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HIGH SPEED TRAIN - FLEET OPERATION

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Describes facilities provided for the maintenance of the High Speed Train within regional depots and railway workshops. Reviews operating experience to date and indicates future trends in high speed operation.

This paper is presented for discussion. Written communications are invited for publication in the Proceedings. Contributors should read the instructions overleaf.

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HIGH SPEED TRAIN - FLEET OPERATION

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In October 1976 British Rail introduced its first 200 km/h service on the London–Bristol and London–South Wales services. This followed several years of design work and extensive testing of a prototype train. The increase in passenger traffic on these routes, during the first two years of high speed operation, clearly indicates that there is a demand for such a service and that the train itself fully meets the need from the passenger viewpoint.

Unlike some railway administrations, who have built separate lines dedicated to high speed services, it is British Rail policy to operate these units on the existing network, sharing it with passenger and freight trains running at conventional speeds. Because of this policy the designer is constrained by track impact force limitations specified by the Civil Engineer and he must also ensure that the train can be operated safely within the existing signalling arrangements.

Bearing in mind the extent of technical innovation it is not surprising that a number of problems have arisen. However, as a result of prompt and effective action on the part of both the railway and the railway supply industries, modifications have soon been introduced to eliminate the problems.

The paper starts with a brief description of the train and the facilities provided to ensure adequate maintenance resources both within regional depots and railway workshops. This is followed by a review of experience to date and the paper concludes with a forecast about future trends in high speed operation.

1 HISTORICAL

Throughout the past two decades, British Rail has made considerable improvements in the quality of its passenger service. The initial plan involved large scale dieselization programmes and was followed by electrification schemes involving both main line and suburban services. Associated with the change-over from steam to diesel or electric traction was the equally important policy of raising the standard of the coaching stock fleet.

Market research has shown that the subsequent reduction in journey time and the improvement of on-train amenities has been an important factor in increasing passenger revenue. To exploit the market further British Rail developed a 'high speed' strategy involving, in the short term, the introduction of a fleet of High Speed Trains capable of operating up to 200 km/h followed by the Advanced Passenger Trains with an even higher speed potentiality and with improved 'curving' ability on existing track.

The High Speed Train (HST) project included the construction of a prototype train and this commenced high speed trials in 1973. The experience thus gained enabled design modifications to be incorporated in the manufacturing drawings. As the earlier production train sets became available they were introduced into service, operating initially at conventional speeds. By October 1976 sufficient trains had been delivered to introduce, as planned, the first 200 km/h service on British Rail.

2 HIGH SPEED PHILOSOPHY

When formulating its high speed strategy the British Railways Board had two options, either to build a new railway route or improve the existing track and associated signalling. The latter alternative was considered the more appropriate for this country, unlike the JNR who chose to construct a completely new railway for their Shinkansen service and SNCF who did likewise, for their high speed route between Paris and Lyons. The decision to operate high speed trains on the existing railway, albeit with considerable improvements, had far-reaching implications as far as the design of the train itself is concerned.

3 DESIGN FEATURES

It is not the intention of this paper to describe, in detail, the design of the train as it has previously received full coverage in the paper 'The High Speed Train' by Sephton (**1**). However, there are a number of features which warrant repetition, particularly as they relate to components or systems which have given rise to maintenance problems, described later in the paper (Fig. 1).

3.1 Weight consideration

Whilst the Civil Engineer has undertaken an intensive track engineering programme, including major track realignment and in some cases bridge reconstruction, he has imposed constraints on the Mechanical Engineer as far as track impact forces are concerned, thereby limiting all-up-weight, axle loading and unsprung masses. These factors have necessitated the provision of two power cars per train, each equipped with a diesel engine having a high power-to-weight ratio. In order to reduce the unsprung mass of the wheels etc., it is essential to mount the traction motors on the bogie and because of this a flexible transmission has been necessary in order to permit the relative movement between the wheel set and the bogie frame.

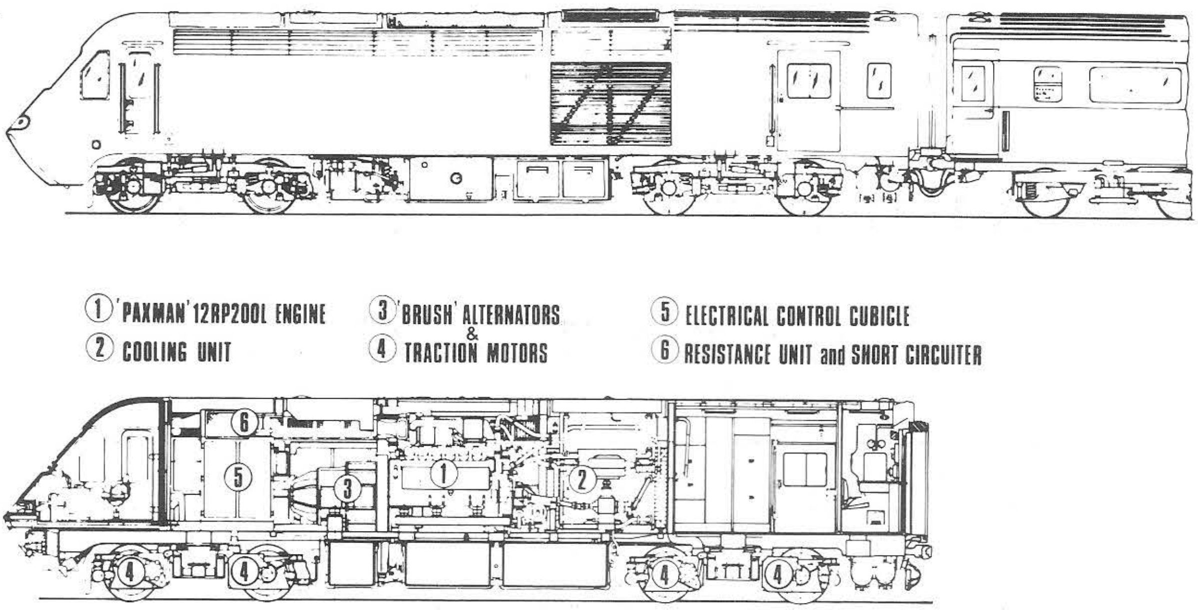


Fig. 1. Power car for High Speed Train

3.2 Brake features

The modern British Rail multiple-aspect colour light signalling was already operational on the high speed routes having been installed to meet the full requirements for conventional trains operating up to 160 km/h. In order to retain the existing system, it became a fundamental design requirement that the braking system should be such that the train could stop from 200 km/h in the same distance as a conventional train from 160 km/h.

To achieve the required braking characteristic, disc brakes are used operating on cast iron discs bolted to the web of the wheel. Of necessity, the brake forces are high and there is the danger of wheel slide. To prevent this happening, all axles, both on the power cars and the coaches, are provided with wheel slide protection. Should a wheel show signs of sliding, the device instantaneously releases the brake and restores it when the condition has been arrested. Normally the slide is corrected within four seconds but if not, in the interest of overall stopping power, the brakes are made to reapply. The power cars have cast iron 'scrubber' blocks operating on the tread of the wheel. These are provided to condition the tread surface and improve the level of adhesion.

