Report of Investigation into Class 50 Rheostatic Brake Problems

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Titled “Report of Investigation into Class 50 Rheostatic Brake Problems” it has no details of the author, the author’s company, any form of issue control, or any copyright details. The only date on it is hand-written (31st March 1978). It has a number of hand-marked corrections, suggesting that it was a draft document not quite ready for publication. However it not known that it was ever published in any form.

It seems likely that the author worked for GEC Traction, as it would have been known at the time, as there is quite a lot of technical detail that may not have been available to British Railways personnel. However the document content suggests that the author must have had reasonable access to British Rail maintenance staff on the London Midland and Western Regions.

The author clearly hoped that a way could be found to reinstate or retain the rheostatic brake on the Class 50 locomotives operating on the Western Region. History tells us that other problems, particularly the poor performance of the inertia air filtering system originally installed, over-ruled this, as removal of the rheostatic brake equipment permitted a better air filtration system to be installed.

The document has been shown to a number of people who worked for British Rail and GEC with professional knowledge of Class 50 operations on the London Midland and Western Regions at the relevant time. None can recall seeing or knowing of the document, but its technical content does seem to be correct for the 1978 date.

The document was scanned by Paul Steane in May 2024 and hosted on his web site in July 2024.

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This front page was created by Paul Steane on 15 July 2024.

REPORT OF INVESTIGATION INTO CLASS 50 RHEOSTATIC BRAKE PROBLEMS

1. Introduction

The Class 50 Locomotives were progressively introduced to the London Midland Region during the latter part of 1967, the complete fleet of 50 locomotives being delivered by the end of 1968. They were designed for fast express passenger work and whilst on the London Midland Region wre used principally on express work between Crewe and Glasgow, and just prior to the electrification of the latter route were used in pairs. However other work was undertaken such as some working of Merry-go-round coal trains. On completion of the electrification of the West Coast Main Line the Class 50 locomotives were systematically transferred to the Western Region and at the same time the hire contract with GEC was terminated and the locomotives taken into full British Rail Ownership. Transfer to the Western Region commenced at the end of 1972 with one locomotive going to Bristol (Bath Road) for crew training, but the bulk of the fleet (35 locomotives) were transferred in May 1974. However it was not until May 1976 that the final Class 50 was transferred to the Western Region (see Graph 1 for fleet size variation). Transfer was to Old Oak Common, Bristol Bath Road and Plymouth Laira Depots but to date all except 6 locomotives still at Bristol, are now based at Laira. Traffic worked by the Class 50 locomotives on the Western Region again consists mainly of express passenger, but a small amount of freight traffic is worked (for example stone trains).

Rheostatic braking was fitted at the outset to all the Class 50 locomotives and is a blended system, that is at the initiation of a brake application air braking is introduced whilst the rheostatic brake circuitry is set up. The air brake is blended out and the rheostatic brake takes over full control until a low speed is reached and the air brake blends in again. The pneumatic system is part of the Westinghouse proportional braking system and the electrical control system is of English Electric manufacture.

Rheostatic braking is difficult to justify in a pure economic sense, but is has obvious advantages in terms of reduced brakeblock wear leading to less of the unpleasant work of brakeblocking in depots. There is also less friction material detritus leading to a cleaner system generally. The critical feature of the rheostatic brake is the blending process as far as passenger comfort is concerned, and to be successful the solution to this problem must be satisfactory.

Various problems eventually overcome were experienced with the rheostatic brake whilst the locomotives were on the London Midland Region and these are described in a subsequent section. After transfer to the Western Region further problems were experienced which eventually led to the Western Region isolating the rheostatic brake on Class 50 locomotives and currently a modification is underway to remove the associated equipment and use the vacated space for improved filtration to the clean air compartment.

2. Objective

The principal objective was to determine whether there was any justification for isolating the rheostatic brake and proposing for its removal. A secondary objective was to study the working of the brake in depth, with a view to avoiding problems experienced with the Class 50 rheostatic brake on any future rheostatic brake system.

