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"The Steam Locomotive: A Machine of Precision"

by

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Following in a line of illustrious Presidents the choice of a title for a Presidential Address worthy of those which have preceded is by no means easy. One might call to mind Mr. Cyril Williams' "The Changing Scene," Mr. Bond's "Years of Transition," or my immediate predecessor's "Growing Up." Some might think that the most appropriate title at the present time would be "Senile Decay." But the technique of constructing and maintaining steam locomotives on British Railways is now at the summit of accuracy, and if and when the steam locomotive fades away in this country, it will not be on account of any decline in the excellency of its mechanism and therefore I propose to work from the title "The Steam Locomotive—a Machine of Precision."

A number of factors have combined to bring a point in the history of this country at which the steam locomotive must decline. In the decade which was closing in 1939, there is no doubt that the British steam locomotive was in its ascendancy, and able to hold its own generally against other forms of prime movers on economic as well as mechanical grounds. There were plentiful supplies of large coal, shed maintenance was at its best and continuity of railway employment was attractive. Now there are counter attractions in the form of a short regular working week in lighter industries, a dearth of large coal and there is no longer a fear of shortage of oil in case of emergency. Nevertheless the supercession of steam in Great Britain will take a number of years and in the meantime the steam locomotive will be called upon to meet many and urgent calls.

The basic mechanism of an orthodox locomotive is unique in that its power is transmitted equally through two, three or more axles whose centres are partly fixed but are subject to considerable movement relative to their locations and to each other. Concentrated power is transmitted between the axles by rigid couplings subject to rotating and alternating tensional and compressive forces. These movements, caused from within the locomotive by its direct or induced forces and from without by irregularities of the track, have an effect upon the dimensions between axle centres and argument may therefore develop as to whether extreme basic accuracy is necessary. It is true that if there are errors in original setting, the movement of axles during motion and power transmission may tend to cancel them out, but they may equally add to the error and also to the stresses set up. It is therefore fairly clear that the greater the original accuracy the lower will be the maximum stresses set up in components and it also enables initial tolerances of working parts to be reduced to a minimum, which in itself reduces hammering effects in bearings and the rate at which wear and slackness develop.

The President would like now to emphasise that the above remarks apply to certain parts of the locomotive and not necessarily to each and every part. In general it is probably correct to say that the more accurately centres of holes are maintained the better, but there are some components in which very close tolerances are detrimental and therefore a proper balance is necessary. But on the basic components of power transmission in a locomotive, and in many other parts, a high degree of accuracy is highly desirable and economical. We should probably all agree that the economical criterion of locomotive performance is cost per mile in similar conditions of operation and one of the greatest factors in producing a low cost per mile is mileage obtained between heavy repairs. In carrying out a heavy repair, the dismantling and erecting costs are fairly constant whatever the mileage and a higher mileage enables these to be spread and to produce a lower overall figure. High precision in basic details of a locomotive can make a big contribution to economy.

There are two ingredients in the production of accuracy in a locomotive mechanism, viz., measurement and working to measurement. Measurement has to cater for three-dimensional requirements over an extensive area and many years have been needed to arrive at the present possibilities. Each Works has to cater for a number of combinations of these dimensions within the overall

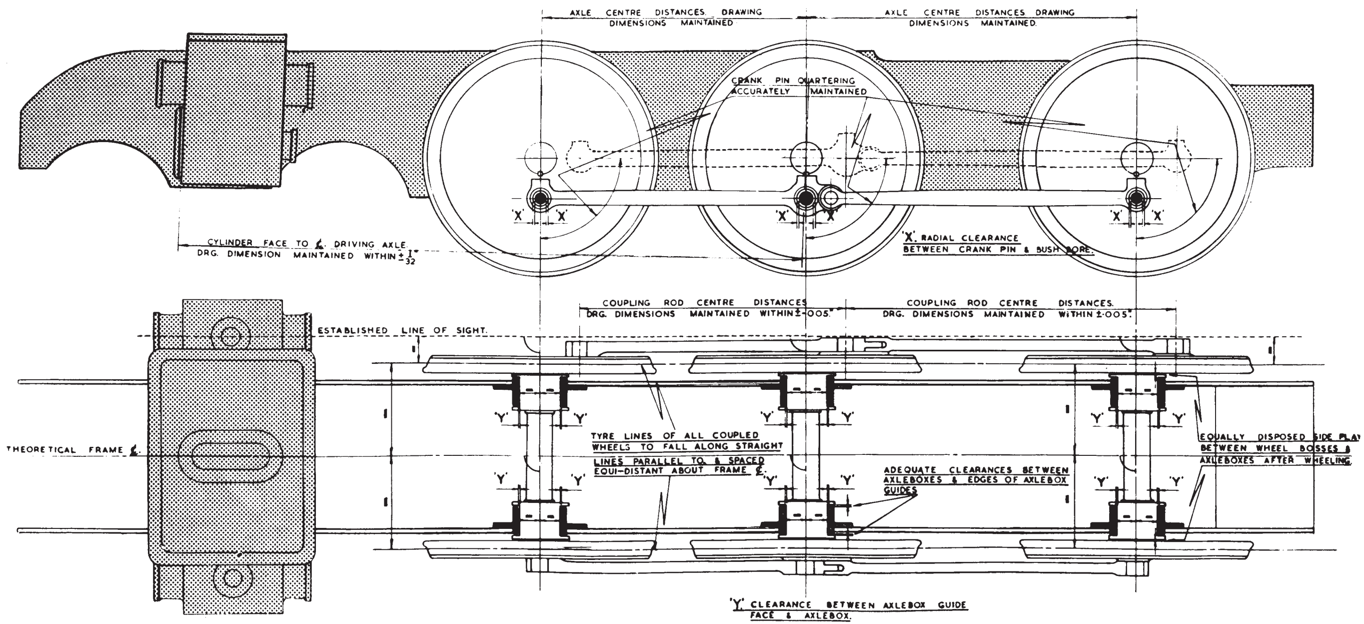

Fig. 1. *Essential requirements of a locomotive alignment system.*

maxima and hence any system must be flexible enough to cater for these at reasonable cost and facility.

In the first place there are the cylinder centre lines throughout the length of the engine with the axle centres to be located at right angles and at correct distance from cylinder barrels. For many years methods remained fairly uniform using simple apparatus in the form of fine cord or wire stretched from front cylinder faces to rear of engine, set by calipers from front and back of cylinders, meeting a straight edge clamped on supports in the centres of the driving axlebox guides. The supports incorporated fixed or movable centres from which checks fore and aft to similar centres in adjacent axlebox guides could be made by trammels either solid or adjustable. Check for normality of axis to cylinder line was by large steel squares and for parallel of framing and horn edges to centre line by steel rule. Should right angles of axis not be proved, the lines had to be removed, adjustments to surfaces made and the lines and straight edge reset for checking.

There was a good amount of subterfuge in the olden days for making lines appear to run true and in subsequent machining of components it was generally assumed that wear or inaccuracies were equal on each side of engine. Nevertheless with good craftsmen working under favourable conditions fairly good results were obtainable and high speed locomotives were repaired and maintained on these methods, although in general at the expense of slack initial fits of some wearing parts. But when things did not proceed according to schedule, poor light, blunt pops and a shortsighted erector, considerable inaccuracies did occur and many engineers have spent much time in endeavouring to develop better systems. The road was difficult and much time was spent with little progress until optical methods became available and opened up the way for advances in direct measurement.

The general term of "Frame Alignment" used in connection with optical methods rather camouflages the main quest. More important is the setting of axle centres relative to each other together with length of coupling rods and throw and angle of crank pins. Nevertheless it will be shown that following on this a complete alignment throughout of wheels relative to framing is achieved.

The first major step was due to a well known German optical instrument maker who, in the late 1920s, produced a telescope in conjunction with a collimator. The telescope, of course, enabled a sight to be taken free of all deflection and the function of the collimator was to pick this sight up in absolute parellelism.

The cross lines of the infinite scale of the collimator will only register zero from the telescope if the former is correctly located parallel in the line of sight. Hence if this be suitably and accurately

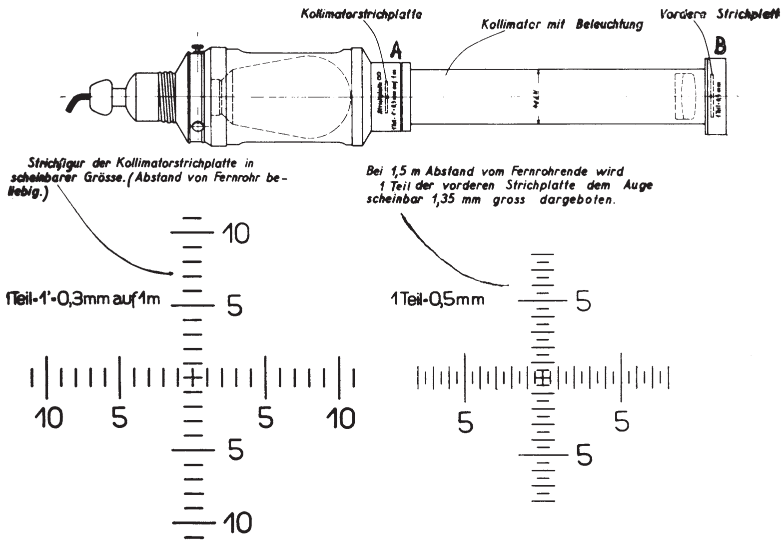

Fig. 2. *Collimator scale on German optical system.*

mounted at right angles to a straight edge or tube supported horizontally in the driving horns, at the designed distance from locating point on the cylinder, an axis has been set up co-incident with the desired centre of driving axle. In this application, the

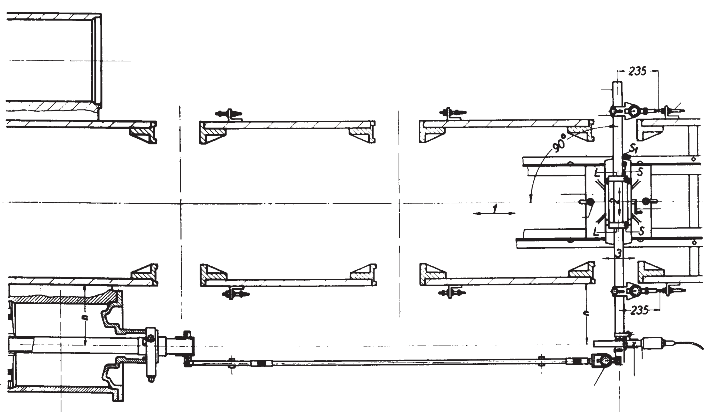

Fig. 3. *Application of German optical system to a locomotive frame.*

collimator is clamped in Vee blocks accurately set at right angles to a cross tube, mounted on a stand having means of easy adjustment in all directions. The cross tube accommodates a micrometer carrier by which measurements can be taken to front and back guide faces and also to adjustable measuring studs from which, by suitable measuring rods, centres in adjacent guides can be set up.

By this means, an accurate survey of all guide faces relative to cylinders at commencement of repair can be made and decision taken as to the most economical directions for correction. With optical systems it is usual to work from the front cylinder face, setting the location point of the telescope flush with it. At the rear

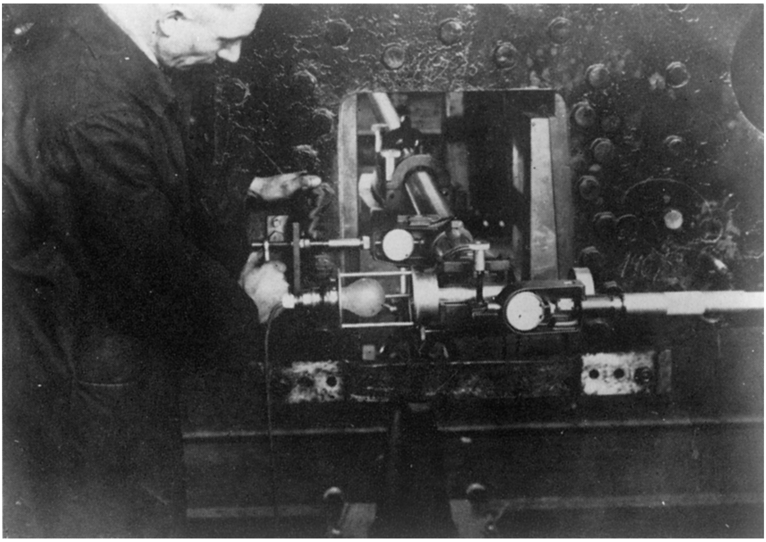

Fig. 4. *Cross-tube and collimator application.*

end of the telescope tube there is an anvil from which the measuring rod to collimator cross tube is set up. Under this system an attachment holding a dial indicator is mounted at one end of all measuring rods and the rods are such that the designed length is shewn when the dial indicates 200 (graduated in thousandths of an inch), and the length gauges allow where applicable for the four inch dead length of the adjustable measuring studs. The telescope can also sight on to scales fixed to each horn face or frame at any point and coincidence with or divergence from the designed measurements be ascertained.