Concurrent with improvements in the permanent way the Signal and Telecommunications Engineer has equipped sections of the line with reversible signalling, enabling trains to be signalled in either direction on both tracks in absolute safety.

3.3 Fixed formation concept

Whilst operationally it has always been the policy to keep the train as a fixed consist, the prototype coaches were nevertheless designed to be completely interchangeable with their Mark III locomotive hauled equivalent. As such, they were provided with buffers, drophead buck-eye couplings and capable of accepting the standard 800 V d.c. or 800 V single-phase a.c. train supply. Prototype experience confirmed that there would be considerable benefits by providing a three-phase a.c. supply direct from the power car instead of 800 V d.c. which then required a motor-alternator on each vehicle to generate the necessary three-phase a.c. supply. Having taken the decision to provide a three-phase a.c. supply, interchangeability with locomotive hauled stock was no longer a consideration, and it became possible to eliminate the buffers and adopt a solid shank buck-eye coupling.

4 MAINTENANCE POLICY

From the outset, it was decided to maintain the train as a fixed formation which means that the examination frequencies for the power cars, coaches and catering vehicles have to be in phase. Whilst the train is fuelled daily, the basic examination, known as the 'A' examination, is undertaken every second day and requires the train to be placed on a road with centre and side pits. In addition there are monthly, three-monthly and six-monthly examinations also undertaken in the regional depots. After a year in service the train is driven to Derby for its annual workshop overhaul.

Following the standard practice, the Chief Mechanical and Electrical Engineer at the British Railways Board (CMEE–BRB) is responsible for the preparation of all High Speed Train maintenance and workshop overhaul schedules. He nominates the chairman of each committee, which includes regional and British Rail Engineering Limited (BREL) workshops representatives, whose task it is to produce the required schedules. Inasmuch as the High Speed Train represents an up to date application of established railway technology, much information and experience is available to assist the committee. Where there has been a degree of technical innovation, due consideration is given to experience with the prototype and to manufacturers' recommendations, where this is applicable. The system is geared to react quickly should it become apparent that there is a need to alter the frequency or work content of a particular examination or repair.

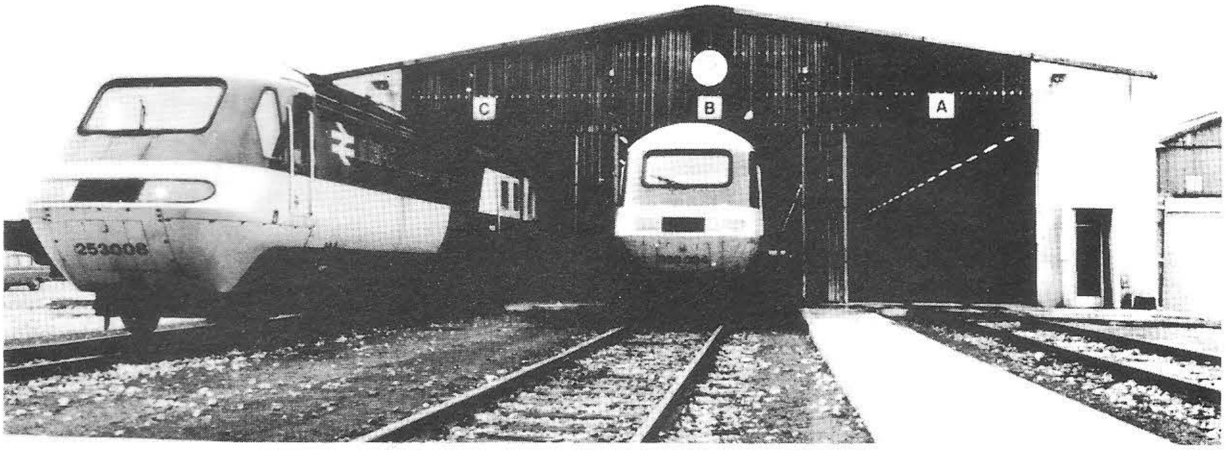


Fig. 2. High Speed Train Depot

Once the schedules have been prepared it is possible to calculate the manpower requirement, having provided a suitable contingency allowance for the additional unscheduled work likely to arise. The regions, in conjunction with BREL workshops, predict the likely material user rates and recommend the levels for consumable and repairable spares. Of particular importance are the major spares such as traction motors, diesel engines, etc., which the CMEE—BRB must specify sufficiently early to incorporate them in the initial build programme.

4.1 Depot location and size

Bearing in mind that it takes several years to design and construct a modern maintenance depot, early consideration had to be given to the location and size of these facilities. The decision was taken to build two depots, one at London (Old Oak Common) and the other at Bristol (St Philips Marsh), both natural night-time stabling points from an operating point of view. In addition fuelling facilities have been provided at Cardiff and Swansea.

In order to optimize on the day-time availability the 'A' examinations are undertaken, as far as it is possible, on the night shift. Having established a meaningful down-time for this examination, it is relatively simple to calculate the total number of berths required at the peak time. The result has been to provide both depots with three roads (Fig. 2), adequate for the night workload and well capable of dealing with the larger examinations and heavy repairs undertaken during the day time.

4.2 Depot facilities

In the interests of standardization the British Railways Board have issued guide lines for depot designs and these have been followed in the case of the new High Speed Train depots. Despite this the layouts for the depots differ considerably due to the influence of the local 'geography'. For example, the Bristol depot (Fig. 3) has through roads whilst at London the depot, perforce, has a dead-end on all three roads. The depots are purpose built to take a fixed formation of two power cars and seven intermediate vehicles. Each road con-