3. Strategy

The project was tackled by firstly becoming thoroughly familiar with the brake system on the Class 50's. After this various people on the L.M.R., who had been involved with the Class 50's, were consulted to build up a picture of the L.M.R. experience with the rheostatic brake. This same procedure was adopted on the Western Region. Other factors also had to be taken into account, these being the dirt problem on the Class 50's and the tyre problem. Finally sufficient information was to hand to be able to come to a reasoned conclusion regarding the working of the rheostatic brake on the Class 50 locomotives.

4. The Working of the Rheostatic Brake on the Class 50's

4.1 Pneumatic

Control of the rheostatic brake is provided through equipment associated with the proportional brake, and is initiated either by a deliberate brake application made by the driver, or an automatic emergency application. When working, the rheostatic brake takes priority over the locomotive proportional brake.

Rheostatic brake operation is sensed by the air brake apparatus through a Restricted Application Control Valve (RACV) which is an electro-pneumatic device, in which output pressure produced is in inverse proportion to the current applied to a magnet coil in the RACV. With brakes released, this is de-energised and it applies an output pressure equal to the maximum pressure from the loco distributor to a capacity reservoir connected to one side of a diaphragm in each of the Restricted Application Relay Valves (RARV) which are 1:1.2 step up in pressure of air to the bogie brake cylinders. Air also flows through a check valve to a reference reservoir and applies the same pressure to the other side of the control diaphragm in the RARV thereby balancing it.

On applying the brake, air from the distributor pressurises a timing reservoir (the pressure being dependent on the amount of application), a Rheostatic Brake Potentiometer (RBP) and the 2 RARV. The Rheostatic Brake Potentiometer transmits to the rheostatic brake control equipment an electrical signal proportional to the air pressure applied.

A signal also comes to the RACV in proportion to the rheostatic brake current being generated. This causes the pressure output to the capacity reservoir to be reduced approximately in inverse proportion to the electrical signal applied. The check valve retains the pressure in the reference reservoir. This unbalances the diaphragm in the RARV reducing the brake cylinder pressure by an amount equal to the difference between the reference and capacity pressures.

Brake cylinder pressure reduction is approximately proportional to the rheostatic braking current, and when the rheostatic brake current fades as speed reduces, the signal applied to the RACV reduces increasing the pressure in the capacity reservoir thus equalising the diaphragm in the Restricted Application Relay Valve.

A relay air valve between the Rheostatic Brake Potentiometer and timing reservoir has a connection to the straight air brake and if the straight air brake is applied whilst the proportional brake is being applied, the Rheostatic Brake Potentiometer will vent causing immediate suspension of rheostatic braking eliminating the possibility of 2 simultaneous brake applications. See enclosed layout of air/dynamic brake blending system.

4.2 Electrical Control

When the brake valve handle is moved to a braking position a microswitch is engaged, and pressure is passed to a Brake Relay Governor (BRG). The Locos control gear will connect the traction motors as series type motors in 3 parallel branches with motor contactors M1, M2, M3 in the negative connection and M4 and M5 in the positive connection, or as separately excited generators for braking purposes in which the fields are connected in series by Dynamic Brake contactors DB4 and DB5 and excited by the main generator. The motor armatures are connected to fixed value resistors by contactors DB1, DB2 and DB3. Traction motor armature generated voltage (proportional to flux times armature rotational speed) will drive current through the resistances and react as a retarding force on the wheels.

On moving the brake handle, control is set to drop out the main contactors, energise EP valves to open shutters for rheostatic brake resistance cooling purposes, connect resistors across the armatures and connect one of the split generator fields to the series connected traction motor fields.

Originally a Brake Timing Relay (BTR) caused a 3 to 4 second delay between dropping out M1 to M5, and connecting the resistors across the armatures to allow the generator field to collapse. This was subsequently removed (see later).