The telescope is a compound appliance, having the telescope proper mounted within the telescope tube and which can swivel horizontally within the outer tube. It is not unusual—in fact it is usual—for there to be a slight misalignment between cylinder bore and the theoretical centre line. Within limits there is no need to correct this and by setting the telescope proper to the established line of sight the theoretical line is set up and from this all dimensions can be obtained to enable the wheels to be correctly positioned throughout the engine in their correct operating position relative to frame and rail.

Having surveyed the frame and taken all necessary measurements, it can be decided exactly the amount to be taken off or added to each axlebox guide face. There can be a small amount of give and take in the length cylinder face to driving box guides provided the cylinder clearance is maintained and by using this one way or the other, the minimum amount can be specified to be removed from each axlebox guide face to bring axle centres correct. In the fixing of these amounts, in thousandths of an inch there need be no tolerances, but the other ingredient comes in in the form of how accurately the corrections can be made. The method

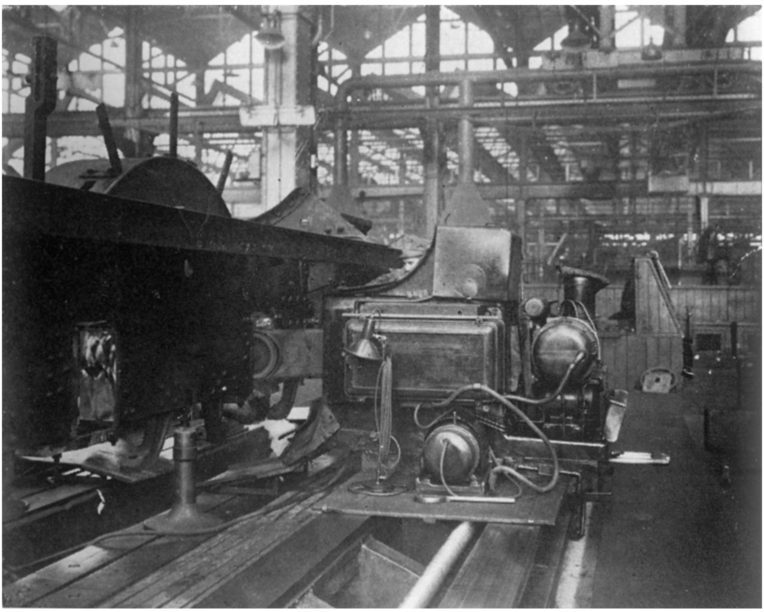

Fig. 5. *Axlebox guide grinding machine* (*fixed bed type*).

par excellence, is a fixed grinder with rigid bed and grinding heads, which can produce accurate plane surfaces. Such a machine, however, is expensive and the layout of some erecting shops does not lend itself to facilitate the convergence of all frames at the one location of the grinding machine. Accuracy within two or three thousandths can, however, be produced reasonably quickly by the use of portable grinding machines and surface plate, entailing a greater demand on human effort.

Slides follow which shew two forms of portable hand grinding machine, one using a cylindrical abrasive wheel and the other a cup wheel, also an adaptation of a portable cup wheel grinder

Fig. 6. *Rod-type pneumatic grinder.*

into a semi-fixed machine. Having a hand operated oscillatory wheel traverse this machine can be set at various points along a prepared floor to suit all horns.

Such optical equipment was installed in about 25 German Railway Works and one Works in Great Britain, but later, the manufacturer became inaccessible and remains obscured in the folds of the Iron Curtain. At the Machine Tool Exhibition of 1952, a British optical exhibit was noticed which appeared to be capable of development although at that time it had no reference to locomotives. The makers became very anxious to co-operate and quite quickly a method much simpler than the German, and capable of proceeding very much further in the quest for accuracy

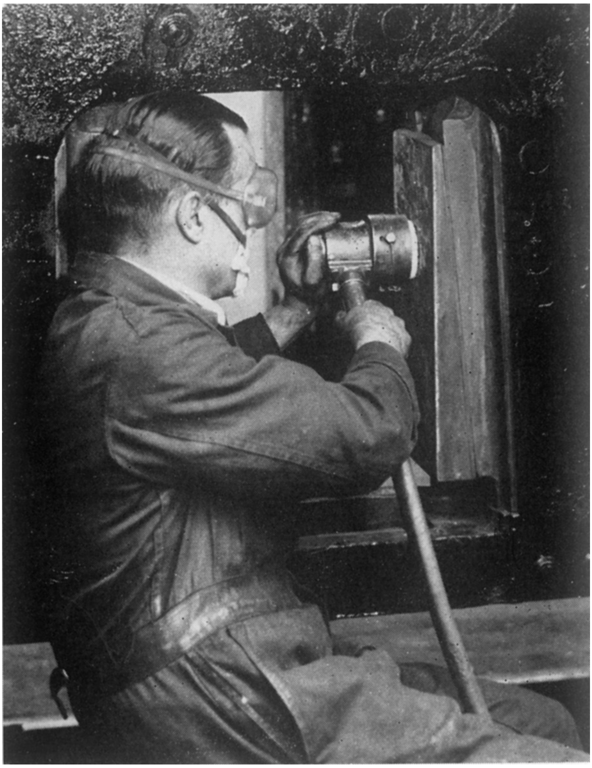

Fig. 7. *Cup-type pneumatic grinder.*

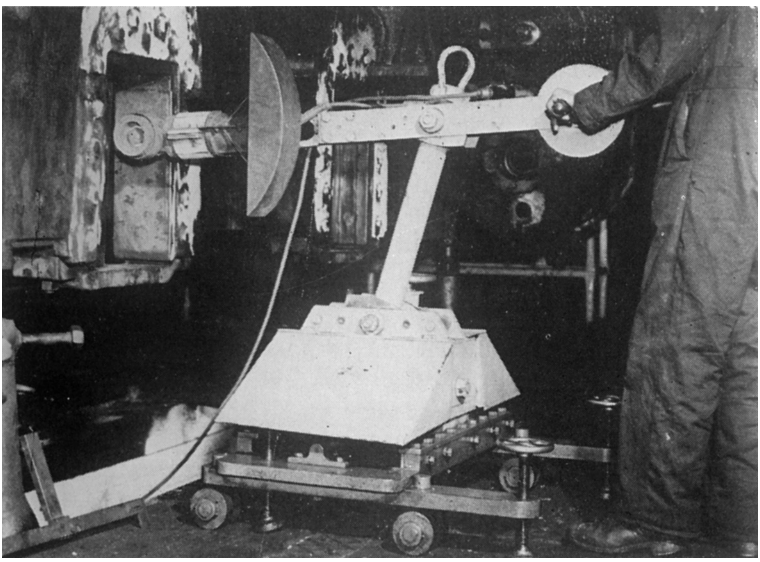

Fig. 8. *Semi-fixed type grinding machine.*

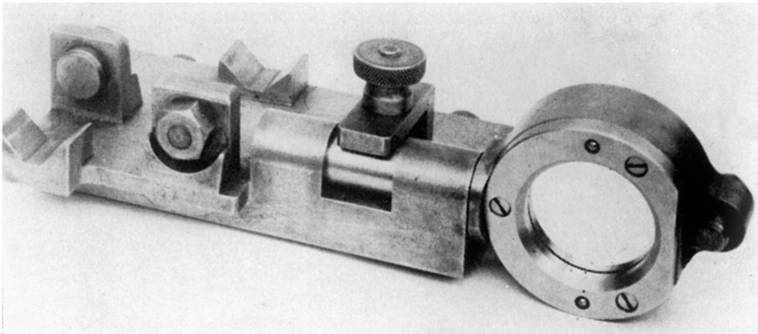

Fig. 9. *Mirror carrier.*

was produced. It became known as the Auto-Reflection method, utilising instead of a collimator a reflecting mirror fixed parallel to and in line with a straight edge. The auxiliary apparatus and measuring rods also are much simpler. The fundamentals are illustrated on this slide which shews the mirror holder with mirror. The 2″ front silvered mirror is mounted on a carrier so that the mirror face is parallel to and in line with the rear edge of a straight edge set between the driving horns.

The slide (Fig. 10) shews the telescope sighting on to the mirror under conditions in which the straight edge has an angular displacement and it also shews the view through the eyepiece of the telescope which in the present case gives a reading of 115. This reading when divided by the distance between the end of the telescope and mirror face (in feet) is the angular error in thousandths of an inch per foot. On the carrier also the measuring anvils facing fore and aft, in line with mirror and straight edge, with measuring bar supports should be noticed.

The telescope unit is approximately 18″ long and weighs 10 lb. The main part of the body is $2\frac{1}{4}$″ diameter, hardened and precision ground to an accuracy of .0003″ cylindrical and parallel within .0002″. It is ideally suited for mounting in a self-centring fixture in a locomotive cylinder for outside application or in an adjustable bracket for inside cylinder application. The lens system is totally enclosed within the body and is of the internal focussing type. Rotation of the focal control provides for objects as close as 20″ or as far as 150′ from the end of the telescope to be brought into focus in the plane of the cross-wire graticule.

The telescope holder and adaptor consists fundamentally of two tubes, the inner one, which accepts the telescope itself being concentric with the outer one when the adjusting dial is at zero. The outer tube is self centring at the rear end in the cylinder stuffing box and at the front in the cylinder mouth by three cam operated