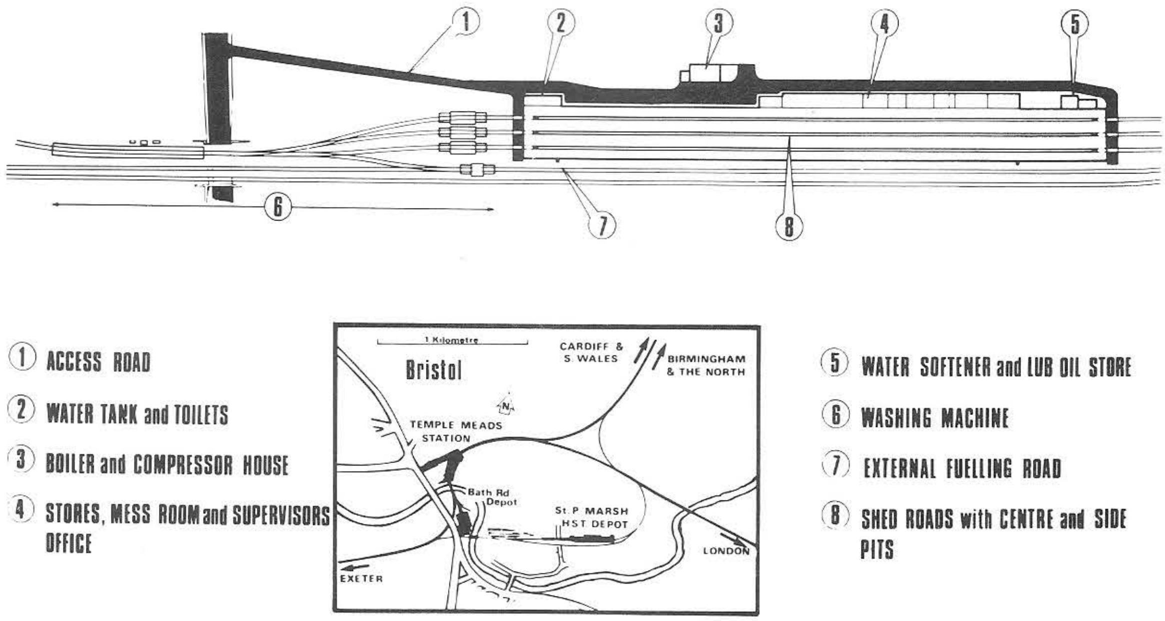


Fig. 3. St Philips Marsh High Speed Train Depot

tains two fully equipped servicing stations at the precise location where the power cars stand. The station can dispense fuel oil lubricating oil and coolant as well as permit the emptying of fuel tanks and coolant systems via return pipelines into separate storage tanks. In addition, both depots have external fuelling roads.

Four synchronized power-jacks permit bogie removal whilst two $1\frac{1}{2}$ tonne overhead gantries, on the middle road and spanning the power car engine compartments, enable light components to be lifted. In order to take full advantage of the module concept forklift trucks capable of handling a $2\frac{1}{4}$ tonne load are provided. A separate storage area, adjacent to the main stores, has been set aside for the coach modules which separately house the battery, air conditioning and brake equipment.

All depot roads and stabling sidings are provided with three-phase 415 V shore supplies, thus permitting all systems on the train to operate without the need to run either diesel engine. As is to be expected, high standards have been maintained as far as heating, ventilation, lighting and general staff amenities are concerned.

Both depots have the advantage of being close to existing heavy lift shops involved in the maintenance of main line diesel locomotives. As a result of recent refurbishing programmes, the overhead cranes at both locations are now capable of lifting an HST engine/alternator set.

When it becomes necessary to reprofile either a power car or coach wheel set, this work is undertaken on the ground lathe at the Cardiff depot.

4.3 Depot manpower

The cornerstone of good maintenance is the well-trained and conscientious craftsman and with this in mind a comprehensive training programme was undertaken to precede the introduction of the production trains. Included in the courses, all of which had a high practical content, were sessions devoted to fault diagnosis and, where applicable, training in the use of specialized test equipment.

Initially, the local staff were given the opportunity to seek transfer from conventional traction and coaching stock maintenance to the High Speed Train and thanks to a high degree of co-operation between the shop committees and depot management, the required staff redistribution was quickly effected to the satisfaction of all. It is worth mentioning that staff, both wages grade and supervisors, from separate traction and rolling stock backgrounds have integrated well. The need for a systems approach is generally recognized. Traditionally brake faults on conventional trains have been followed up by separate traction and rolling stock staff each looking at their own particular part of the train but the only sensible way to locate a similar fault on the High Speed Train is for a craftsman fully conversant with the complete braking system to carry out the investigation.

4.4 Main workshops

Whilst the railway supply industry has been responsible for supplying proprietary equipment such as the diesel engine, electrical machines, braking equipment, etc., the railway workshops have manufactured most of the mechanical parts and have been responsible for the production of the completed train sets. Having built the trains they are obviously well capable of undertaking the annual overhaul.

The train is sent to Derby for its annual overhaul, the power cars receiving attention in the locomotive works and the coaches in the carriage works. Investment programmes in the locomotive works have included the provision of test cells for checking the diesel engine/alternator/cooler group as an integral unit and load banks for static testing of the completed power car. In the carriage works provision has been made for individually testing all the coach modules. For example, test cubicles enable the air conditioning module to be subjected to full environmental tests. The completed coach, like the power car, is subjected to a full static check in a test berth specially equipped with a shore supply. In order to cope with the increased length of the Mark III coach it has been necessary to undertake considerable alterations to buildings and trackwork.

Because the trains have been introduced into service in a relatively short period of time, there is a likelihood that 'batching' will occur when they fall due for their annual overhaul. To prevent this happening, sets were shopped early, a decision which had the added benefit of enabling workshop staff to familiarize themselves with the problems likely to be encountered and prepare for them.

The current aim is to reduce the period out of service, for annual overhaul, to three weeks. This will give shops fifteen working days to undertake the repairs. The extent to which the target is not being met is largely due to teething problems with some components. The reduced number of repaired components immediately available means that the policy of overhaul by unit exchange cannot be fully implemented. Once the fifteen working day repair has been achieved it is intended that all movements to and from works should take place at the weekends, thereby further improving availability.

5 PERFORMANCE

At the project development stage, it is obviously necessary for the engineer to predict availability levels for the train. Only then is it possible to establish the size of the fleet required to operate the particular service and assess the economic viability of the proposals.

With a new train like the High Speed Train it is necessary to quote two availability figures, the short term availability and that which can be expected once all the initial problems have been overcome. It is pleasing to record that since October 1976, when the high speed running commenced, there has been a progressive increase in the number of trains in traffic. With each successive timetable the opportunity has been taken to introduce more trains and for the 1978 Summer service twenty out of a fleet of twenty-seven have been made available, approximately 75 per cent.

In order to maintain this figure effective control is necessary and this is achieved by an 'operations' and a 'maintenance' control at the Regional Headquarters in London. The two controls work closely together and deal, appropriately, with operational and engineering matters as they arise. A constant feed back to Control of 'in-service' defects enables depots to be advised in advance about items requiring attention during the night. It will be appreciated that tight control has to be exercised on both the depot movement of trains and the allocation of staff if the night's programme of fuelling, cleaning, repairs and examinations is to be completed.

Because of the variation in brake pad wear rate, it has not, as yet, been possible to undertake a campaign change as part of an examination. The result is that, quite often, trains which could otherwise have gone direct to the stabling sidings, after external fuelling, take up valuable pit accommodation in the depot whilst the particular brake pads are being replaced. There are other reasons why train sets, not requiring the two-day examination, have to be placed on a road within the depot. For example, it may be necessary to position the train over a pit in order to investigate a complaint about the running gear. In order to programme the total night-shift workload the depot must be given advice, without delay, on all such matters.