The degree of dynamic braking corresponds in conjunction with road speed and excitation to that degree set by the position of the DBV handle - the air pressure signal is translated to an electric signal by the Rheostatic Brake Potentiometer which then controls generator excitation in the KV10 solid state load regulator.

Braking current is measured on the drivers desk ammeters by the Direct Current Current Transformers which also provide a feedback signal to the CU1 control unit to control generator excitation in conjunction with DBP. Braking current is also measured as a voltage drop across a resistor across armatures 2 and 5 and is used to operate 2 electric fan motors, the Brake Modulating Valve (BMV) coil in the RACV, and the current coil of the Brake Cut-Off Relay (BCR) which is opposed by the voltage coil connected across the generator. Imbalance between these 2 coils causes suspension of the rheostatic brake and introduction of air braking at about 12 miles per hour when field amps are too high or road speed too low.

See enclosed electrical schematics and the Dynamic Brake characteristic.

5. <u>Setting Up Procedures</u> - contained in Standing Order No. G.135 Appendix C.

5.1 <u>Adjusting Maximum Dynamic Brake Output</u>

Prior to making the adjustment to maximum dynamic brake current of 1650 Amps the locomotive power output must be adjusted if necessary i.e. if power output is adjusted the rheostatic brake current must be reset. This is because the current and load control unit (CU1) varies the control signal passed to the field supply unit which sets the generator field current to control generator excitation for both power output and when braking rheostatically. The control signal can be varied by adjustments of certain resistors in the CU1 unit.

Setting the Dynamic Brake output consists mainly of shorting out the DB4 contactor, isolating all motors, applying full power with air brake off and measuring the voltage between two terminals on the CU1. (Voltage X). The shorting link across DB4 is then removed, the motors de-isolated and the proportional brake placed in the full service position, with the control handle at OFF. The voltage across the same two terminals on the CU1 is then measured (voltage Y). The relationship between voltage X and voltage Y should then be Y = x - 2.2. If this is not the case, two potentiometers R23 (coarse) and R13 (fine) can be adjusted to give the required relationship.

5.2 <u>Other adjustments</u>

Other adjustments affect the working of the rheostatic brake :-

5.2.1 Brake Relay Governor - this has to be adjusted to actuate at 14 psi and open again at 10 psi air pressure from the distributor.

5.2.2 Field Divert Relay - the adjustment of this relay is critical to the value of rheostatic brake current which will cause suspension of the rheostatic brake due to overloading.

5.2.3 Brake Cut Off Relay - the current coil and the voltage coil have to be adjusted correctly to give correct blending out of the rheostatic brake at about 12 miles per hour.

5.2.4 Brake Modulating Valve - correct adjustment of this is necessary to give correct blending between the air brake and the rheostatic brake.

5.2.5 Dynamic Brake Potentiometer - requires setting to give correct response to the CU1 due to air pressure output from the distributor.

6. <u>Class 50 Rheostatic Braking Problems & Service Experience on the LMR</u>

6.1 All the problems experienced whilst the locomotives were on the LMR can be listed as follows :-

6.1.1 Tyre troubles. In common with the a.c. electrics fitted with rheostatic braking, the Class 50's suffered damage to tyres and it seems fair to conclude that a combination of an air friction brake and a dynamic brake causes tyre damage that otherwise would not occur. (This is looked at in greater depth in Section 6.2).

6.1.2 Utilising of Microswitch in M8(A) proportional brake controller. This was a modification carried out from 1971 onwards to provide immediate initiation of rheostatic braking as soon as the driver moved the brake handle. This therefore by-passed the BRG in application and it was hoped that by decreasing the time the air brake acted at the commencement of an application, the tyre problems would be alleviated to some extent.

6.1.3 Brake Timing Relay removal. This was originally intended to delay the action of the rheostatic brake to allow the generator field to decay. If this is not done, over-excitation of the motors occurs causing overload. The BTR was removed simply because it was not found reliable enough in operation, and there were no suitable replacements on the market at that time (1971). This lead to the situation whereby the driver had to pause for 4 or 5 seconds between shutting off power and applying the brake. Failure to do so would cause overloading, and through the action of the Field divert relay, suspend operation of the rheostatic brake causing braking shocks.