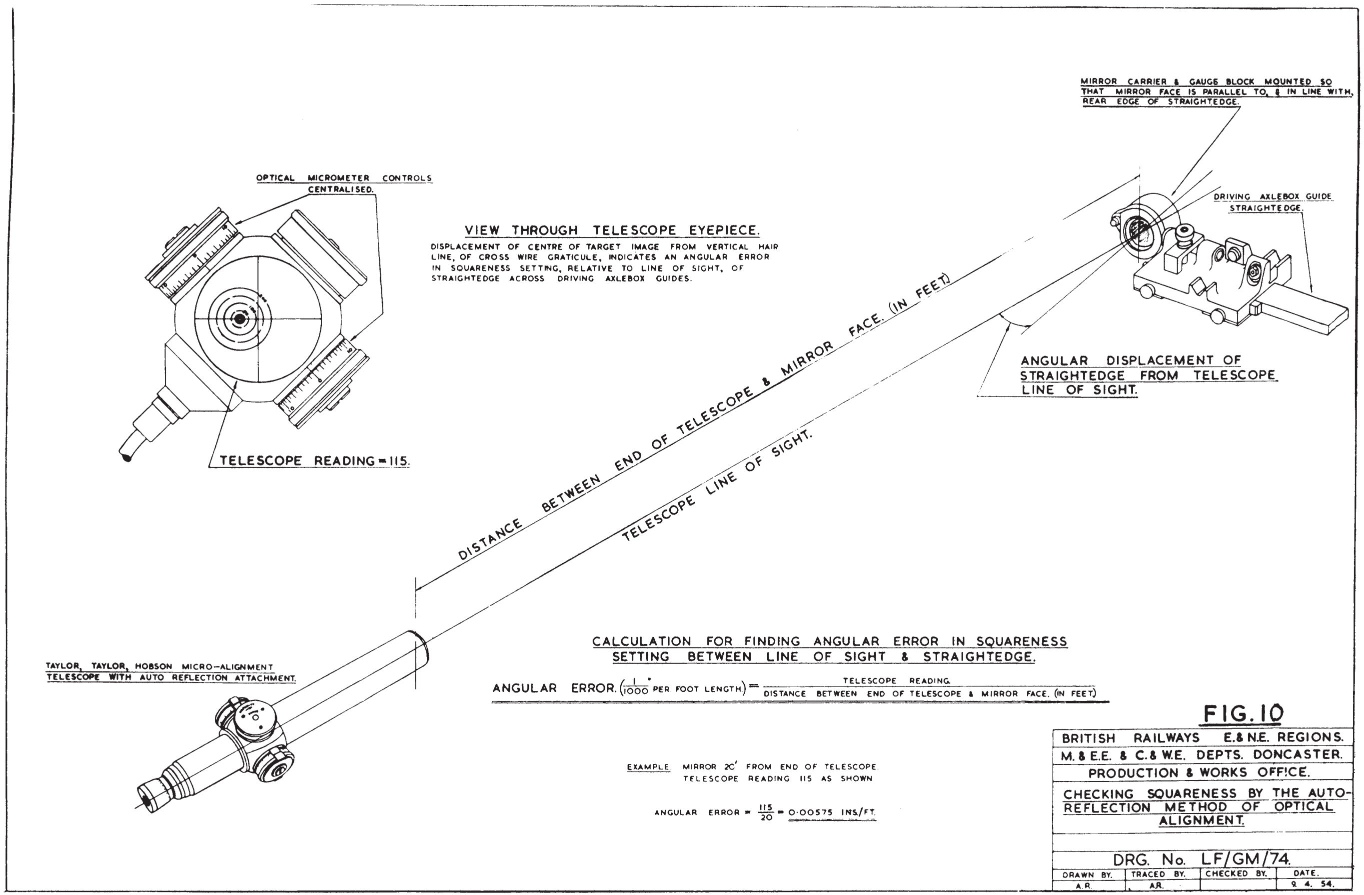

Fig. 10. *Checking squareness by auto-reflection method.*

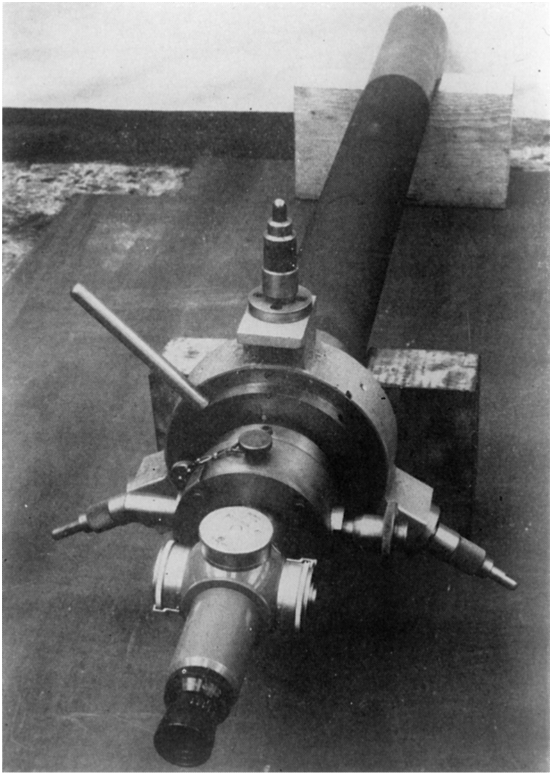

Fig. 11. *Telescope adaptor with telescope in position.*

locating pins which have steps machined on them near their tips. When these tips abut on the front cylinder face, the anvil at the rear end of the adaptor becomes a zero for measurement from cylinder centre. The outer tube carries a pedestal to accommodate a spirit level for horizontal setting which is important for ascertaining angular displacement.

The optics of the telescope are shewn in Fig. 12, particularly the eye lens, erector lens, cross-line graticule, movable objective and fixed objective lens. The front end of the telescope is provided with a cover glass upon which is marked a circular pattern target. The circles are numbered to a suitable scale and are concentric with the body diameter. These circles are not visible when observing forward through the eyepiece as the main lens system is at all times focussed at a distance beyond the cover glass. An illumination within the telescope provides light for projecting the image of the circles forward from the end of the tube. The telescope

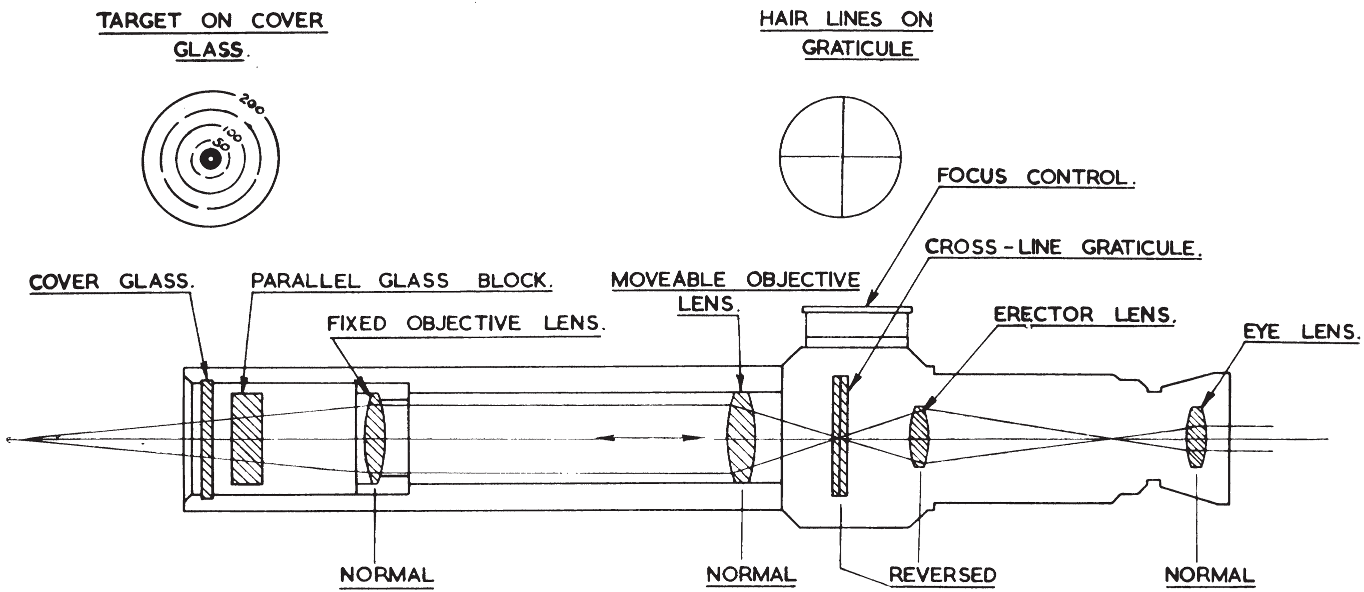

FIG. 12.

DIAGRAMATIC OPTICAL ARRANGEMENT OF TELESCOPE.

Fig. 12. *Optical arrangement of telescope.*

optics ensure that the images of these circles travel in line parallel and co-axial within the telescope line of sight.

To reflect the target graticule circles back into the telescope the 2″ diameter silvered mirror is placed in the telescope line of sight. The reflected image is viewed in the telescope with respect to the internal crosslines. The overall magnification of the lens system is 30, thus making 1/64″ reading on a steel scale possible over long distance. It is possible to measure displacement of objects or targets in relation to the line of sight of the telescope to accuracies of .004″ at 100 feet and proportionately for longer or shorter distances. The accuracy of squareness settings becomes greater as the distance between telescope and mirror increases. Settings can be made to an accuracy of 8 seconds of arc with the mirror 1 foot away from the telescope and to half a second, at a distance of 25 feet. Readings can be at distances of 150 feet.

A slide now shews the effects of the mirror being normal and at an inclination to the telescope. In the former condition there is no displacement of the image from the optical axis of the system and consequently the cross wires are seen cutting the centre of the target. The latter shews a condition which exists if the mirror or axle centre line is not at right angles to the established line of sight.

It is considered at the outset that the essential requirements of a satisfactory Locomotive Frame Alignment System should embrace the following features:—

(1) It should be universally applicable to all classes of locomotives.

(2) Axlebox guide faces should be equi-distant about axle centre-line and axleboxes bored centrally.

(3) Axle centre lines should be parallel to each other and at right angles to the established frame centre-line.

(4) Horizontal centre distances of coupled wheels should be maintained to drawing dimensions within limits specified.

(5) Driving axle distance from cylinder centre should be maintained to drawing dimension.

(6) Tyre line of all wheels should fall along straight lines parallel to the established frame centre line and spaced equi-distant about it.

The equipment is illustrated in diagrammatic form in the next slide (Fig. 14) applied to an outside cylinder engine. The telescope is set up in one of the cylinders sighting on to the mirror which is reflecting the rays back to give a zero reading. An enlarged view outside shews the mirror attached to straight edge and on the mirror carrier three gauging anvils, with length bars in position, the outside one being an adjustable one for length from the front cylinder face with one fore and one aft to adjacent axlebox guides. On the left hand side is an adjustable straight edge for use in

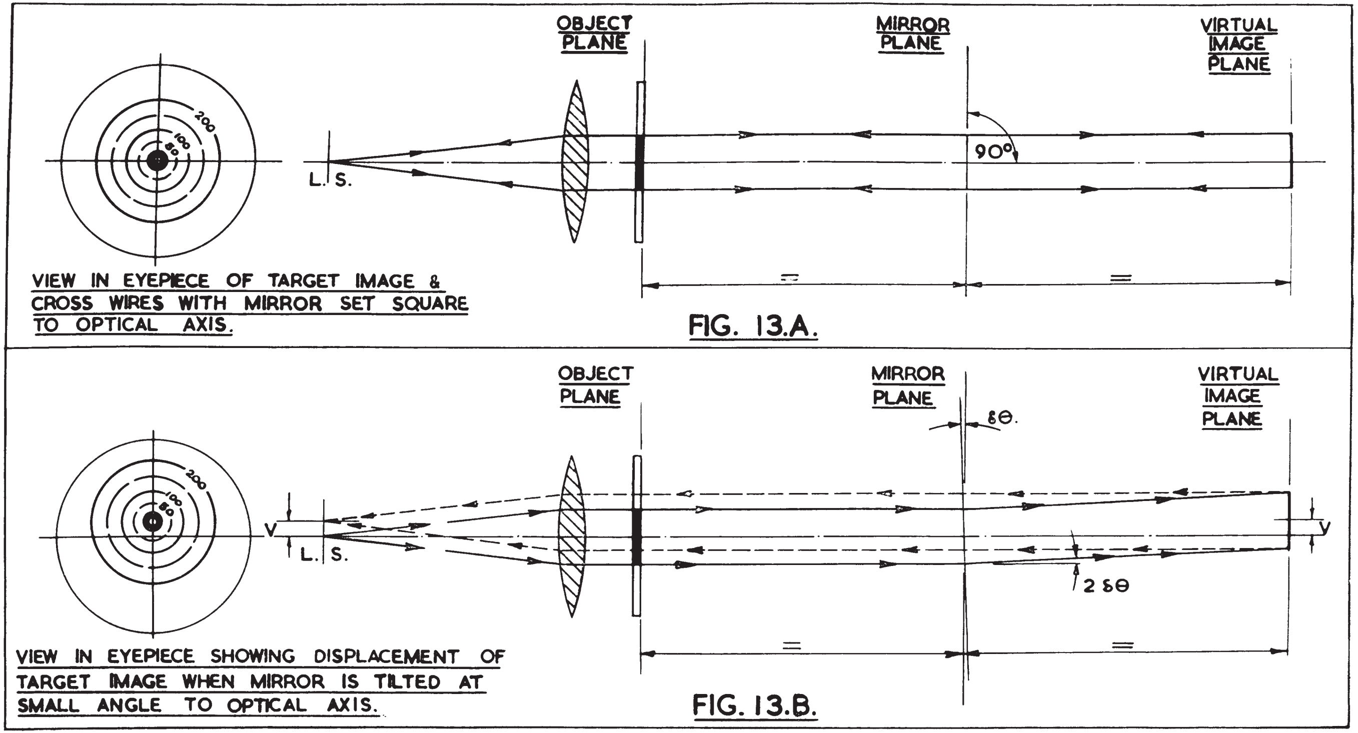

Fig. 13A & B. *Diagram shewing the effect of the mirror being normal and at an inclination to telescope.*