5.1 Reliability

On British Railways, reliability is expressed in terms of km per failure, a failure being recorded each time a technical defect results in the train being delayed more than five minutes. It is a stringent measure, but despite this recent statistics have shown an average figure of 20 000 km per casualty with an improving trend. Only in a few isolated cases have there been complete failures of the train. This is due to the fact that there are two power cars either, on its own, capable of working the train through to its destination. In the majority of these cases the train is seldom more than ten minutes late on arrival. Commencing a journey with only one engine may lead to greater delays but it is worth mentioning that this is usually preferable to operating the service with a conventional train which, with its maximum capability of 160 km/h, is no substitute for an HST.

Casualty Investigators at the depots ensure that all failures are thoroughly investigated and the cause established. A Service Problems Committee under British Railways Board chairmanship, meets regularly to discuss defect trends and allied engineering problems arising in the maintaining depots and workshops. The aim is to initiate corrective action and in order to ensure a co-ordinated approach representatives from the regions, workshops and manufacturers (if considered necessary) attend each meeting.

Bearing in mind that the High Speed Train represents a 25 per cent increase in the maximum permitted speed over existing trains, it is not surprising that there has been a number of problems. In the interest of overall weight reduction, some components have been lightened whilst, at the same time, expected to produce or transmit more power. Other components, particularly those associated with the running gear, are additionally subjected to forces which increase disproportionately with the speed.

6 SERVICE PROBLEMS

This section of the paper deals with some of these problems and shows how the railway in association with the manufacturers have sought to overcome them.

6.1 Cylinder heads

Whilst little trouble was experienced with cylinder heads on the prototype train fractures occurred when the production trains started operating the new service. The problem manifests itself in two ways: firstly by the need to top-up the coolant and secondly, by the spectrographic analysis of the lubricating oil showing the presence of sodium from the coolant inhibiter. Another feature not immediately appreciated was that the turbo-charger thrust bearing, lubricated by the engine oil, suffers damage if coolant is present in the oil (Fig. 4).

An investigation into the fractures revealed departure from the drawing requirements, as far as wall thickness in the port areas was concerned, whilst a metallurgical examination showed a need to achieve an improved micro-structure in this critical area. Regarding the latter, it was found that by maintaining close control on the level of tin addition in the iron the desired pearlitic structure could be achieved whilst modifications to certain shell cores, from hollow to solid, ensured a reduction in the grain size. An improved foundry technique now ensures the exact location of these cores, and has overcome the problem of wall thickness.

The turbo-charger thrust bearings have a copper-lead lining and this is attacked if coolant is present in the oil. Laboratory tests have shown that the glycol anti-freeze oxidizes to form an organic acid which dissolves the lead leaving an etched surface. The slight taper on the thrust bearing is attacked and this leads to failure of the 'wedge oil' feed, followed by rapid wear (Fig. 4, enlargement).

6.2 Turbo-charger–nozzle ring (Fig. 5)

The first batch of production engines were supplied with a turbine nozzle ring with thirty-two vanes, similar to that used in the prototype train. When the foundry supplying the turbo-charger manufacturer suddenly closed down, no company could immediately be found capable of producing the nozzle ring with thirty-two vanes. It was necessary to resort to a ring with twenty-four vanes but unfortunately this has proved less reliable.

Fatigue cracking originates at the junction between the blades and the inner and outer annular rings (Fig. 5, enlargement). A technical analysis is made more difficult because it involves the stress analysis of complicated shapes under transient thermal loads. For example spike temperatures, possibly due to fuel after-burn, may last only for a few micro-seconds and yet be sufficient to initiate fine surface fractures.

In the short term, the problem has been overcome by more effective radiusing at the failure initiation point and changing the blade material from an austenitic steel to Nimonic 75 (nickel – chrome alloy), the latter having a much higher creep strength. Longer term, nozzle rings with thirty-two blades and manufactured in Nimonic will be introduced as standard on all turbo-chargers thus achieving the best of both worlds.

6.3 Blade connecting rods (Fig. 6)

Several blade rods have failed from fractures originating at the base of the threads in the big-end bolt holes. In order to appreciate the nature of the problem, it must be understood that whilst the rod is being nitrided, the threads in the big-end bolt holes are intended to be protected by a barrier paste. If the paste is not completely removed, then it is possible to increase the hoop stress in the rod, during tightening of the bolt, due to a

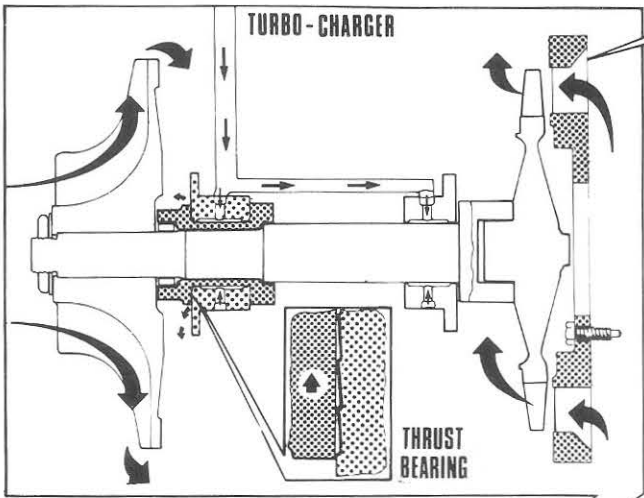


Fig. 4. Turbo-charger showing thrust bearing

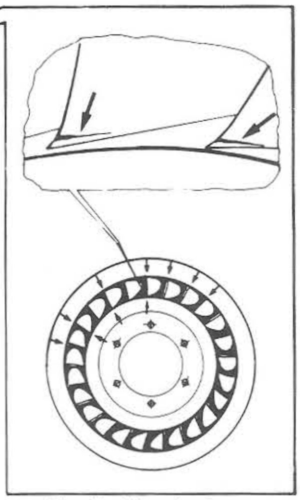
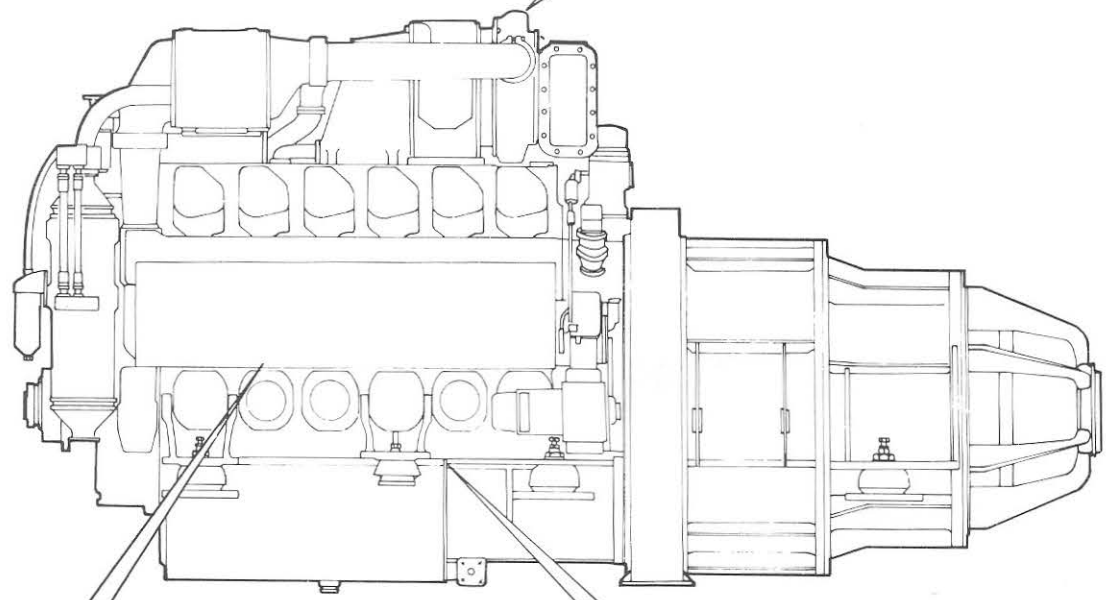


