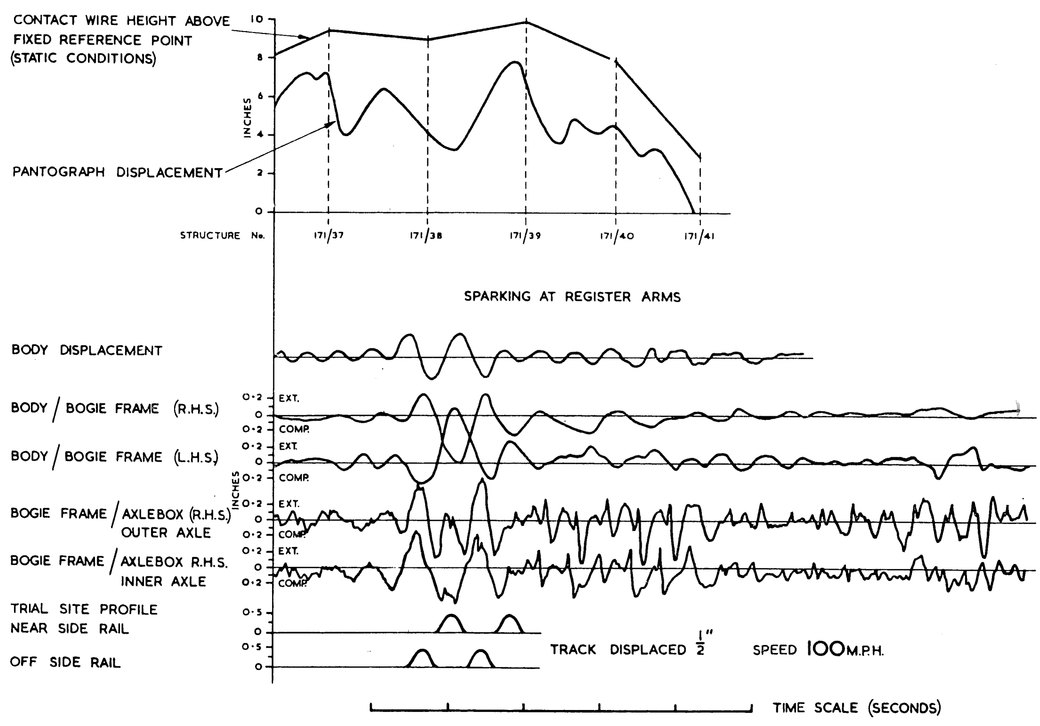

TEST D

Fig.1 (contd.). Locomotive and Pantograph movements

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