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Paper 20

Pantographs for Locomotives and Multiple-Unit Trains

E. E. Chapman, BSc, MIMechE, MIEE
Director and Chief Engineer, J. Stone and Co. (Deptford) Ltd

1. Introduction

The pantographs described in this paper have been standardised by the British Transport Commission for all their 25/6·25 kV 3,300 h.p. locomotives and 900 h.p. motor coaches of multiple-unit trains. They are known as type AM–BR (fig.1) and derive from the pantograph type AM developed by Etablissements L. Faiveley, Paris, in association with the S.N.C.F. They have been designed and made by J. Stone & Co. (Deptford) Ltd, under license from Etablissements L. Faiveley to the specification and under the guidance of the Chief Electrical Engineer of the B.T.C. Two pantographs are fitted on each locomotive and one for each motor coach of multiple-unit trains. Orders in hand exceed 700 pantographs and over 600 have been delivered.

2. Choice of Pantograph for British Railways

In spite of very satisfactory performance with conventional pantographs on its 1,500-volt overhead electrifications, several factors led to the choice of the AM type for the new standard. Among these were the saving of length needed on the roof and the expectation that consistent performance and minimum maintenance would result from a construction using ball/roller/bearings in essential joints of the mechanism, which are reduced to the minimum by the geometry of the construction.

The former consideration is of great importance in view of the very restricted loading gauge to which the motive power units must conform which, coupled with a relatively large wheel (see paper 3) reduces the headroom within the locomotive to the bare minimum, whilst the requirement of maximum weight restricts the length of the locomotive. The necessity of mounting the pantograph above the guard's van of multiple-unit trains (see paper 4) to avoid loss of seating accommodation demands a pantograph of minimum length. At the same time the total range over which sparkless current collection is required is from 13 ft 5 in. to 20 ft 6 in. and on many sections of electrified line the contact wire frequently varies to one extreme or the other from its normal height of 16 ft. above track on account of overbridges or level crossings frequently close to one another.

These problems are more severe than those normally encountered. In addition, because of the traffic pattern of British Railways (see paper 5), it is essential that contact wire wear is reduced to the minimum to avoid maintenance. This was considered to demand the use of graphite collector strips, a major difference between the AM–BR pantograph and its French prototype. The frequency of junctions and cross-overs and the high cost of obtaining the necessary air clearance for insulation are shown later to explain other important differences such as the use of a curved pan capable of collecting current over its whole width of 5 ft 3 in., fig.(2) and arrangements to avoid tilting of the pan transverse to the track.

Two other special factors remain to be mentioned. Firstly that current collection is required at full power at both 25 and 6·25 kV up to speeds of 100 m.p.h. Secondly, the pantograph must not only collect satisfactorily from the light overhead equipment associated with high voltage A.C. electrification, but motive power units running into the Liverpool Street Station, a London terminal of the Eastern Region, must also be able to collect from the much heavier overhead equipment installed in 1949 for the Liverpool Street – Shenfield electrification and retained in commission after the conversion to 6·25 kV.

The foregoing requirements in the aggregate clearly demand a pantograph of very elegant design, manufactured with great precision. Further, certain details of design incorporated in the AM–BR pantograph to assist maintenance are considered to be improvements.

3. Major Design Features

Although development is still proceeding, the major design features of the pantographs in current production described in detail in sections are unchanged from those ordered initially, after brief trials of prototypes on the Lancaster – Morecambe – Heysham and the Liverpool Street – Shenfield electrified lines. The former of these lines has weight-tensioned equipment, the other is fixed equipment in which the tension on the contact wire varies with the ambient temperature.

B.T.C. practice in regard to the design of catenaries is described in paper 31, briefly weight-tensioning wherever possible and compound catenary suspension for speeds above 60 m.p.h. and is preferred to stitched catenary, simple catenary construction being used for track restricted to speeds below 60 m.p.h. The catenary supports and register arms are arranged to keep the wire within 19 in. of track centre but sway and track variations are of importance and this aspect is discussed in detail in Paper 21.