Fig. 5. Nozzle ring



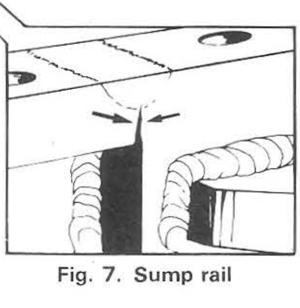


Fig. 7. Sump rail

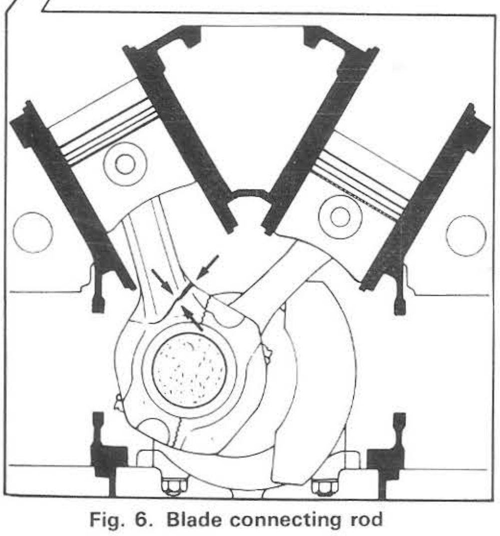


Fig. 6. Blade connecting rod

'tight' thread. Additionally, if, due to inadequate protection, some nitriding of the thread is allowed to take place, then the resulting differential hardness may also initiate fractures.

The corrective action as far as the blade rod is concerned involves electro-chemical cleaning of the threads and eddy-current testing for fractures, whilst the big-end bolt is being shortened and its end coned. The combined effect will be to ensure a satisfactory thread in the rod and reduce stress levels in the critical area near the bottom of the hole.

6.4 Sumps (Fig. 7)

Investigation into oil leakages revealed a number of fractured sumps. Fractures occur at a welded joint on the top of the sump rail and propagate into the side wall of the sump wrapper plate. The drawing calls for a 'J'-type preparation, but due to incorrect machining and setting-up the two flat faces practically butted together allowing inadequate penetration of the weld. Cracking originating at the toe of the weld resulted from fatigue stressing. All the sumps are being carefully examined and rectified where this is considered necessary.

6.5 Traction motor – commutator wear (Fig. 8)

The brush wear rates, to date, have been quite satisfactory. With the application of Tensator springs, which ensure a constant brush pressure over a wide range of brush lengths, it should not be necessary to renew brushes between annual shopping.

It has been suggested that there is a degree of brush instability leading to unequal pressure on the two halves and unequal current distribution which in turn has lead to some deterioration of the commutator surface. The Feinprufe profile recorder shows a differential wear on the brush track, of up to 0.1 mm and this has necessitated the machining of the commutators after a year in service.

In order to overcome the problem, a double brush spring arrangement is being tried. It is considered that, with the steeple top and accompanying wedge action, each half of the split brush will move independently under the influence of its own pressure finger thus leading to improved current collection.

6.6 Short-circuiter (Fig. 9)

The short circuiter is provided to protect the electrical power equipment from power earth faults and rectifier failures. Operating experience has shown that it needs very careful initial adjustment and meticulous maintenance in order to obtain trouble-free operation. Where possible, 'shake proof' nuts are being used.

Whilst the present design short circuits the three-phase output from the traction alternator to earth, an alternative is being considered which will operate on the direct current output from the main rectifier (Fig. 9, shown dotted). This will have the advantage of a single pole device without detriment to diodes in the rectifier.

Power earth faults have occurred, particularly during inclement weather, when water has entered junction boxes in the vicinity of the traction motor. A simple and effective temporary solution has been the provision of 'polyolefin' shrink sleeving to insulate the connection.

6.7 Control equipment (Figs. 9 and 10)

The control equipment has performed well but there is one contactor which is worthy of comment particularly as it caused a number of failures during the first few months of fleet operation and the way in which the defect manifests itself is interesting.

The contactor in question is used as the main alternator exciter field contactor (GX) which has an interlock in the traction motor and reverser circuits. The operating spindle of this interlock was prone to sticking which meant that on occasions the traction motor contactors could not open thereby holding the reverser in a fixed direction. Having changed ends at a terminal station, the driver applies power and because the direction of the affected reverser does not correspond with the direction requested, the alternator on that power car does not excite and as a result the driver receives an output from one power car only. As the speed builds up, the traction motors (with reverse field) in the affected power car starts to generate and feed current into the short circuit formed by the rectifier diodes in the conductive direction. A state of balance is reached at about 8 km/h when the electrical braking load on one power car equals the traction output from the other (Fig. 9).

The problem was overcome in the short term, by providing greater clearance between the interlock spindle and the guide. The modified guide has a PTFE lining and, instead of relying on gravity to open the interlock, in the de-energized condition, the spindle has now got a return spring for this purpose (Fig. 10).

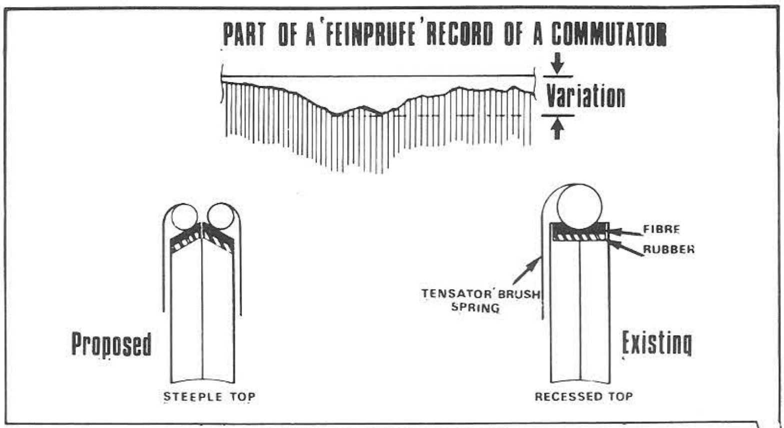
6.8 Wheel slide protection

A number of wheel slide arrangements have been applied to the power cars and to the Mark III Coaches and catering vehicles. The device uses speed probe units to obtain signals relating to each wheelset on the vehicle. These signals are constantly monitored and the brakes released on the appropriate wheelset if tendency to slide is indicated.