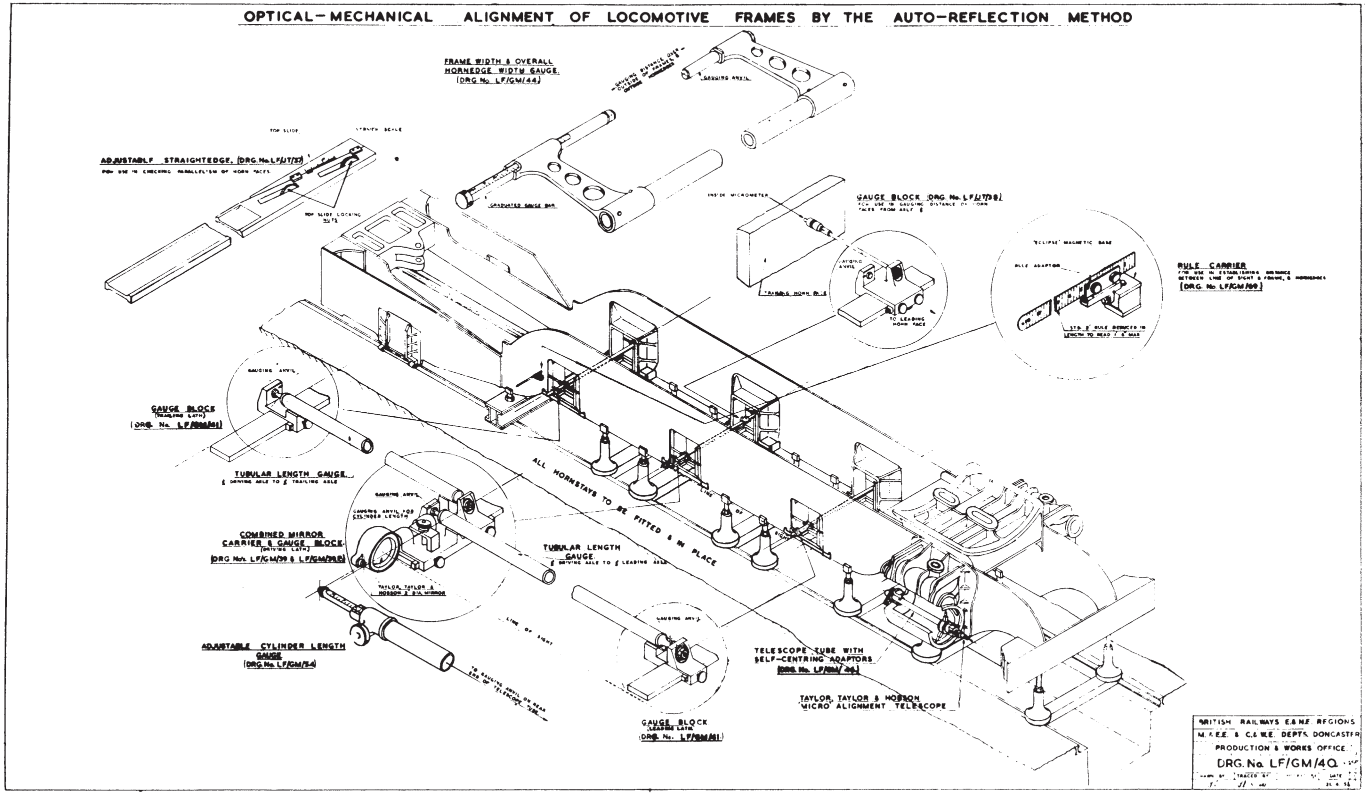

Fig. 14. *Pictorial diagram shewing application to locomotive with outside cylinders.*

checking parallelism of horn faces. Width of horn gaps need not be equal even for the opposite position, but condition No. 2 can still be met. Above is the frame width and overall guide edge width gauge. Further to the right is the gauge block for measuring to axlebox guide faces and lastly the magnetic rule carrier for measuring from line of sight to horn edge or frame.

Fig. 14a shews close-up mirror carrier with measuring rods in position.

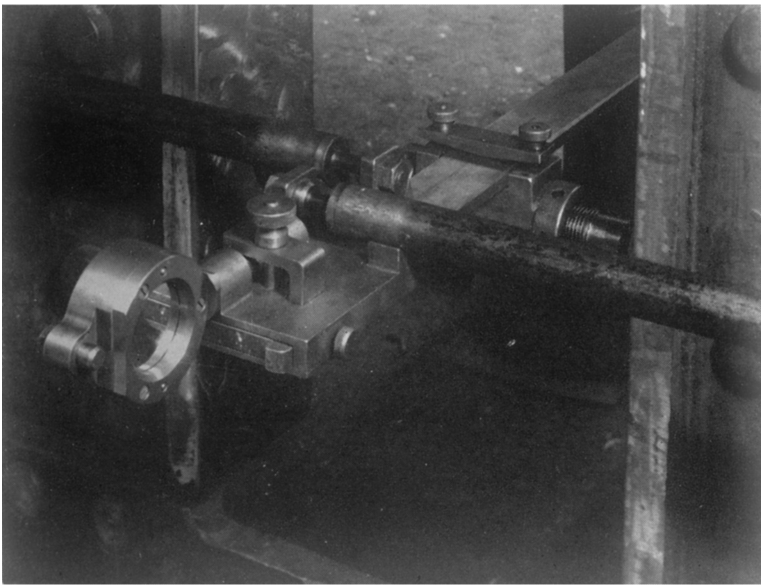

Fig. 14A. *Close-up of mirror carrier with measuring rods in position.*

The application to inside cylinder engines is shewn in the next slide. The telescope now is mounted in a tube and universal bracket fixed to the outside of the engine frame with the optical axis at approximately horizontal axle centre height. The straight edge is set up in the centre of driving axlebox guides and normality to the telescope axis is read as before. Measurement is effected from a knife edge on the carrier mounted on the straight edge to the anvil on the cylinder length bar which, therefore, checks measurement to the cylinder front face.

The apparatus is fully usable in the construction of locomotives to ensure initial accuracy. In railway shops the predominating use is in connection with general repairs to ensure and maintain accuracy over a long working life and it is primarily this aspect with which the illustrations and descriptions deal.

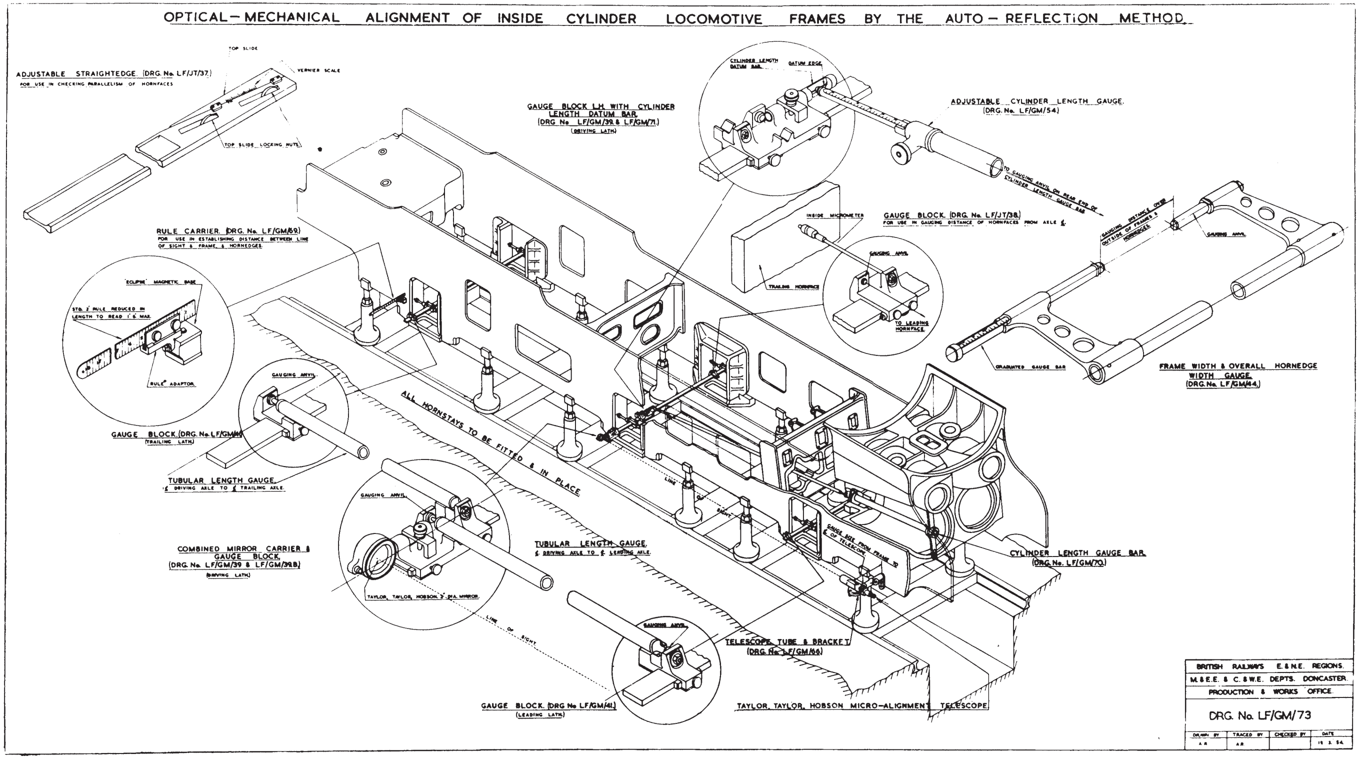

Fig. 15. *Pictorial diagram shewing application to locomotive with inside cylinders.*

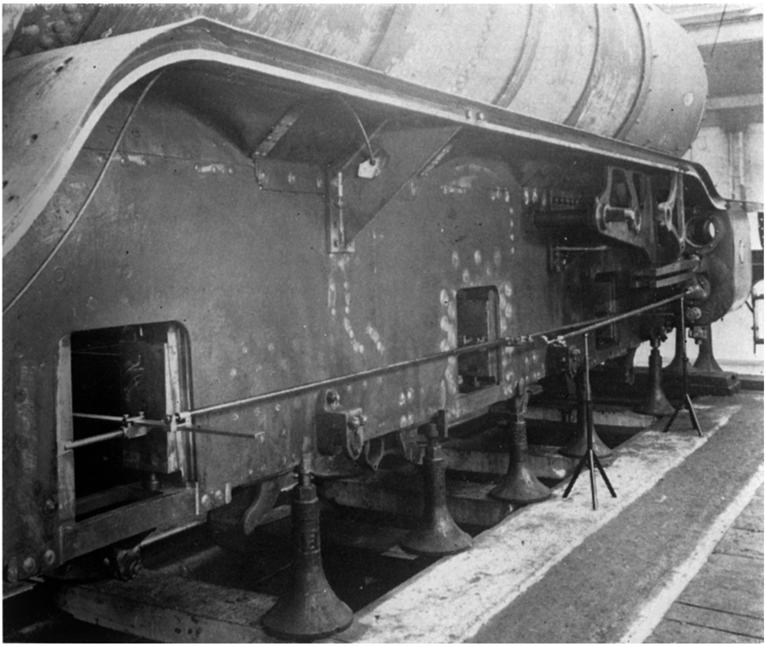

Fig. 16. *Application of tubular length-gauging rods.*

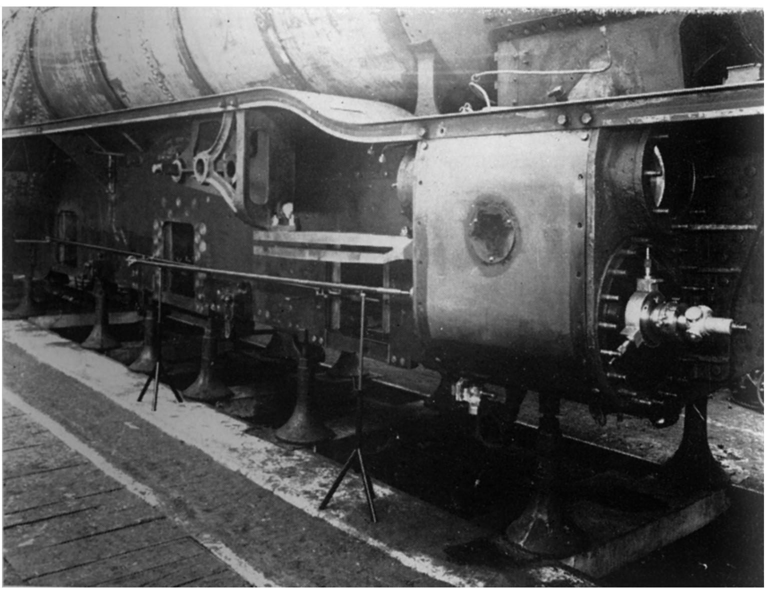

Fig. 16A. *Front view of locomotive shewing telescope and length-gauging rods in position.*

Fig. 16a shews front view of locomotive shewing telescope and length-gauging rods in position.