6.1.4 Generator Field Mod. This was carried out from 1971 onwards as a result of the BTR removal in an effort to speed up the decay of the generator field, and was done by freewheeling the 2 Generator fields through a 2 ohm resistor. The mod was also done as part of a generator flashover protection scheme i.e. to decrease the amount of damage suffered by the main generator in the event of flashover.

6.1.5 Burn out of Z4 rheostatic brake resistances. This occurred circa 1972 due to a fault in the BCR coil across the generator which resulted in the rheostatic brake not being suspended at low speed. A modification was carried out by altering the value of the Z12 resistance from 650 ohms to 860 ohms (see enclosed schematics).

6.1.6 SAV3 Interlocks - Originally these interlocks became contaminated with oil and were difficult to get at. In 1972 these were modified by reversing the cams in the interlock box to make use of a spare pair of more easily accessible contacts.

6.1.7 Braking Shocks. These were looked into by the Tyre Damage Working Party as described in Section 6.2.

6.1.8 Brake Relay Governor. If not set correctly, surging can occur when the rheostatic brake is suspended, and can also cause a superposition of air braking and rheostatic braking.

6.1.9 Overloading. This can occur either when a driver makes a brake application before decay of the generator field has taken place, or if the dynamic brake current has been set too high. Overloading causes braking shocks due to immediate rheostatic brake suspension and time lag before the friction brake has time to blend back in.

6.1.10 Setting up of maximum dynamic brake current. Adjustment of the R13 and R23 potentiometers is difficult due to their situation in the cubicle, and they are easily damaged or broken without knowing. There were a number of occasions at Crewe Traction Maintenance Depot when the R13 and R23 sliders were found loose due to the lock nut not having been tightened up properly resulting in the adjustment changing due to vibration when in motion. Also in practice, to set the maximum current of 1650 Amps the loco had to be given a light run. R13 and R23 could be set within limits with an avometer but to obtain an accurate measure of dynamic brake current the loco had to be run to actually measure dynamic brake current and if incorrect the locomotive had to be stopped to reset the resistances. The setting of the potentiometers can thus be a trial and error process and also a time consuming operation.

Also any adjustment to the maximum power setting of 2400 Amps to the traction motors affects the rheostatic brake settings and thus power adjustments have to be made prior to any rheo brake adjustments.

6.1.11 Rheostatic brake isolation. The rheostatic brake could be isolated by drivers, simply by isolating the air supply to the shutters by turning an air cock.

6.1.12 Dynamic Brake potentiometer. Diaphragm Failure. An improved design of diaphragm and piston was introduced under a modification towards the end of 1973.

6.1.13 Seizing of Shutter Mechanism. This used to occur on occasions due to inadequate lubrication and resulted in complete non-operation of the rheostatic brake.

6.1.14 Multiple Working. When working in multiple, power loss on the 2nd locomotive used to be a problem, due to non-synchronisation of the BRG's. This was caused by the BRG on the first locomotive opening and allowing power to be taken but BRG on the 2nd locomotive would remain closed longer preventing power from being taken from the 2nd locomotive.

6.2 Tyre Damage Investigation

Various studies have been undertaken into tyre damage virtually since the Class 50 locomotives were built, and this culminated in the setting up of a Tyre Damage Working Party at the beginning of 1973 and this was disbanded in mid-1974. Associated with this were studies of the problems of braking shocks and their relationship to the tyre damage problem.

6.2.1 Definitions

(a) Thermal cracking:- Radial cracking due to thermal cycling produced by tread braking.

(b) Spalling:- Thermally induced cracks which propogate by rolling contact fatigue, eventually causing areas to fall out.

(c) Shelling:- Mechanically induced fatigue cracking (rolling contact fatigue) which starts below the surface and eventually causes pieces to drop out of the surface. It is caused by excessive contact stresses e.g. wheelslide and slip.