Cognisant of the importance of close collaboration between all contractors concerned, in view of the contract boundaries for overhead equipment and rolling stock terminating at the vital point where current is collected, the Chief Electrical Engineer of the British Transport Commission arranged for the necessary interchange of information and ideas between all concerned from the inception of the decision to use a standard pantograph ordered by him as a free issue to all contractors for motive power units.

The following design parameters stem from his consideration of all the factors so far mentioned :—

(*a*) The pantograph profile, fig.2, essentially a compromise between a narrow pantograph easing the clearance problem and a wide one permitting more freedom with the position of the contact wire relative to the track.

(*b*) The adoption of graphite collectors over the major (and most used) part of the pan and the use of rubber in the resilient mounting of the pan.

(*c*) The use of ball-bearings wherever possible with a construction of great strength to produce a thoroughly reliable mechanical design capable of consistent performance under all operating conditions and with fewer joints than the conventional type.

4. The Development of the Design

The foregoing parameters are met by a design in which the following features are important:—

4.1 *Collector Head*

A collector head assembly which is as light as possible and is connected to the main articulated system by separate resilient mountings to ensure the maximum response to small changes in the height of the contact wire. This resilient mounting is so arranged that the virtual fore-and-aft centre of rotation of the collector head is at or above the point of contact with the overhead line. The special resilient mounting of the head provides for a fore-and-aft variation from the horizontal position under normal service conditions of up to $\pm$ 5 deg.

4.2

A main articulated system of low inertia to ensure the ability of the pantograph as a whole to respond quickly to large changes in the height of the contact wire. The design is such that the increase in force on the overhead line due to aerodynamic effects does not exceed 5 lbs. at 100 m.p.h. with a normal force on the overhead line of 18 – 20 lbs. at low speeds.

4.3

All pantographs so far supplied have been fitted with metallised carbon made by Morgan Crucible Co. which has the advantage of being stronger and having a higher current carrying capacity than plain carbon. Nevertheless, the carbon in the metallised carbon strips constitutes a lubricating medium between the overhead line and the collector strips. Whilst an increase in contact force between the collector and the overhead line tends to increase the mechanical wear, this is only a small proportion of the total wear which takes place and is in any case compensated by the inherent lubricating qualities of the carbon collectors.

4.4

The collector head must, as is usual, remain substantially horizontal in the fore-and-aft direction when it is not loaded by the overhead wire throughout the full working extension of the pantograph, notwithstanding the novel construction of the type of articulated system which is used. In the actual design this is kept within $\pm$ 2 deg. of the horizontal position.

4.5

Up to the present it is a particular requirement that the collector head should remain horizontal in the transverse direction as tilting of any noticeable amount is inadmissible on account of electrical clearances. Nevertheless it is also required that the head should have a small amount of resilience in the transverse direction to reduce shocks when picking up an incoming wire and this is also provided by the special mounting arrangements between the head and the articulated system of the pantograph itself.

4.6 *Articulated System*

This is of very robust construction, nevertheless having low inertia and high lateral stability. The main supporting member is an exceptionally strong tubular T piece. However, since this forms the lower part of the articulated system, its effect on the inertia of the pantograph as a whole, is small. The lateral stability of the complete articulated system is such that a side force of 110 lbs. applied at the head does not produce a displacement exceeding $1\frac{1}{4}$ in. at this point.

4.7 *Contact Pressure*

The question of pantograph contact pressure, which is a combination of the static upward force developed by the pantograph working springs and the aerodynamic effect of speeds up to 100 miles per hour in either direction of travel

has been limited to 25 lbs. arranged such that 20 lbs. are allocated to the static force and 5 lbs. for the aerodynamic effects.

The aerodynamic upward thrust was established during wind-tunnel tests on a full size pantograph mounted on a flat surface simulating the flat roof of a vehicle.

The static force has therefore been set at 20 lbs. plus 0 lbs. minus 2 lbs. over the working range. At any loaded equilibrium position a difference in vertical force at the head of not more than plus or minus $2\frac{1}{2}$ ozs. will cause upward or downward movement.

4.8 *Raising and Lowering*

These operations are controlled by an air motor which is operated by the driver. This is arranged so that the pantograph is permitted to rise at a suitable rate to avoid undue shock to the pantograph and to the overhead line. When lowering the pantograph, it will drop quickly until within about 12 in. of its rest position, after which its rate of descent is controlled as the mechanism drops from that point to the rest position.