Having set up straight edges throughout the axes in their correct position a direct measurement is obtained at a point on each guide face of the exact amount by which each face should be

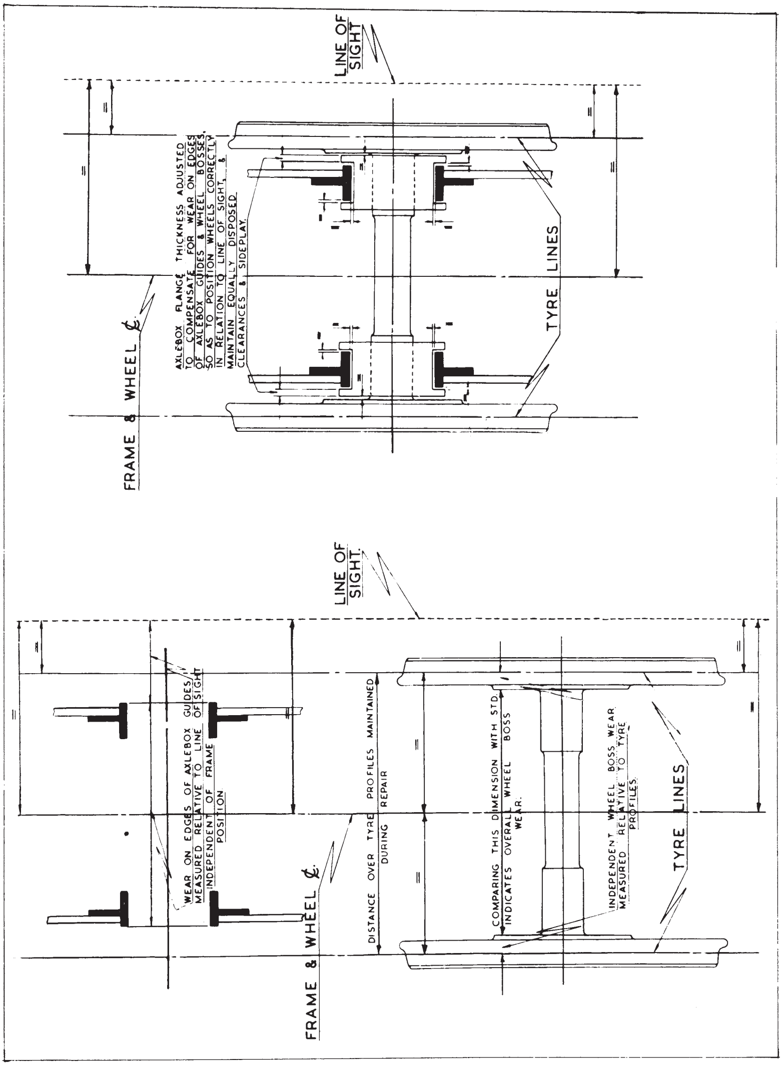

Fig. 17. *Diagram shewing relation of line of sight to frames, axleboxes and wheels.*

corrected. The measuring rods and straight edges can then be moved and the telescope used, in conjunction with the overall gauges, to obtain the dimensions to which axlebox flanges must be machined to ensure that the frame will lie naturally relative to the tyre treads.

The telescope establishes a line of sight parallel to the absolute centre line of the engine at a distance of half the cylinder centres from it. Fig. 17 shews the points which are now defined. First variation of axlebox guide edges, both outer edges of the same pair, must shew the same final distance from established sighting line. This in connection with the overall width gauge establishes deviation from standard and by ascertaining wheel boss position relative to tyre flange, in conjunction with overall distance between bosses after machining, the final required dimension is obtained. This enables the machined axlebox to meet all the requirements shewn on the right hand illustration.

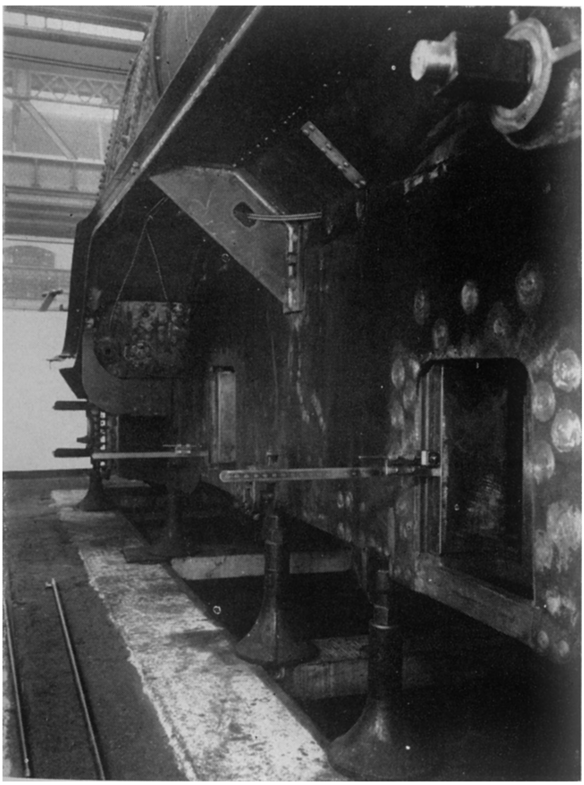

Fig. 18. *Application of magnetic blocks for holding steel rules to axlebox guide edges and frames.*

Fig. 18 shews the steel rules held in position on the axlebox guide edges by magnetic blocks, which enable the actual distance from the guide edges to the line of sight to be taken.

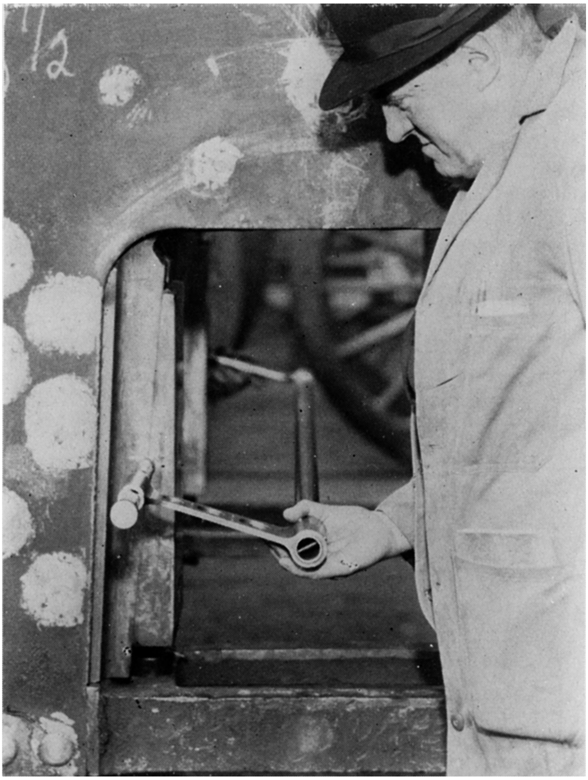

Fig. 18A. *Application of overall frame and horn edge width gauge.*

Fig. 18a shews application of overall frame and horn edge width gauge.

Fig. 19 shews the application of the overall wheel boss gauge.

Fig. 19a shews the application of independent wheel boss gauge.

Crank Pins

A component on which it has proved difficult to ensure accuracy is the set of crank pins, three, four or five pairs as the case may be, affecting the tolerances which can be worked to on coupling rod bushes. Not only is it difficult to ensure accuracy of machining but

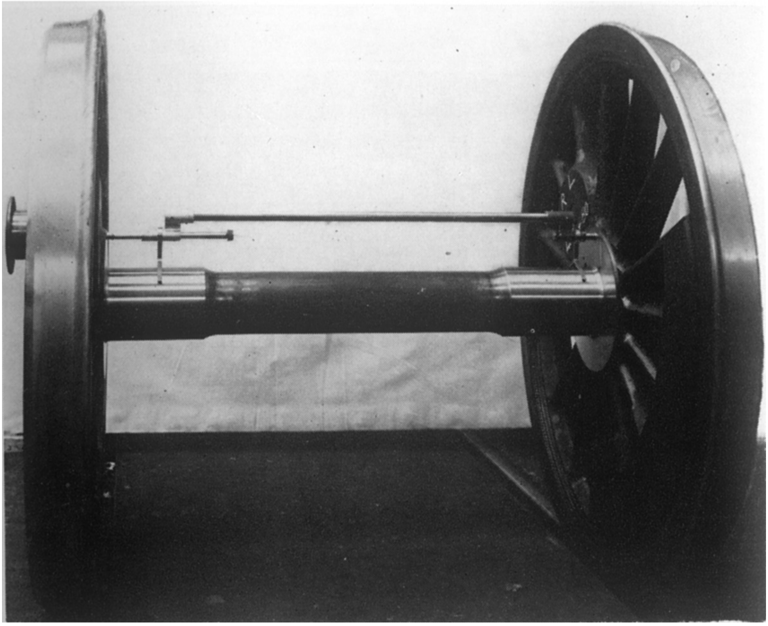

Fig. 19. *Overall wheel boss gauge.*

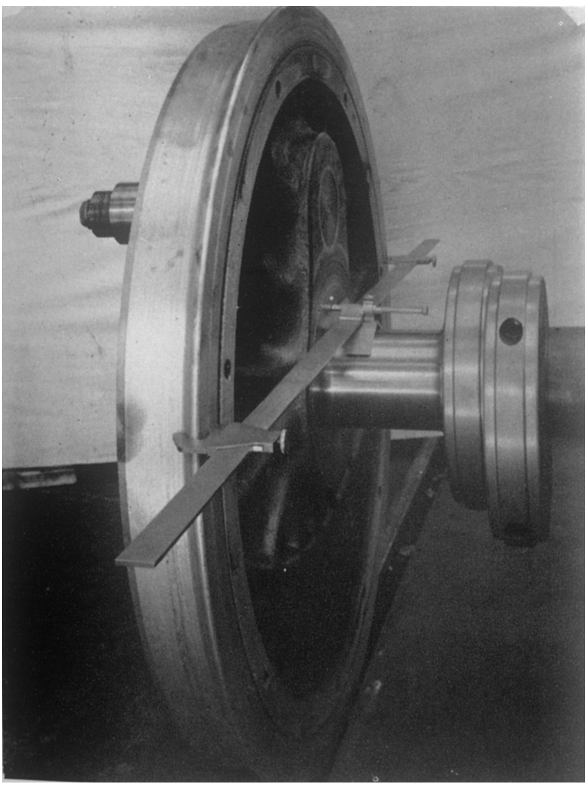

Fig. 19A. *Application of independent wheel boss gauge.*

again so is the matter of measurement, which is desirable particularly as a check of the continuing accuracy of quartering machines.