The preferred system has two units, a differentiator and a comparator. The differentiator unit, using the probe signals, measures the rate of deceleration of each axle independently and releases the brake should a pre-set value of 25 per cent g be exceeded. The comparator relates the probe signals to the speed of the train, indicated by the non sliding axle(s) and releases the appropriate brakes if the speed differential exceeds 5 km/h + 2 per cent train speed.

Initially the device locked-out and became inoperative if it did not correct the condition within four seconds and had to wait for depot staff to investigate and reset. Furthermore, the comparator unit on the power car was unable to distinguish variations in rotational speed due to spin as opposed to slide and hence locked-out, being unable to correct the 'fault' within the given time. This meant that the device was not then available, when required, to give the necessary slide protection. As a result considerable tread damage occurred, reprofiling usually being necessary.

Subsequently two modifications have been carried out. The first permits automatic resetting, leaving an indication that the system has been unable to correct a slide condition whilst the second inhibits the device



TYPES OF CARBON BRUSH

Fig. 8. Commutator wear

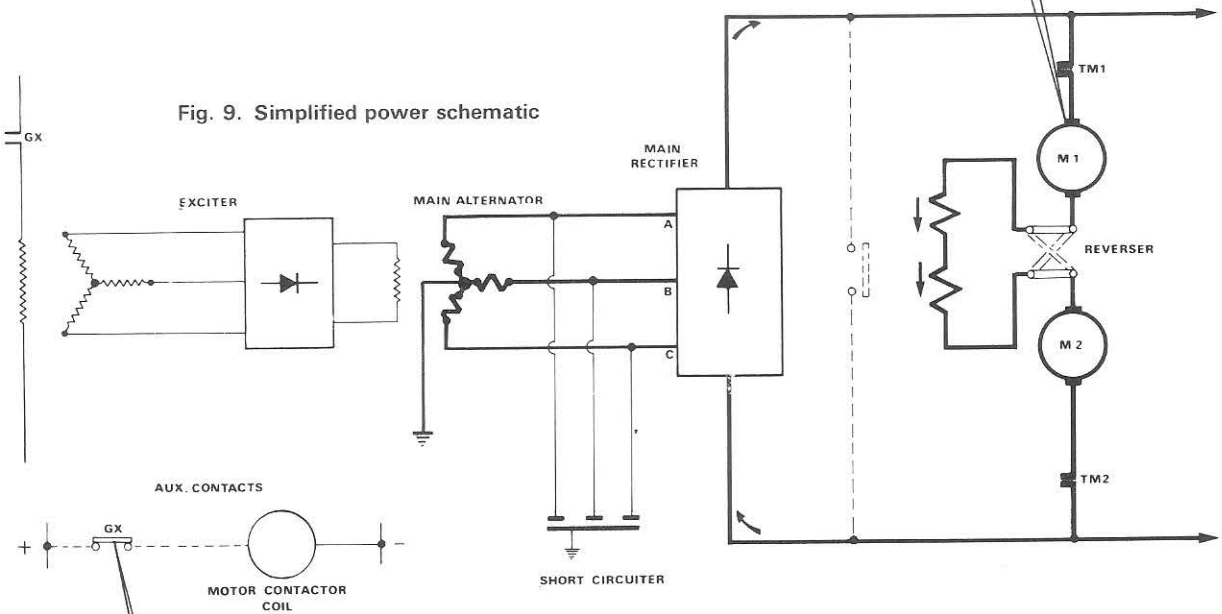


Fig. 9. Simplified power schematic

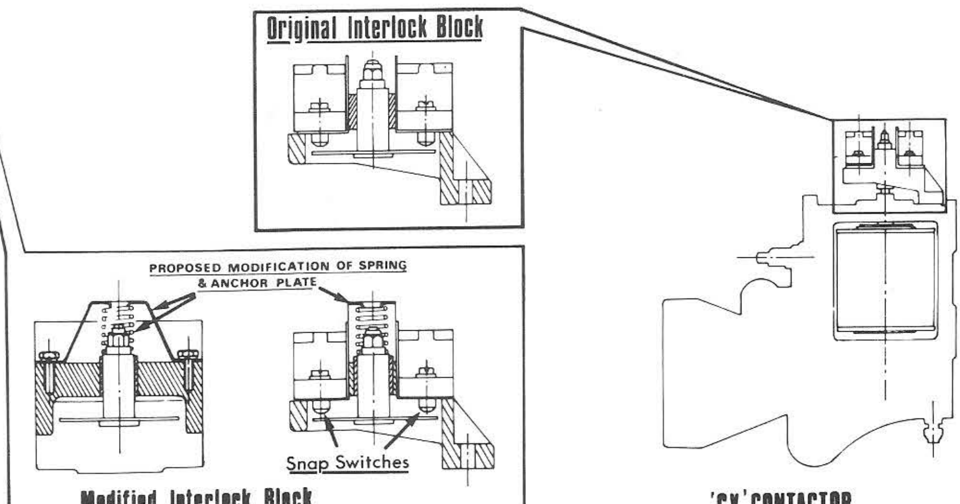


Fig. 10. Original and modified interlock block of the GX contactor

when traction is being applied thereby avoiding response to spin conditions.

Apart from the rectification of damage caused by sliding, little attention is required in order to maintain the profile. Normal running wear is extremely low and no attention should be necessary between annual shopping, in fact a life of 700 000 km between turning is capable of being achieved. At the time of writing the Mark III coaching vehicles have a Pl (1 in 20 taper) profile whilst the power cars have a P8. The P8 is a BR developed 'worn' profile which, following successful experiments on a number of Mark III coaches, will progressively become the common profile throughout the train.

6.9 Battery charger

The feed to the battery charger on both power cars and coaches is from the a.c. train supply. The charging current is regulated by a system of phase angle control in a three-phase half-controlled bridge. The battery protection has three parameters, over voltage, over current and excess a.c. ripple. The choke and capacitor unit in the charging circuit removes the excess ripple, provided there is a reasonable output from the charger.

Difficulty was initially experienced when the train was coupled to the shore supply. The battery chargers on coaches, with batteries in a low state, often tripped. The reason for this is that a battery in such a condition does not instantaneously accept the charging current and as a result, the choke is unable to keep the ripple below the trip value. A modification (to introduce a short time-delay into the operating sequence) has been carried out, thereby preventing the charger from reacting to this transient condition.