6.2.2 October 1969 BRB Test Report No. T131 "Tyre Shelling Tests on Class 50 EE (2700 hp) Locomotive No. 440"

This report concluded the following :-

(a) Dynamic braking causes thermal damage with new brakeblocks.

(b) Serious problems are caused if a brake application is made with power on, or within 5 seconds of shutting off power.

(c) More damage occurs with a full service application than with an emergency application due to higher brake cylinder pressures reached before the air brake is blended out.

The report recommended, that the period during which the air brake acted should be reduced in order to reduce the temperature reached by the tyres, and thus reduce spalling. This led to the use of the microswitch in the M8(A) proportional brake handle as described in 6.1.2.

6.2.3 The Tyre Damage Working Party was set up at the beginning of 1973 to look into tyre problems experienced with Class 86/87 and Class 50's.

(a) TDWP Progress Report number 1, 22 March 1973. This reported, that 3 Class 50 locomotives hauling service trains had been ridden on as follows :-

Loco 421, vacuum braked coaches. In the initial position there was neither rheostatic braking not air braking. The vacuum train pipe had to be reduced to 15 inches of mercury before any brake came on. Locos 431 & 409, air braked coaches. On 431 the rheostatic brake was working alright, but on 409 it was inoperative. Different braking rates between the 2 locomotives could cause braking shocks.

Shocks can result if BCR is not set properly due to rapid suspension of the rheostatic brake causing brake release on the locomotive more quickly than on the train.

(b) TDWP Progress Report number 2, 31 May 1973. This reported on Technical Note number 476/1 "Braking Tests with Class 50 Locomotive number 411". Tests were carried out with light locomotive number 411 on 9 May 1973 and 10 May 1973.

On the first day, full service applications were made with and without rheostatic brake between 100 mph and 40 mph, and the braking rate was found to be at the desired level. It was considered however that the rheostatic brake and the air brake acting together may cause wheelslide leading to thermal cracking.

On the second day the straight air brake was used, firstly with a brake cylinder pressure of 85 psi and secondly a brake cylinder pressure of 60 psi. The results were found to be acceptable with a brake cylinder pressure of 60 psi and this led to the experiment to reduce the cylinder pressure on five Class 50 locomotives.

(c) TDWP Progress Report No. 3, 24 July 1973. This reported on trips on 9 service trains hauled by Class 50 locomotives on 13 June 1973. The results were as follows :-

Locomotive 407 AB train	Rheostatic brake satisfactory.
Locomotive 408 VB train	Rheostatic brake current too low, however brake supplemented by air.
Locomotive 409 VB train	Rheostatic brake isolated.
Locomotive 411 AB train	Rheostatic brake satisfactory.
Locomotive 412 AB train	Rheostatic brake isolated.
Locomotive 415 VB train	Rheostatic brake satisfactory, although current slightly down.
Locomotive 419 VB train	" " " "
Locomotive 430 VB train	Rheostatic brake satisfactory.
Locomotive 448 AB train	Rheostatic brake isolated.

On the whole the rheostatic brake was found to function as designed.

(d) TDWP Progress Report No. 4, 28 January 1974. This reported on the following :-

Experiment DL/444. Four locomotives with the rheostatic brake isolated (412/3/4/32) with rheostatic brake resistors removed due to shortage caused by burn out as described in 6.1.5. Concrete blocks were substituted as ballast. The experiment was to look into the effect on tyre damage of the air brake acting only.

Experiment DL/465. Isolation of the air brake on number 3 wheelset involving locomotives 50016/21/36 to determine the effect of the action on tyre condition of the rheostatic brake acting only. At the date of the report all wheelsets were showing heat affected zones except for the number 3 wheelset which was in good condition.

From this it was concluded that a combination of a rheostatic brake and a friction brake is the main cause of trouble and that some reduction in brake effort was required. It was also decided later in 1974 to terminate experiment DL/465 having found no thermal damage at all on axles with the air brake isolated.