The development of the present gauge arose out of a paper on Metrology by a member of the National Physical Laboratory given to one of the junior engineering societies, wherein for three-dimensional measurements in different planes the use of spirit levels was indicated and particularly the great potentialities in this direction of spirit levels of extreme sensitivity. Hence it was felt that a quartering gauge mounting two spirit levels set at 90° would give the basis of a gauge for checking crank pins designed for this angle.

The spirit level tubes in view have a radius of arc, along which the bubble moves, of 1000 inches and result in terms of locomotive requirements of a movement of the bubble of a tenth of an inch to indicate an angular error of one thousandth of an inch at a radius of 1 foot. A slightly different scale of graduations will apply to the usual run of crank pin throws which vary between 10 and 15 inches. The modus operandi is to place the vee on one crank pin

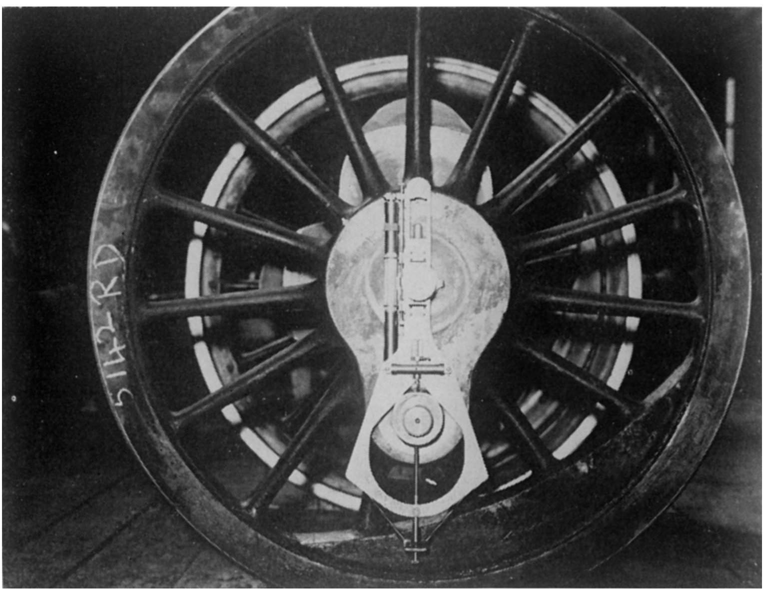

Fig. 20. *Crankpin quartering gauge applied in the vertical position.*

and the sliding centre in the axle centre and pinch the wheels until the cross level shows zero displacement which indicates that this pin is at bottom dead centre. The gauge is then taken to the opposite crank pin and similarly, applied when any error in

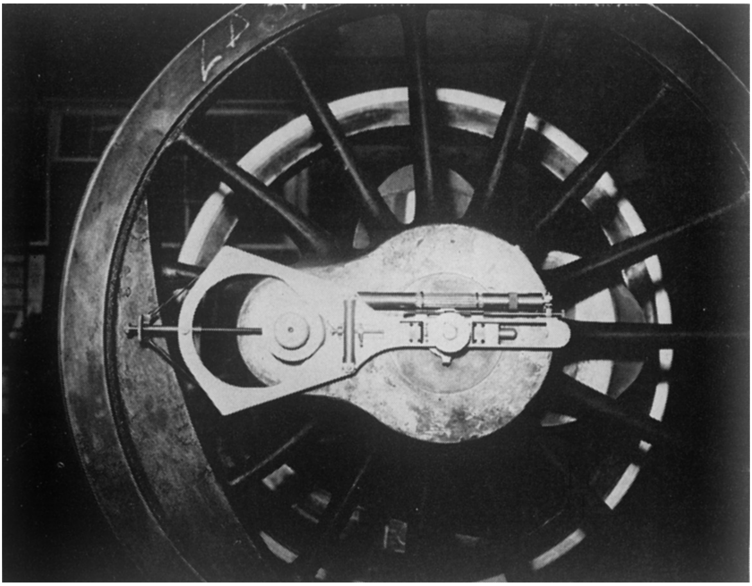

Fig. 21. *Crankpin quartering gauge applied in horizontal position.*

angularity will be indicated by displacement of the level lying along the body of the gauge, the error being directly readable from the graduation if it is not too great.

A considerable amount of ingenuity was expended before the measurement of length of throw reached its present form. Originally the sliding centre had vernier markings which were set in conjunction with a crank pin of standard dimension. Finally a micrometer was incorporated reading from crank pin to an anvil on the sliding centre, and adding half the diameter of crank pin taken by an outside micrometer. The addition of a third spirit level extended the range of the instrument to cover crank pins set at 120° and in its present form it is capable of measuring the angular setting and throw of crank pins of all normal two, three or four cylinder locomotives with strokes varying from 20″ to 30″. The bubble length is sensitive to changes of temperature hence a cursor controlled by right and left hand thread is fitted to indicate the central position of bubble and from which its displacement can be easily read. Six rotatable scales give a direct reading in thousandths for the different throws.

As previously mentioned one of the most important uses of this gauge is to ensure that wheels are coming from the quartering machines correct. On arrival for general repairs there is nearly always ovality, taper or angularity error and it is good practice to

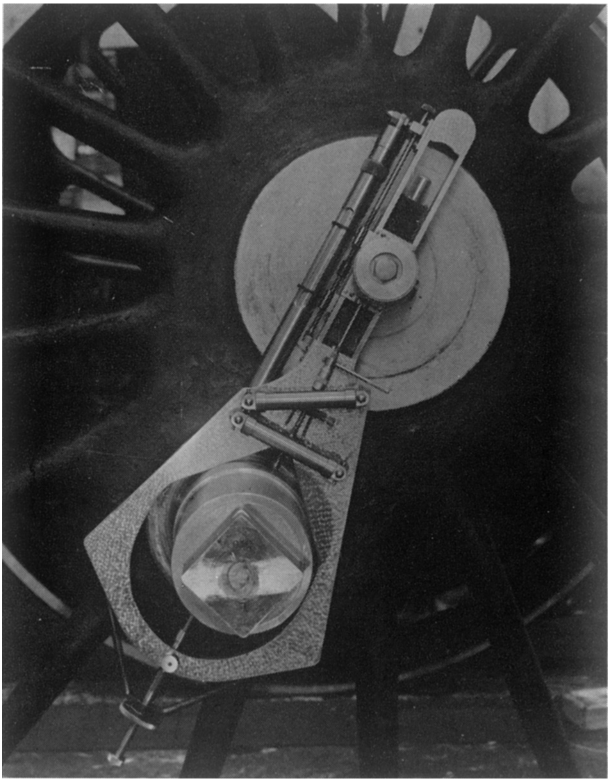

Fig. 22. *Crankpin quartering gauge modified to deal with crank pins set at* 120.

quarter all pins in order to turn engines out with the pins as near correct as possible. Hence it is not politic to check all pins to limits on arrival at the wheel shop. It is very desirable to know that when they come from the quartering machine the desired accuracy has been achieved. Therefore periodical checks on machined pins are made to ensure this.

A particular feature of value is that should the setting of the pins be suspect on a locomotive in service, a fully accurate check can be made on all pins, whilst the wheels are under the engine. This enables the offending pair or pairs to be located with certainty and only these removed for rectification. It is your President's experience that when the phenomenon of slipping at high speed with steam off occurs, the crank pins of at least one pair of wheels, are out of angle. This gauge enables that pair or pairs to be identified with certainty.

In the quest for accuracy the wheels form a good starting point. They can contribute to improved results even though other factors do not initially keep pace but, of course, until frames, axlebox guides and rods are brought up to the same standard, the full benefits of closer tolerances cannot be obtained.

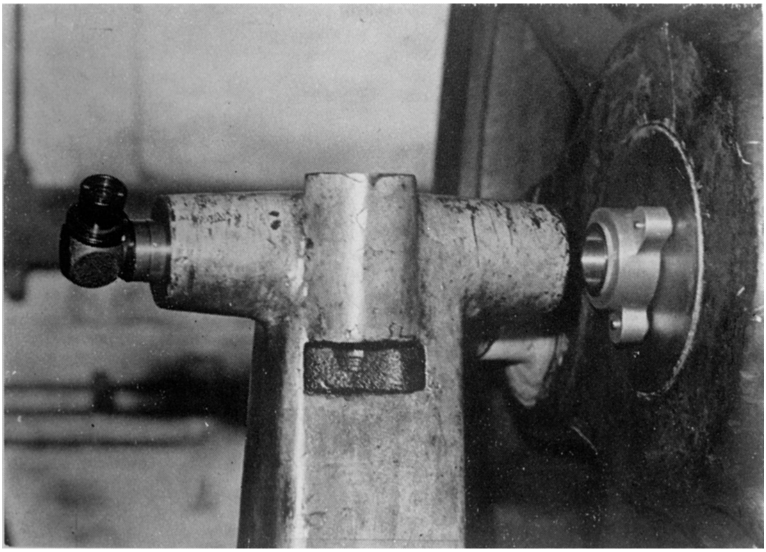

Fig. 23. *Optical setting of wheels in quartering machine.*

The setting of wheels at their theoretical axle centre in a quartering machine is not easy, on account of their weight and varying journal diameters. An optical attachment has been developed so that this can be assured by direct sighting. Modern quartering machines support wheels from the journals and to set optically a hemispherical glass target is held truly co-axial with the axle centre, by means of a spring loaded magnetic carrier. The target graticule is a series of circles with .01″ diametrical spacing and when these are centrally dispersed with the crosslines in the microscope, the wheels are in the correct position in the machine.

Fig. 24 shews a diagrammatic layout of the optical arrangement on the quartering machine.

It will be appreciated that the maintenance of the axle centres is vital in all these operations and a recessed centre, to safeguard against damage to the edges, is recommended.

Coupling Rods

The ideal method of finishing the bearing surface of coupling and connecting rod bushes is for a final precision bore to be made

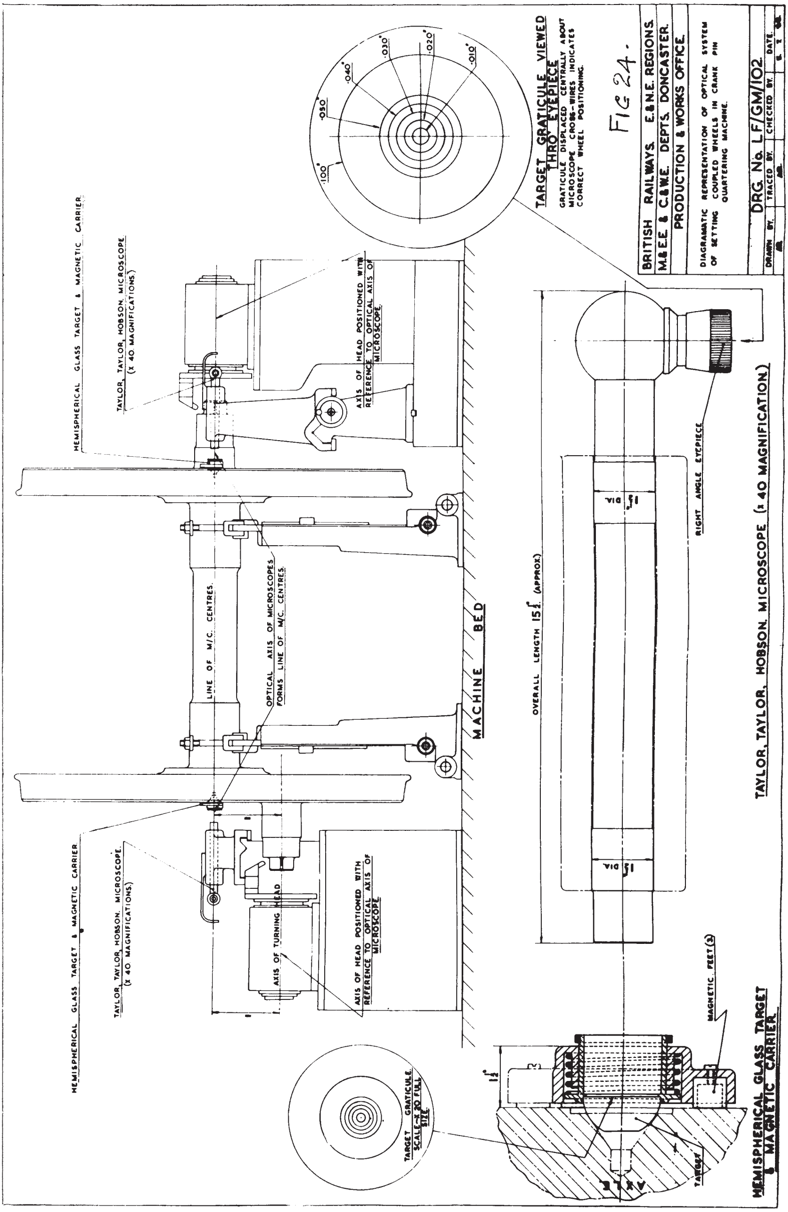

Fig. 24. *Diagrammatic representation of optical system of setting coupled wheels in crank pin quartering machine.*

after the bushes have been pressed into the rods. At the same time in order to facilitate renewal at Sheds when necessary, the final boring of the bushes must be central with the holes in the rod. The old method of trammelling must of necessity give place to positive measurement in order to ensure lengths being within the specified tolerances.