An allied problem on the power car arose from the train disposal procedure which, in keeping with locomotive practice, called for the drivers to open the battery isolating switch (BIS). In this condition, when the train is connected to a shore supply, the power car battery charger output is open circuit. Having no load, the choke is ineffective and the charger, as in the case of the coach, trips on excess a.c. ripple. The problem has been simply overcome by instructing drivers to leave the BIS permanently closed. Depot staff are fully aware of the implications should it be necessary, for maintenance purposes, to open the BIS when the train is on shore supply.

6.10 Traction motor flexible drive (Fig. 11)

Bearing in mind the originality of the design, it is not surprising that modifications were necessary to several parts of the transmission and these are now described.

In order to improve the lubrication of the gearbox bearings and to permit a longer period in service between attention for lubrication, the oil capacity has been increased from 2.3 to 3.4 litres. In addition, oil weirs with oil priming holes have been provided so that the bearings are no longer totally dependent on splash lubrication.

Following some early fractures, the standard of finish of new supplies of the flexible drive links has been improved, whilst those in service with surface imperfections have been replaced. During manufacture, where dressing of the casting is necessary, this is now done along, as opposed to across, the plane of the principal stress. Where it is necessary to change a link, the complete set is replaced by a weight-matched set in order to ensure dynamic balance.

The gearbox torque reaction link couples the gearbox to the bogie frame transom. The bushes at both upper and lower positions are of the bonded rubber type which depend on adequate axial load in the securing pins to provide the necessary friction grip between the central metal sleeve of the bush and the lugs of the gearbox or transom, thus ensuring that any movements are absorbed by the rubber. After several months in service, a lower securing pin fractured and the subsequent examinations revealed high wear rate between the head end of the pin and the bush in the gearbox lug. To eliminate the problem, the pins have been machined with tapered heads to which are fitted tapered split collets. The collets take up any clearance that exists between the pin and the bush and wear on the metal interfaces is prevented (Fig. 11, enlargement).

6.11 Disc brakes (Fig. 12)

Problems have been experienced with the disc brakes on the Mark III locomotive hauled stock and on the HST power cars and coaches. The discs each side of the wheel web are secured by bolts tightened to a specified torque setting. Two of the bolts are 'fitted' whilst the remainder are 'clearance' bolts.

Initially the discs on the locomotive hauled stock, which have the fitted bolts at the corners, began to fracture in this area. It was felt that a better arrangement for both the HST power cars and coaches would be to locate the fitted bolts on the radial centre line of the disc (Fig. 12) thereby permitting unconstrained thermal expansion to take place at the corners. Despite this, fractures of the fitted bolts and the disc have continued and as a result considerable design effort is being put into this particular problem. As far as the power car is concerned, action to date includes increasing the diameter of the fitted bolt from 13 mm to 18 mm diameter and uprating the torque setting of clearance bolts in order to reduce the load on the former.

At the time of writing a series of special tests are being arranged in conjunction with the Research Department. Using strain gauges and thermo-couples, continuously monitoring events, it is hoped to establish both the physical and thermal conditions in the brake discs and securing bolts and determine a correlation. The tests will include braking from above 200 km/h in order to establish the consequential increase in physical and thermal strain. The higher road speed, and hence higher rotational speed of the wheels, will simulate the physical conditions likely to be experienced under normal service conditions when wheel sets have been turned to their minimum diameter. It is appropriate to mention that, as an additional safeguard, an electronic overspeed protection device is currently being fitted to all power cars which will automatically cut back power when the maximum permitted speed of 200 km/h is reached.

Numerous complaints have been received from passengers about brake block smells and the matter is receiving attention. The first alteration was to arrange for the coach air-intake shutters to close during braking, thereby keeping out most of the smell. Whilst this has not completely eliminated the problem, it has brought about a considerable improvement. Now the manufac-