It is, of course, essential that the air motor should be capable of lowering the pantograph at any train speed and keeping it at the rest position under such conditions.

5. Description

The pantograph is shown diagrammatically in fig.3 and isometrically in fig.4.

5.1 *Main Frame*

This comprises a sub-frame of welded section, which is insulated from the roof of the vehicle, to which are attached the bearings (3) which carry the main tubular T member (4) which forms the lower portion of the articulated system. The upper part is formed from two tapered tubes which are joined at their lower extremity by a yoke casting and this assembly is carried on the T member (4) by ball-bearings. The fore-and-aft attitude of the head in the unloaded condition is controlled by the lever arrangement (8, 15, 14 and 10), together with a spring loaded parallelogram linkage at either end of the spreader (see fig.4).

The pantograph is raised by two springs which, together with the four spring fulcrum adjustable stop abutments, ensure the substantially constant upward force throughout the working range as shown in fig.5. This figure also shows the high degree of consistency in making large batches of pantographs.

5.2 *Collector Head*

A diagram of the mounting of the collector head is shown on fig.6. The head is supported on resilient rubber mountings which are inclined to the vertical both transversely and in the fore-and-aft direction, so giving the head a small amount of transverse resiliency with an adequate amount of fore-and-aft tilt. Another feature of this suspension arrangement is that the virtual centre of rotation of the collector head is arranged to be at, or slightly above, the overhead wire, thus providing the most satisfactory contact conditions between the collector strips and the overhead wire.

The central part of the head is of the lightest construction consistent with the necessary attachment arrangements for the metallised carbon strips which are clamped with set screws to the collector frame. The Morgan Crucible Co. have been of great assistance in connection with these clamping arrangements and the desirable characteristics of the collector head suspension. Pressed metal horns are provided at either end of the head and these are fitted with renewable stainless steel rubbing strips.

5.3. *Air Motor.* The air motor is straightforward but fig.7 shows the control valve in greater detail than that indicated in the schematic diagram fig.3.

Referring to fig.7, when air is admitted through the orifice (15) by means of the driver's control, it will leak slowly through the central vent in the valve body (12) into the air motor. Referring to fig.3, the air pressure will force the air motor piston (1) against its springs (2), thus permitting the working springs (16) (see fig.4) to raise the pantograph at a controlled rate until the collector meets the overhead wire. The air motor piston then completes its full stroke. At this stage the pantograph is free to operate through the whole of its working range without any interference from the air motor by virtue of the slot (4) (fig.3) in the insulated rod between the pantograph and the air motor.

When the driver's control is moved to lower the pantograph the air pressure in the air motor cylinder lifts the valve body (12) (fig.7) completely off its seat against the pressure of the spring (3) so that the air motor is freely vented to atmosphere through the apertures (13). However, as soon as the force of the spring (3) balances the air pressure in the air motor cylinder the valve body (12) is forced back on to its seat and thereafter the rate of descent of the pantograph is controlled by the leak through the central vent in the valve body (12).

5.4. *Insulators*

Doulton Industrial Porcelains Ltd are sub-contractors for the porcelain insulators. The foot insulator is of the pin and cap type capable of withstanding test conditions of 90 kV dry and 60 kV wet. It is designed to stand up to a mechanical tension and cantilever test to 10,000 lbs. and 5,300 lbs. respectively.

The air motor rod insulator is capable of withstanding a test condition of 90 kV dry, and 70 kV wet.

6. Service Experience

6.1. The S.N.C.F. have had considerable experience on this type of pantograph supplied by Etablissements L. Faiveley (Type AM) which is similar in principle to the type AM–BR shown in fig.1 with very satisfactory results. In this connection reference may be made to the article by M. Garreau and M. Dupont of the S.N.C.F. in the 'Revue Generale des Chemins de Fer' dated December, 1957.