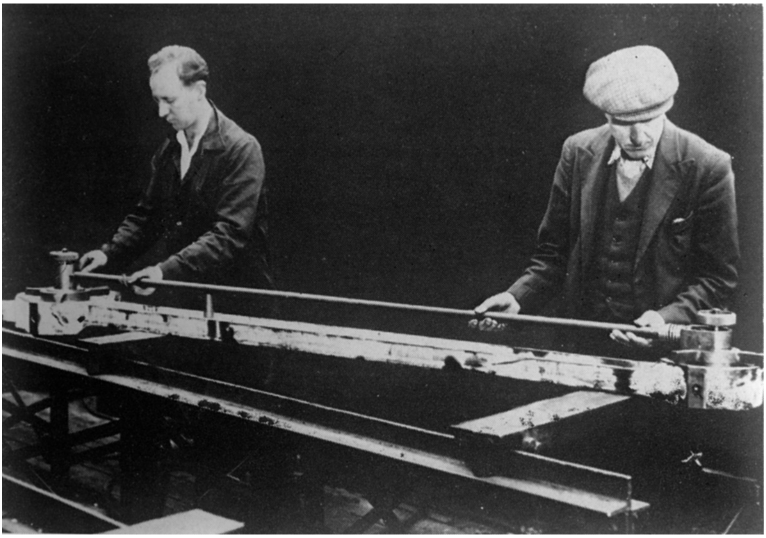

Fig. 25. *Checking centre distances of coupling rods.*

The coupling rod without its bushes, is set on the rod bench, well supported in order to avoid any sagging and self centring gauging heads are placed in the rod bores and expanded by an internal sliding cone. These heads are provided with 3″ diameter gauging plugs integral with the self-centring heads. The distance between the peripheries of the gauging plugs on any one rod is therefore equal to the centre distance of the rod bores, less 3″. Tubular length gauges are provided for checking rod lengths between centres, allowance being made for the 3″ diameter gauging plugs.

For the convenience of applying limits, namely, plus or minus five thousandths, the gauge rods are made .005″ short. Therefore if the gauge is admitted between the gauging points in conjunction with feeler gauges not exceeding .010″ in thickness, the rod length is within specified limits.

The fit of bush in rod is becoming of greater importance with felt pad lubrication in order to effect an oilseal and therefore

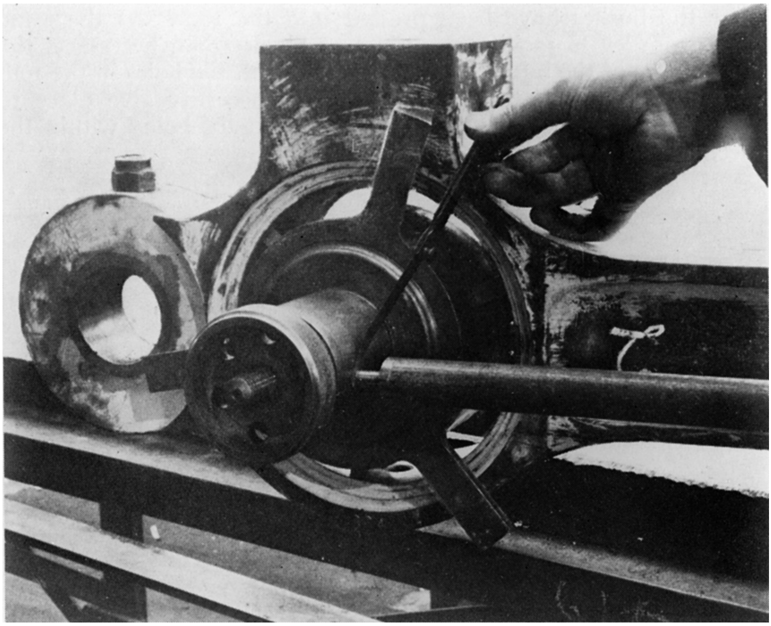

Fig. 26. *Near view shewing application of feeler gauge in conjunction with length gauge.*

the ovality of bore is not allowed to exceed .010″. Should either the ovality or centre distance exceed the limits specified the rod is corrected by boring out either one, or both, of the bush holes, on a twin spindle vertical boring machine. In the machine illustrated one spindle is arranged for rod boring, whilst the other is fitted up for boring and burnishing the bush bores after the bushes have been pressed into the rods. Much distortion takes place as bushes are pressed into the rods and to obtain a close fitting accurate bore, subsequent machine finish is necessary.

These methods may bring under review the practice sometimes encountered of making centres of trailing rods on narrow firebox engines long to drawing. This is very unmechanical and generally implies very slack fit of bush on crank pin. Lengthy experience has shewn that this is unnecessary if throughout accuracy is maintained and considerable advantages accrue from working strictly to standard.

A slide is shewn of the coupling rods of a 2-8-0 W. D. locomotive on which the frame and horns have been accurately aligned. These engines were not built to such accuracy but on completion of realigning all bush clearances were .008″ to .010″ completely white-

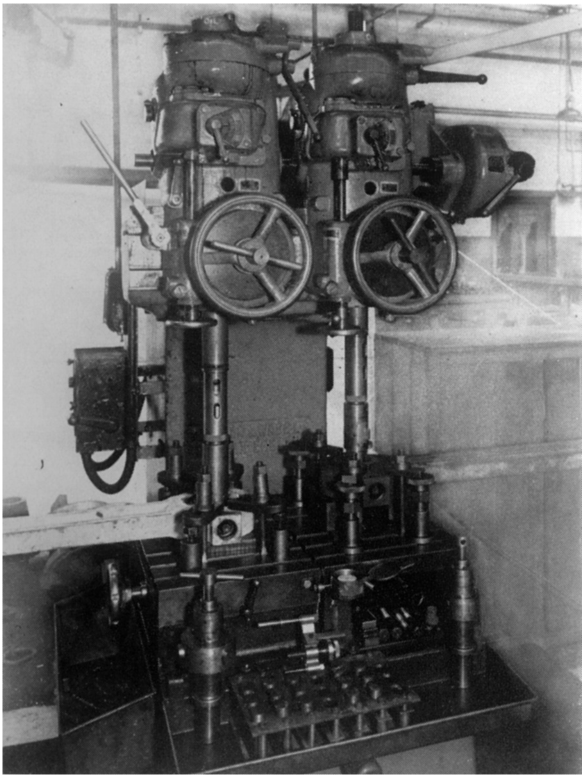

Fig. 27. *Twin spindle drilling machine converted for rod bore and bush boring.*

metalled and fitted with pad lubrication and at the time of photographing had run 39,000 miles and the wear which had developed was .005″ to .010″. The slide shews the lubricating felt pad in position. The oil has free access to the upper surface of the pad which must form a seal and prevent any egress of oil other than through the pad, the density and compression of the felt being the means of regulating the oil flow. A so-called restrictor has had to be placed in the oil pipe to break down the practice of using a worsted trimming. From experience gained the bush clearances on both coupling and connecting rods have been further reduced on subsequent locomotives optically aligned, the clearances now range:—

from .004″ $\begin{matrix}+ .002''\\ - .000''\end{matrix}$ for pins 3″ to 4″ diameter

to .01″ $\begin{matrix}+ .002''\\ - .000''\end{matrix}$ for pins 9″ to 10″ diameter

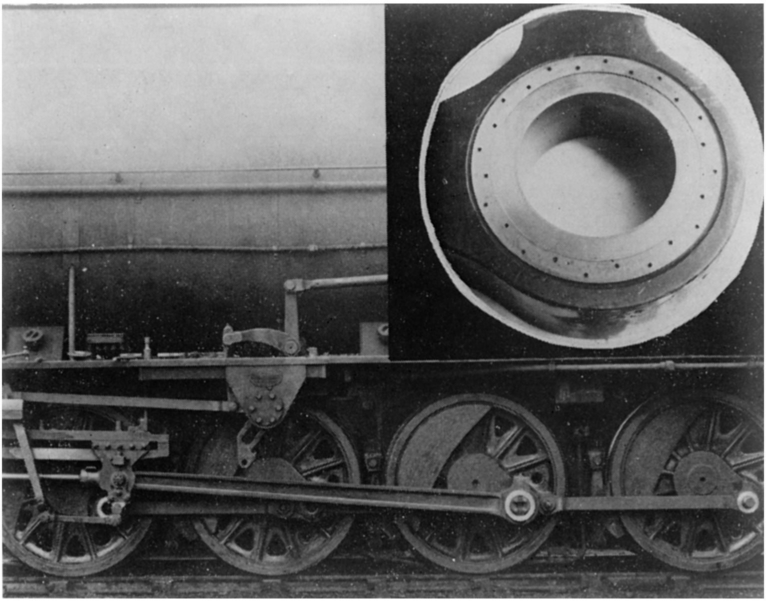

Fig. 28. 2-8-0 W.D. *coupling rod shewing felt pad in position.*

Improvement in performance of the small end bushes in the connecting rod has also been noted, the original bushes giving 34,000 miles service, in comparison with 10,000 on engines not optically aligned.

It has taken a long time on steam engine practice to get away from the hand-scraped and bedded down bearing but there is no doubt that the accurately machined finish is greatly superior, and reduces initial wear. Such practice is essential in diesel engines and also applies to locomotive connecting rods both of the solid bush and split brass inside big end types. As the President has humbly sat in the chairs of both Churchward and Gresley, it is not surprising that there has been some cross-breeding. The next slide shows a Churchward inside big end on a Gresley Pacific with completely machined bearing and felt pad lubrication. The following slides shew a Gresley Marine type big end of similar finish to the previous slide; a set of Gresley Marine type brasses with complete whitemetal bearing surfaces and felt pads, ready for assembly; a set of brasses similar to the previous slide which have run 50,000 miles with .004″ wear.