The experiment involving five Class 50 locomotives with reduced brake cylinder pressure was implemented under experiment DL/464.

(e) TDWP Progress Report No. 5, 31 December 1974. This reported on experiment DL/444 to the effect, that 3 locomotives had attained a mileage of 120 000 miles before tyre turning.

The TDWP was now disbanded, with no results from experiment DL/464, however during 1976 at a meeting to discuss progress of work to obviate tyre damage it was stated by the Western Region, that "tyre damage on the Class 50's was not now a problem" so further work was allowed to lapse.

6.3 Reported Rheostatic Brake Defects in 1973

Drivers repair book entries for all the Class 50's for the year 1973 were examined, and the entries concerning rheostatic braking noted. It is difficult to conclude a great deal from these entries except to say, that during the whole of 1973 there were 116 reported defects regarding the rheostatic brake. This works out at about 10 per month between 50 locomotives. Many of the reported defects are non specific in nature e.g. "Rheostatic Brake Faulty", and there are also a significant number of "rheostatic brake isolated" reports and for about a third of the above defects no fault in the system could be found when followed up at Crewe Diesel Depot. This tends to suggest that drivers could have been isolating the brake due solely to general dislike of the brake. The other principal defects consist of problems of the blending between air braking and rheostatic braking, suggesting that in these cases the system was not set up properly. There are also twelve reported cases of overloading occurring, and this was probably due to the dynamic brake current being set incorrectly.

7. Conclusions of Rheostatic Brake Operation on the LMR

From discussion with various people on the LMR at CM & EE BRB Derby, CM & EE LMR Derby, Stoke Division, Crewe Diesel Depot and BREL Crewe, and from the facts available, it is concluded that the rheostatic brake on the Class 50's was reasonably successful whilst they were in use on the LMR. Many of the problems were eradicated, but some remained notably the effect of the rheostatic brake on tyres, the adjustment of R13 and R23 resistors on the CU1, the feature of overloading occurring due to making a brake application before complete decay of the generator field and also a dislike of the brake by drivers (drivers dislikes are described in section 10). There was no evidence to suggest that the rheostatic brake caused wheelslide, and a further factor in favour of the view that the rheostatic brake was successful on the LMR was that a member of staff at Stoke Division involved with the Class 50's rode on every Class 50 during 1974 and found 9 locos with rheostatic brake isolated. These 9 were broken down as follows :-

4 had had the rheostatic brake equipment removed with substitution by concrete blocks due to 6.1.5 and experiment DL/441, 2 were isolated unnecessarily and 3 were incorrectly set up. Also an extra incentive at this time to keep the rheostatic brake working was that the locomotives were then on loan from English Electric whereby BR paid EE £60 per day, except if stopped by BR for unscheduled work whereby EE would pay £50 per day per loco if more than 8 locos out of the 50 were stopped for classified repair and routine maintenance. However it was sometimes difficult for BR to prove that the fault was caused due to some defect over and above scheduled maintenance i.e. due to a manufacturers defect.

Finally everybody spoken to on the LMR were of the opinion that the rheostatic brake was a good brake and that the WR were totally unjustified in pressing for its removal.

8. <u>Rheostatic Braking Problems on the WR</u>

8.1 The problems experienced with the rheostatic brake on the Western Region can be listed as follows :-

8.1.1 Personal differences between the WR CM & EE and the LMR at the time of the transfer of the Class 50's resulted in a lack of cross-fertilisation of information from the LMR to Western Region depots. This resulted in WR depots being very much "thrown in at the deep end" when the Class 50's arrived. A further result was that depot staff were unable to undergo any training on the LMR, but instead went on a 2 week electronics course and a 2 week course on Class 50's at Swindon. It could thus be argued that the WR were ill-prepared to receive the Class 50's due to lack of maintenance information and a lack of staff training, in that prior to the Class 50's no knowledge of electronic control systems had been necessary. It has also been said, that at Laira depot the best of the maintenance staff used to be allotted to the maintenance of the Class 52 diesel hydraulics as these were very familiar to staff, and this was to the detriment of Class 50 maintenance.