6.2. Experience in this country on the Stone-Faiveley type AM–BR Pantograph, as shown in fig.1, is not extensive to date. However, such experience as has been obtained indicates satisfactory and reliable operation. A number of these pantographs have been in operation on Multiple-Unit stock at 25 kV on the Colchester – Clacton line during the last 18 months and also on the Styal line at this voltage for some months. Recently locomotives have also been brought into operation on the Styal line. Additionally, a small amount of experience has been obtained on Multiple-Unit stock at 1,500 volts D.C. on the Liverpool Street – Shenfield line.

6.3. As regards the life of the metallised carbon collector strips such service experience as has been obtained indicates a life of 10,000/20,000 miles on Multiple-Unit stock on the 25 kV Colchester – Clacton line. The life obtained, also on Multiple-Unit stock, at 1,500 volts D.C. on the Liverpool Street – Shenfield line is of the order of 3,000/5,000 miles. It must be borne in mind that these results have been obtained under extremely difficult conditions due to the contamination of the overhead line by steam trains. Optimum carbon life will not be obtained until the overhead line is satisfactorily bedded, free from contamination and used only with carbon collectors. Notwithstanding the difficult conditions referred to above, experience indicates almost sparkless current collection with the type AM–BR pantograph.

SUMMARY

This paper described the 700 pantographs which have been ordered by the British Transport Commission from J. Stone & Co., as a standard issue for use on all the locomotives and multiple-unit trains of the 50 cycle electrification. After acknowledging the derivation of this pantograph from the type AM developed by Etablissements L. Faiveley in association with the S.N.C.F., it describes the special conditions which the pantographs have to fulfil on the British Railways' schemes and the modifications that have been made as a consequence of them. The major differences are the use of a curved pan with graphite collector strips, the strengthening of the main arm and the addition of further protection to the various joints which, in this design, are in any case a minimum, and finally the use of rubber suspension for the pan itself.

The details of design of the pantograph are then described and the paper concludes with a note of the service experience so far obtained.

RÉSUMÉ

La British Transport Commission a adopté le pantographe décrit dans cet exposé comme type unifié pour toutes les locomotives et les automotrices fonctionnant en courant industriel 50 Hz et en a commandé 700 à J. Stone & Co. Après avoir rappelé que ce pantographe dérive du type AM développé par les Etablissements L. Faiveley en collaboration avec la S.N.C.F., l'exposé décrit les conditions spéciales que ces pantographes doivent remplir dans les électrifications des Chemins de Fer Britanniques et les modifications qui en résultèrent. Les différences essentielles sont l'emploi d'un archet courbe avec de barres d'usure en graphite, le renforcement du bras inférieur, des protections supplémentaires des articulations qui, dans cette construction, sont réduites de toute façon au minimum, et finalement l'emploi de la suspension en caoutchouc de l'archet.

Les détails de la construction du pantographe sont alors décrits, et l'exposé se termine en mentionnant l'expérience de service obtenue jusqu'à présent.

ZUSAMMENFASSUNG

Dieser Bericht beschreibt die 700 Stromabnehmer, die von der 'British Transport Commission' als Standardausführung zur Anwendung auf allen Lokomotiven und Triebwagenzügen der 50 Hz-Elektrifizierung bei der Firma J. Stone & Co. bestellt wurden. Die Herleitung dieses Stromabnehmers vom Type AM, welcher von den 'Etablissements L. Faiveley' in Verbindung mit der S.N.C.F. entwickelt wurde, wird erwähnt. Der Bericht erörtert ferner die speziellen Bedingungen, die die Stromabnehmer gemäss den Entwürfen der 'British Railways' zu erfüllen haben, und die vorgenommenen Veränderungen auf Grund dieser Entwürfe. Die Hauptdifferenzen sind: Die Anwendung eines gebogenen, mit Graphitschleifkon takten versehenen Stromabnehmerkopfes, die Verstärkung des Hauptarmes, das Versehen der verschiedenen Gelenke mit zusätzlichem Schutz, wobei die Anzahl der Gelenke sehr klein ist, und schliesslich die Anwendung einer Gummiaufhängung für den Stromabnehmerkopf.

Im Weiteren werden die Einzelheiten der Stromabnehmer-Konstruktion beschrieben. Der Bericht schliesst mit einer Bemerkung über bisher gemachte Erfahrungen.