These remarks have dealt with accuracy as applied to the fundamental mechanism of the steam locomotive. There are many other details upon which one could dilate, viz., firebox stays and

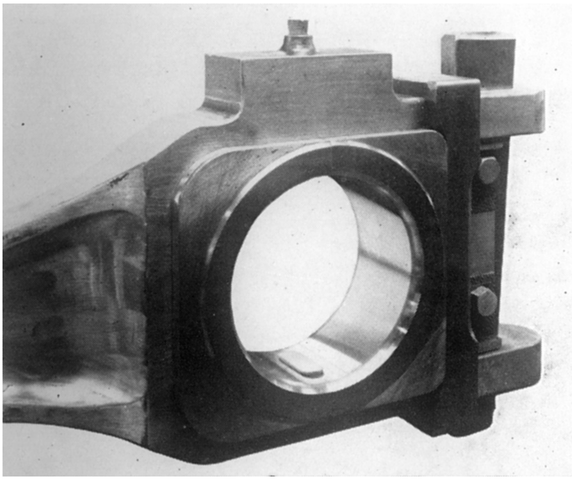

Fig. 29. *Churchward type big end on a Gresley Pacific.*

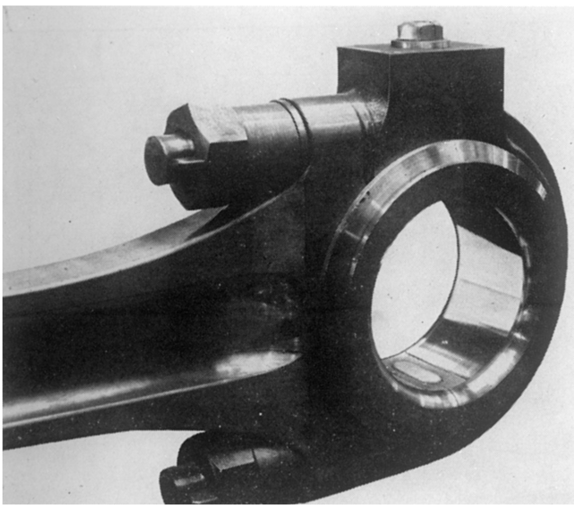

Fig. 30. *Gresley marine type big end of similar finish to the previous slide.*

taps, valve gear pins and bushes but enough has been said. One detail on which initial clearance cannot be cut down to that utilised on other prime movers is the piston in cylinder and some advantage would accrue if it could, but apparently relative expansion is much more rapid.

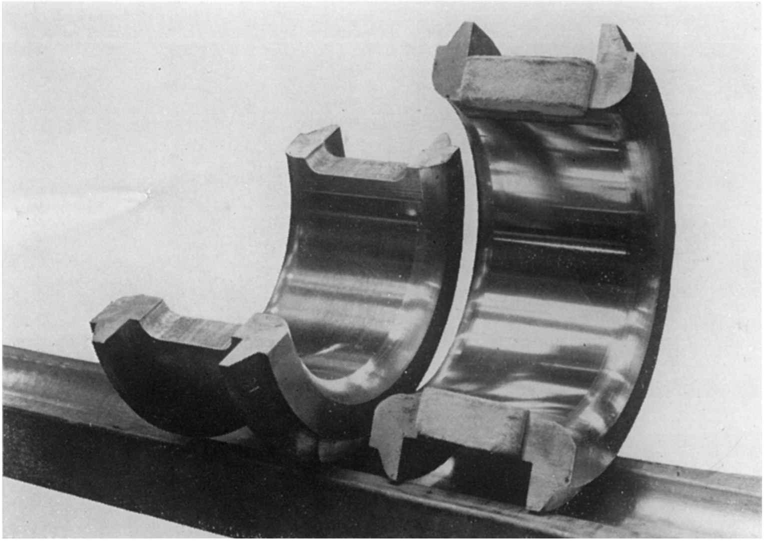

Fig. 31. *Gresley marine type brasses with complete whitemetal bearing surface and felt pads.*

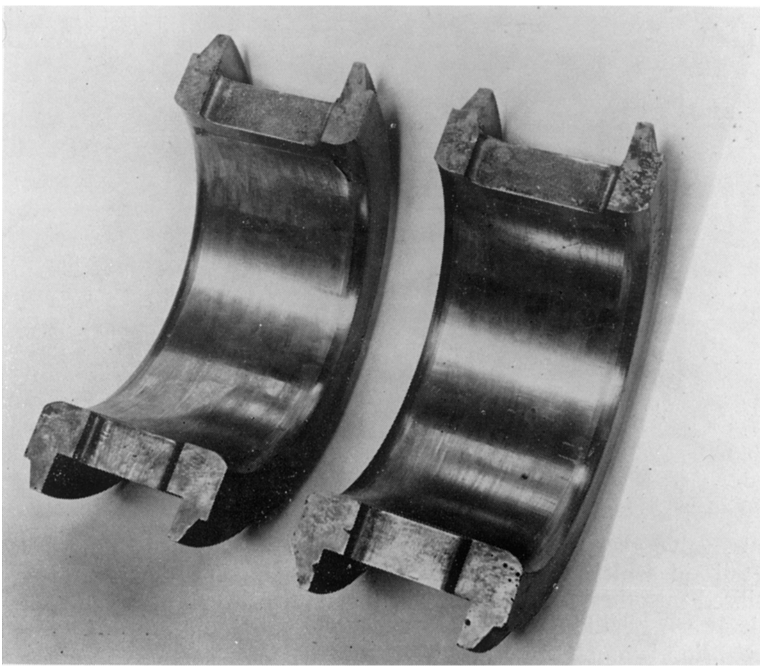

Fig. 32. *Similar brasses to previous slide after the brasses have run* 50,000 *miles with* .004″ *wear.*

At a period prior to World War II there was a considerable body of industrial opinion who regarded the railway workshops as a collection of primitive and antiquated machines and quite beyond the pale of making any contribution to wartime needs of production. Possibly this arose from the fact that by statute railway workshops have to stand aloof from the outside engineering industry, to deal with their own internal requirements only. The condition of their machine tools was probably well known amongst the machine tool makers who had derived considerable benefit during the slump years from the railways' practice of keeping equipment up to date, but industry in general and officialdom in particular had a complete misconception of the wide range of capacity necessary to provide for the mechanical and productive needs of a great railway.

During World War II the cloak was removed and the railway workshops became open doors to all who wanted help. But it took a little time to pierce the cloud. At the end of exploratory visits by the productive Ministries, the officials began to scratch their heads and exclaim, "We are on the wrong line—we have been looking to find out what you can produce—we should have been seeking what you cannot." Our own answer to Ministerial enquiries of "what can you do?" was very short and very sweet, viz., "Anything or anybody." One official of the Ministry of Aircraft Production exclaimed "You have the finest toolroom outside the

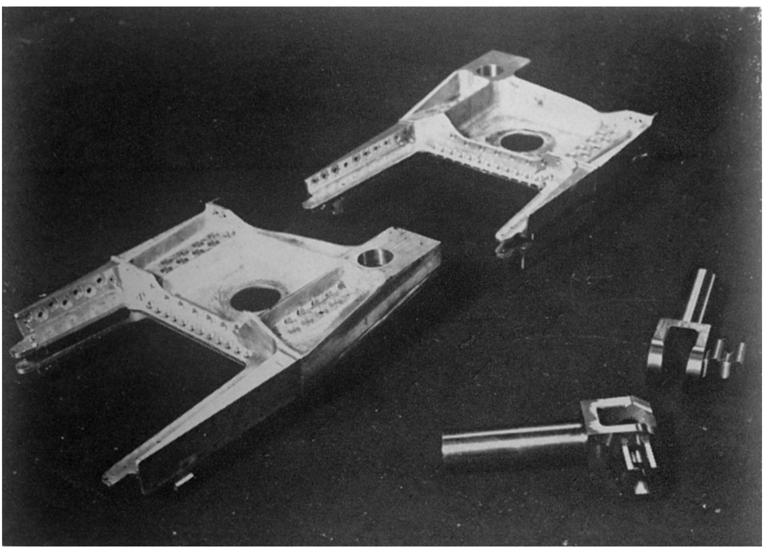

Fig. 33. *Latch pin and attachment for the folding wings of the Fairey Firefly Aircraft.*

Aircraft Industry." Later during the war he knew that there was hardly an aircraft factory which was not using ground thread taps produced in that toolroom. There were also two articles urgently required which were designed by the aircraft industry but which for many months baffled the aircraft industry to produce. One was the latch pin and attachment for the folding wings of the Fairey Firefly Aircraft. For many moons the only Fireflies delivered to the Fleet Air Arm carried these parts completely machined in a railway workshop.

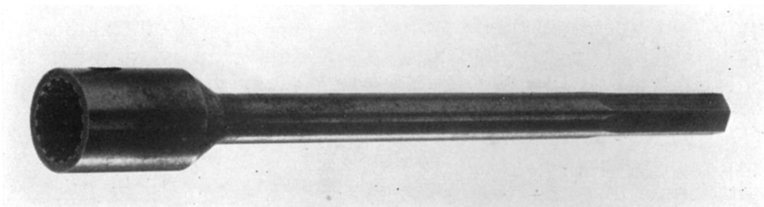

Fig. 34. *Part for the Oxford Trainer with $\frac{3}{8}''$ dia. internal splines.*

Another part was a small piece with $\frac{3}{8}''$ dia. internal splines. Twelve were produced in a few days from the request and a most profuse letter of thanks was received indicating that, thanks to these, the Oxford Trainer would now be able to be used with its proper equipment and the bottleneck had been overcome. A month or two later, an urgent request for more was received with the information that they had tried all over the Midlands and Lancashire and Yorkshire, but still could not find anyone to produce these parts.

A locomotive wheel shop has ideal equipment for machining tank turret rings and a slide is shewn of some of the 13,000 produced in one shop. In the gear ring of each set there are 392

Fig. 35. *Tank turret rings.*

internal teeth. When the contract was placed on the Works with eight weeks in which to produce the first four sets, the advice was offered that the gear cutting would cause no trouble as there was plenty of gear cutting capacity in the country. But it was found to be a very different story when efforts were made to sublet this work. There was, however, in the toolshop a gear hobber

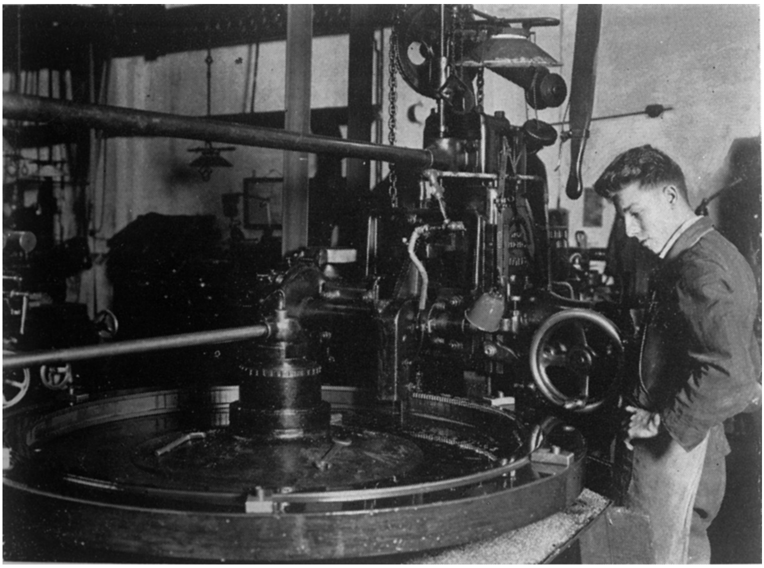

Fig. 36. *Hobbing internal teeth in gear ring.*

utilised on jobbing millwright work and this was pressed into service. Hobs were manufactured in the shop and eventually the production time was reduced to five hours and by continuous working over thirty were produced per week. Production had risen from the original promise of eight sets per week to this figure. The cost of gear cutting, with full toolroom overheads was £2 9s. 6d. per ring. In order to get the production up to the tank builders' requirements of fifty sets per week, it was necessary to place sub-contracts and the lowest quotation at first obtained from an outside firm was £11, ultimately reduced under pressure to £9 per ring. Similar conditions obtained in all railway works.

It is not suggested that everything can be produced more economically in railway workshops or that such comparisons would hold for every kind of article. There is, however, at the present moment an article freely used in locomotive boiler repairs, manufactured in at least three railway works in which, as it happens, the above figures of cost and purchase apply almost exactly.

These incidents have been quoted to indicate that British Railways' Workshops are not behind in their quest for mechanical efficiency and if the steam locomotive disappears, as well it may in a few years' time, the Workshops are capable of dealing with any alternative mechanisms. If, for example, it is necessary to chase a tenth of a thou' round the plunger or bore of diesel engine fuel pump or injector, that tenth can be found in a locomotive workshop on British Railways.

It is hoped that this address has vindicated its title. It was your President's thought to make the title "The British Locomotive, a Machine of Beauty and Precision." Until 1950 that would not have been inept, but with the advent of certain engines with a strong continental or transatlantic appearance, it was thought that this would not now be suitable.