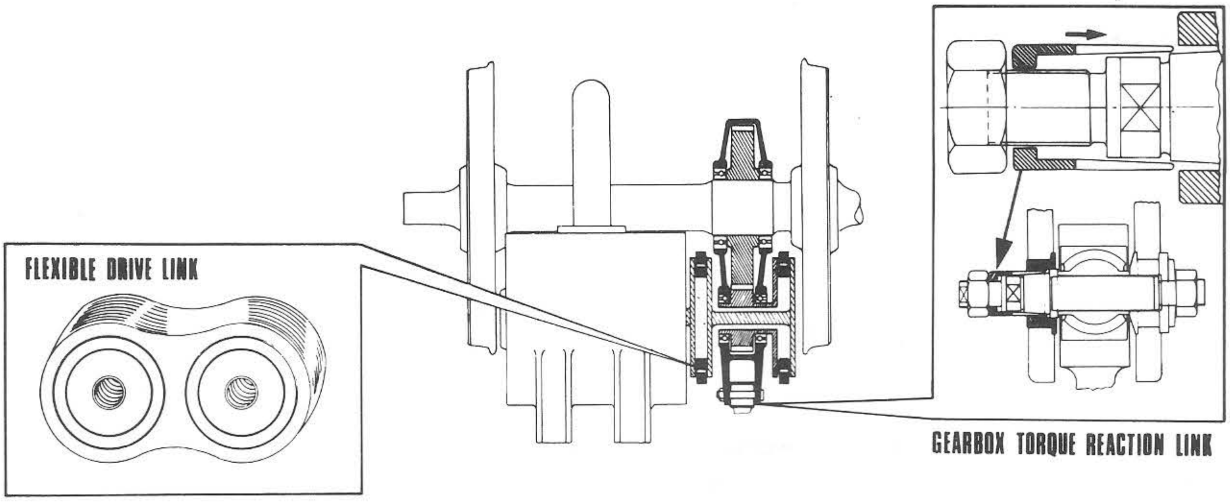


Fig. 11. Traction motor flexible drive

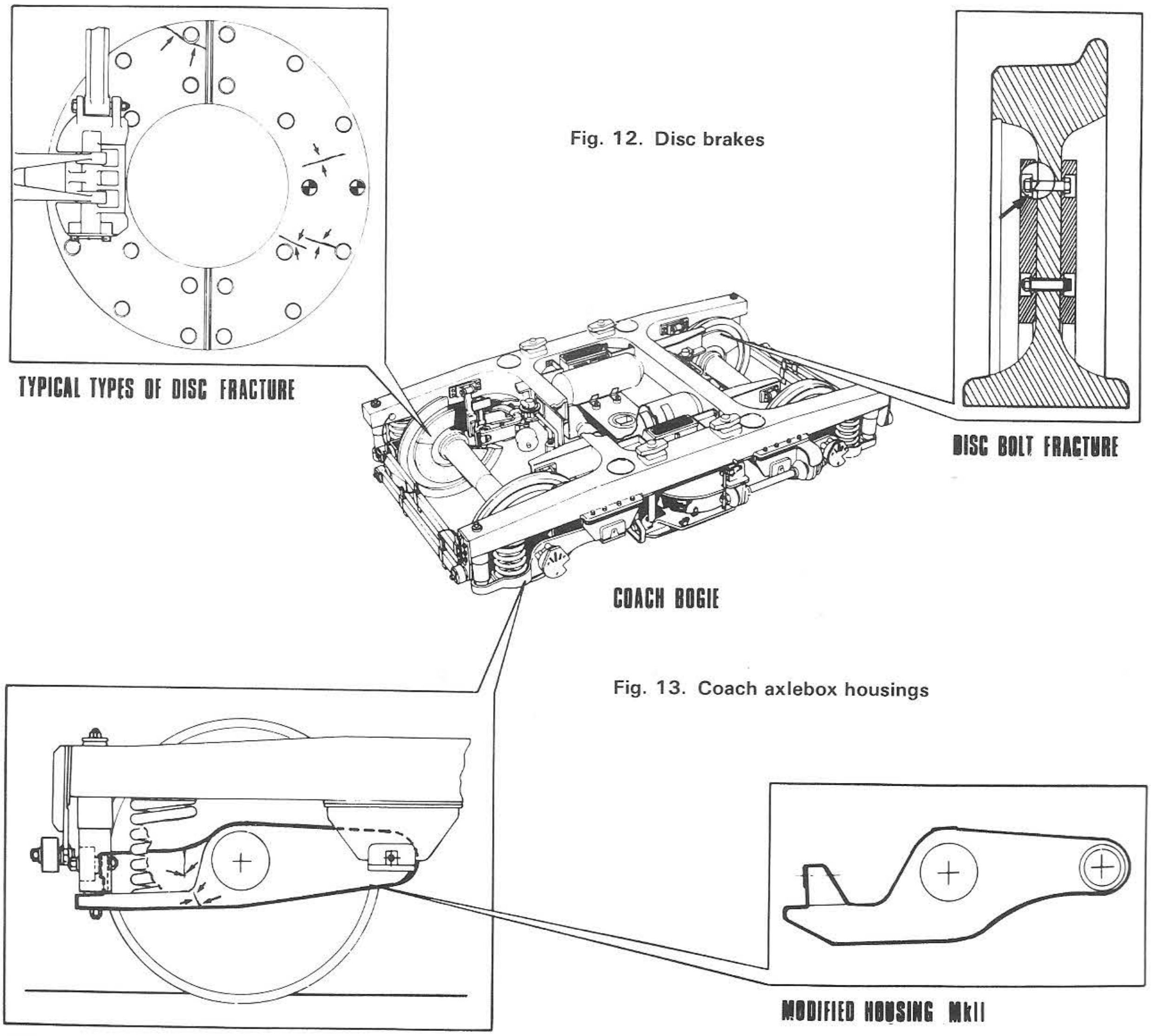


Fig. 12. Disc brakes

Fig. 13. Coach axlebox housings

turer is hoping, by using a different bonding resin, to develop a block which will eliminate the problem at source.

6.12 Coach axlebox housings (Fig. 13)

The BT 10 bogie is the production version of the BT 5 bogie which was fitted to the prototype HST and gave a satisfactory performance in service. It was designed to achieve specific yaw and lateral stiffness in order to ensure bogie stability at all operating speeds.

The axlebox is designed to provide the anchorage points for the vertical, lateral and longitudinal springs and ensures accurate wheelset alignment through the principle of a swinging arm.

Following discovery of a fractured axlebox on a Mark III locomotive hauled coach, an immediate survey of all HST coach axleboxes was undertaken and this resulted in a number of vehicles being withdrawn from service.

A comprehensive testing programme was initiated involving static and dynamic strain gauge measurements. The outcome was a policy decision to design and manufacture a new axlebox with a view to replacing the existing one. This new axlebox, the Mark II, has been designed using the latest computing techniques and the fatigue analysis suggests that, unlike the Mark I, an infinite fatigue life can be expected.

7 OPERATING CONSIDERATIONS

Introducing a high speed service on an existing system means that the operator has to overcome the problems of scheduling trains involving four different speedbands, i.e. High Speed Trains, locomotive hauled passenger and parcel trains, diesel multiple units and finally the freight services.

The problem is partly solved by adopting the 'flighting' technique. High Speed Trains are despatched as a flight of trains at five minute intervals followed by trains in descending order of speed, leaving a time gap before the departure of the next flight. The fact that the train is a fixed formation with a driving cab at each end means that a quick turn round time at terminals is possible. Unfortunately the fixed formation presents its own problems, particularly at busy weekends when trains are normally strengthened in order to carry the increased traffic. The alternative is to provide additional locomotive hauled services but as these operate at conventional speeds, it is often difficult to find suitable paths. Requests have been made to consider providing an additional trailer vehicle on certain sets and whilst this may be acceptable from the point of view of available horsepower, it makes the train incompatible with the depots, purpose built to accommodate a specific formation.

7.1 Catering

Shore supplies are provided at terminals and stabling sidings. The latter are particularly important and must be connected during the night lay-over period to run refrigerators and thereby prevent damage to the food stored on board the catering vehicles. At the time of writing, three different types of catering formation are provided within the present regional allocation: the separate kitchen and buffet formation, the original style buffet only and the combined buffet/kitchen vehicle. This means that when it has been necessary to switch sets, certain services may end up with the incorrect formation and it may not be possible to provide the range of meals advertised. With the move from multi-course meals, the regional policy is now to have only two formations, either the buffet only or the combined buffet/kitchen and this will ease the problem.

7.2 Cleaning

Automatic washing machines, with side and top brushes, are provided at both High Speed Train depots. Future plants will have additional side brushes to clean the valances on the coaches and existing machines will have them fitted.

An unexpected problem was the staining of the drivers' windscreen and the area above it. The cab shape is aerodynamically efficient and this causes the exhaust gas from the trailing power car to cling to the body, depositing a carbonaceous film along the roof and over the cab end. Experiments with a roof deflector plate have been encouraging and a modification to fit all power cars is proceeding. The modification consists of a plate, held 100 mm above the power car roof. When the train is in motion, clean air is induced under the plate and forms a permanent boundary layer over the cab roof and windscreen.

7.3 Commercial

The only way to combat competition from the private car is to achieve shorter journey-times and provide a high standard of passenger comfort on the trains. On average, the journey times from London to Bristol and South Wales have been cut by about twenty-five minutes whilst passengers in the new coaches enjoy comfortable seating, air conditioning, good lighting, low noise and vibration levels with a catering service to meet present day requirements. The success of this policy is clearly revealed in the growth of traffic on the high speed routes, having increased by 30 per cent since October 1976. In addition to capturing a larger share of the existing market, the service is generating new travel business.

8 CONCLUSION

Following the introduction of the high speed service on the East Coast Main Line, the next fleet of trains will be allocated to the London–West of England route. Preparatory work for the new service, starting in October 1979, is well in hand and includes the construction of a new maintenance depot, capable of handling both conventional and high speed trains, at Plymouth. Full advantage will be taken of the experience gained during the past two years to ensure the success of the project.

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