RESUMEN

En este documento se describen los 700 pantógrafos encargados por la British Transport Commission de J. Stone & Co. como norma para todas las locomotoras y trenes de unidades múltiples en el sistema de electrificación de 50 ciclos. Tras de admitir la derivación de este pantógrafo del tipo AM desarrollado por Etablissements L. Faiveley en asociación con S.N.C.F. (Société Nationale de Chemins de Fer), pasa a describir las funciones especiales que los pantógrafos tienen que desempeñar en los sistemas de los Ferrocarriles Británicos, así como las modificaciones que se han tenido que efectuar como resultado directo de dichas funciones. Las principales diferencias giran en torno al uso de una cubeta curvada con placas colectoras de grafito, el refuerzo del brazo principal y una protección más eficaz en las diversas juntas que, en este diseño, se reducen al mínimo, y finalmente, el uso de suspensión de caucho para la cubeta propiamente dicha.

A continuación se describe detalladamente el pantógrafo y el documento concluye aludiendo a la experiencia que hasta la fecha se ha adquirido en servicio activo.

Fig.1 Stone-Faiveley pantograph, type AM/BR

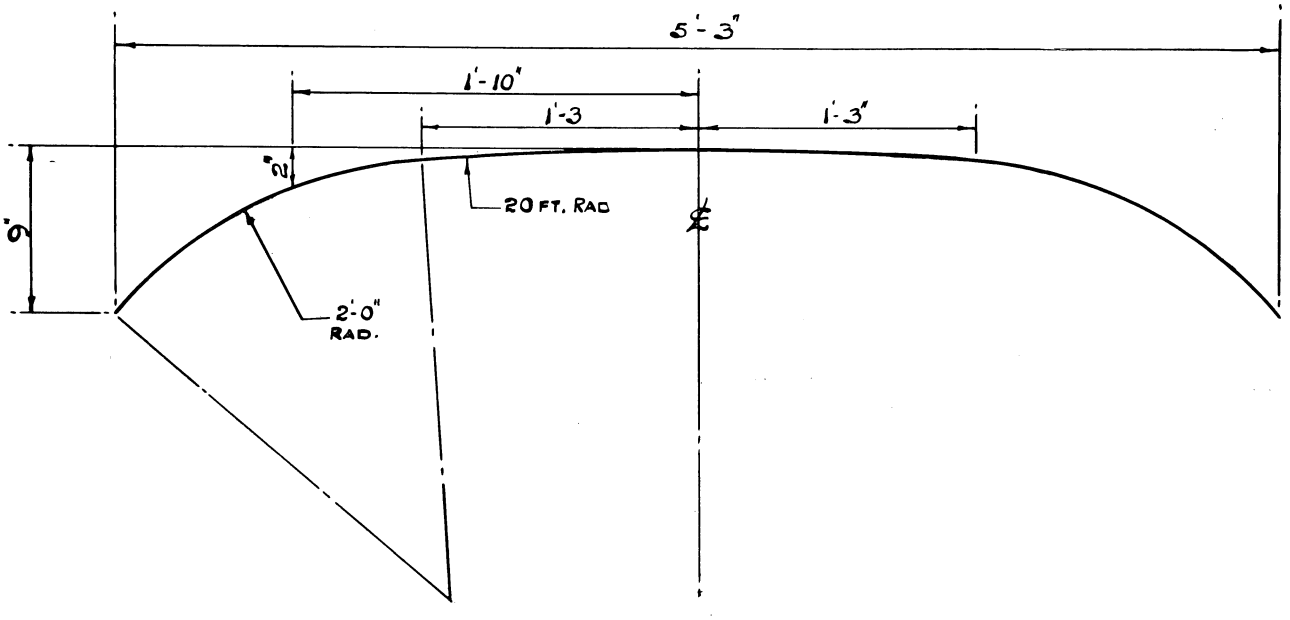

Fig.2 Current collector pan profile for pantograph, type AM/BR

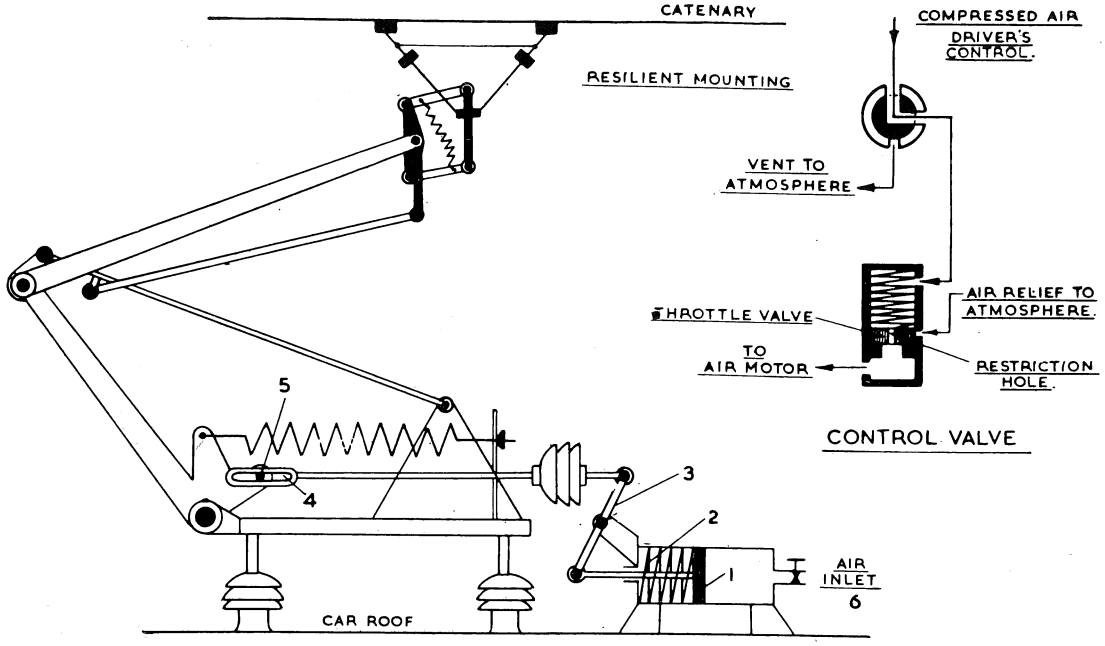

Fig.3 Stone-Faiveley type AM/BR pantograph schematic diagram

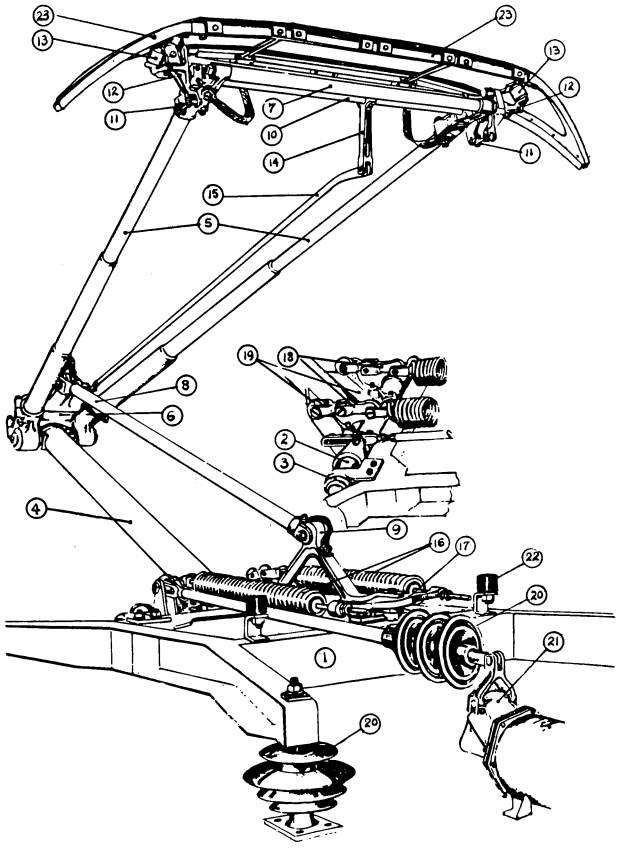

Fig.4 Isometric sketch of the Stone-Faiveley type AM/BR pantograph

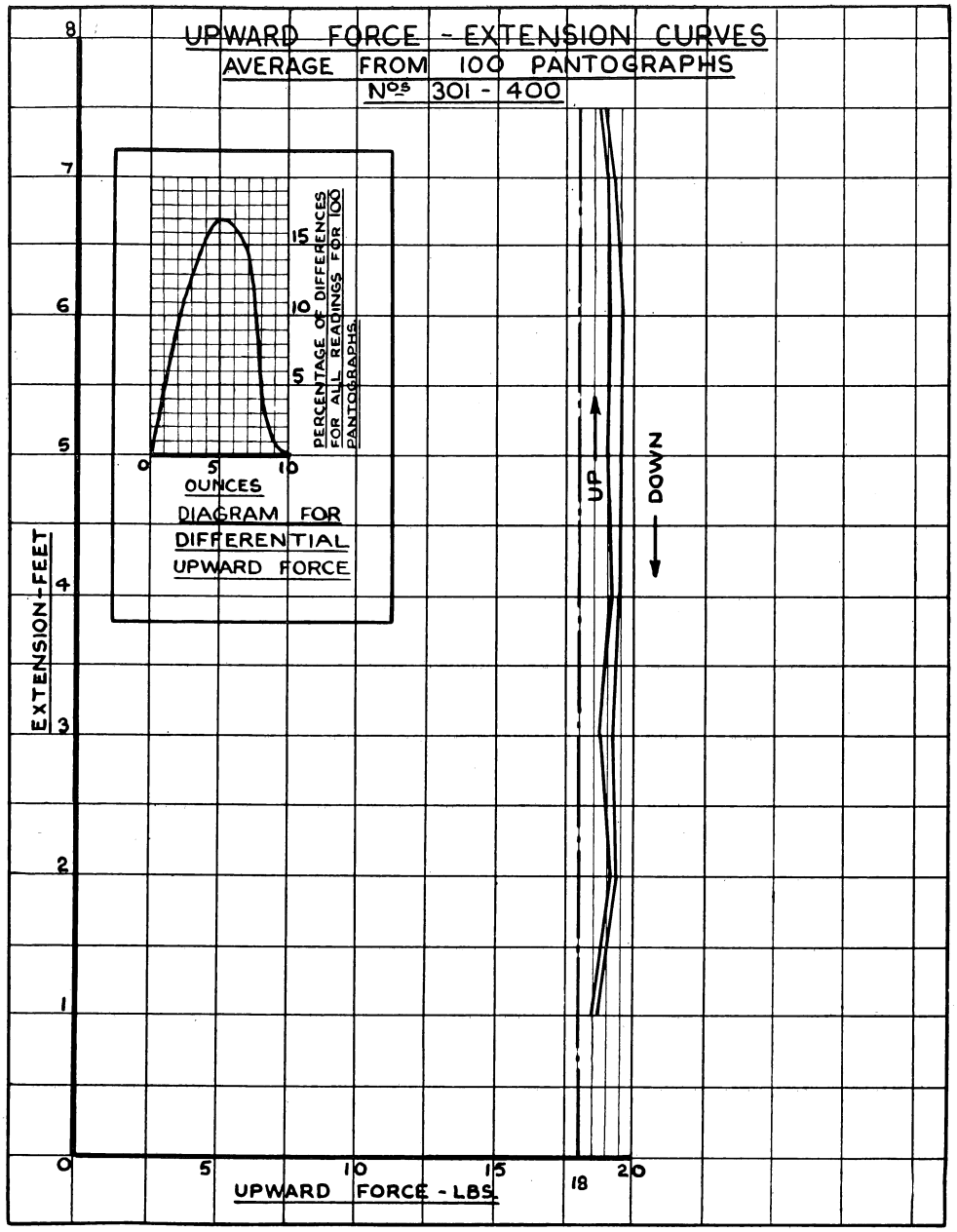

Fig.5 Upward Force—Extension Curves for Stone-Faiveley type AM/BR pantograph

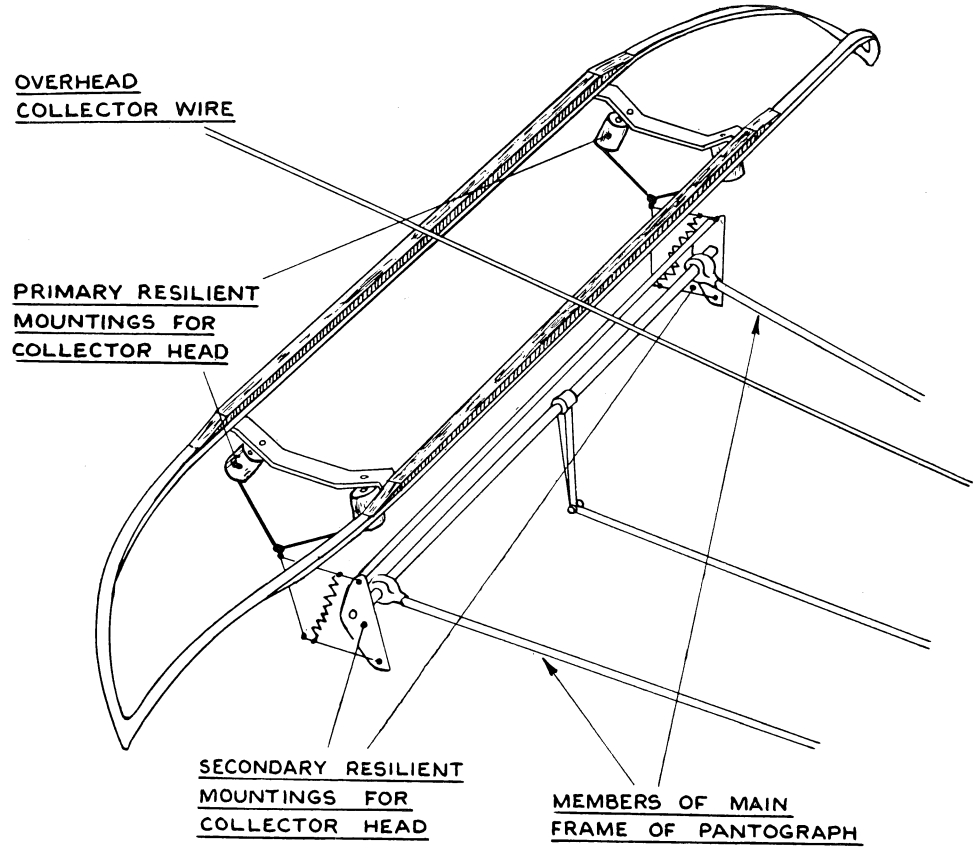

Fig.6 Sketch showing double resilient collector head mounting for Stone-Faiveley pantograph, type AM/BR

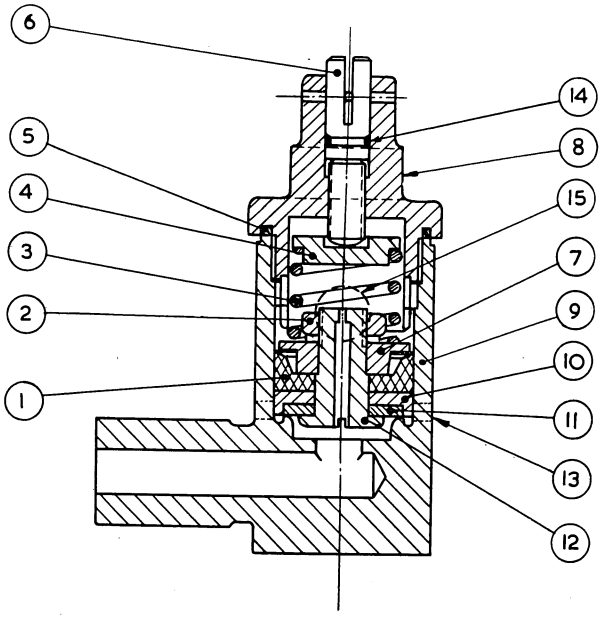

Fig.7 Stone-Faiveley type AM pantograph-valve assembly

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