8.1.2 Brake Relay Governor setting. This frequently used to be incorrect resulting in BRG not opening during brake release. This resulted in power not being able to be taken for a few seconds.

8.1.3 SAV3/1 interlock. This particular shutter air valve interlock caused problems by sometimes not making contact due to oil and broken wires.

8.1.4 Loss of power after a brake application. This was due to incorrect BRG setting and also on occasions there were problems with disintegration of the lower section of rheostatic brake contactors, a problem also occurring occasionally with the main motor contactors.

8.1.5 Problems setting up the dynamic brake current as on the LMR.

8.1.6 Power Earth Faults due to ingress of water through bodyside grilles when passing through carriage washing plants and passage along Dawlish sea wall during heavy seas. This could also lead to burn out of Z4 and Z5 resistances.

8.1.7 Locomotive dirt problem. This is discussed further in section 8.5 but several years of dirt accumulation in the cubicle have led to repercussions on the control side of the locomotive. (The cubicles have never been removed since the locomotives were built).

8.2 **Service Experience**

Transfer of Class 50's from the LMR to the WR followed the pattern depicted in Graph 1 and at present 44 Class 50's are based at Laira. It is now about 18 months to 2 years since an attempt was made by any WR depot to set up the rheostatic brake on any Class 50 so it is almost certain that now no Class 50 has the rheosatic brake in operation. Since concentration of the majority of the locomotives at Laira depot, a concerted attempt has been made to raise the once dismal level of miles per casualty. As an experiment the rheostatic brake was isolated just to see if the miles per casualty figures improved (see Graph 1), and this they did and was then used as the basis for isolating the rheostatic brake on all locomotives permanently by making various disconnections in the cubicle, and also shorting out the Brake Relay Governor. Contactor DB4 has been re-connected to function as a sixth main motor contactor. Also on two locomotives the 2 Main Generator Field Contactors have been removed. All this work has been carried out before the relevant modifications have been processed. The modification proposals are described in section 8.4. In order to prepare a financial case for removing the rheostatic brake some brake block wear measurement tests were carried out on 8 locomotives based at Bristol Bath Road, and briefly the results obtained were that a dynamically braked locomotive with a brake block wear rate of 117 mile/mm would require 31 block changes a year and a locomotive with the dynamic brake isolated with a block wear rate of 86 miles/mm would require 42 block changes a year.

8.3 **Discussion of Brake Block Wear Measurements**

The Western Region tests involved the use of 4 locomotives with the rheostatic brake isolated and four locomotives with the rheostatic brake in use and were reported on in the 11 Mar 76 Class 50 SPWG minutes. It is very doubtful whether the Western Region results for the Class 50 locomotives with the rheostatic brake supposedly in operation are valid, because of the small amount of difference in block wear rates compared with the Class 50 locomotives with rheostatic brake isolated. In these tests there was no guarantee that the rheostatic brake was in use the whole time, on the locomotive concerned and block wear rate is notoriously difficult to measure. Also during 1973 whilst the locomotives were on the LMR, brake block wear tests were conducted between BRL4 brake blocks and BRL5 brake blocks on 4 locomotives under experiment DL/395. This was at a time when it was proposed to replace BRL4 blocks with BRL5 blocks due to excessive flanging of the former. Unfortunately due to problems encountered in monitoring block wear, results were obtained from only one locomotive, but these were, that the BRL5 block achieved 24 000 miles/in and the BRL4 block achieved 15 000 miles/in working out at 947 miles/mm and 595 miles/mm respectively. As a result of experiment DL/395 a modification subsequently resulted in the fitting of BRL5 brake blocks to all Class 50 locomotives and if the brake block wear results from the LMR (947 miles/mm) are compared with WR results for Class 50 locomotives with the rheostatic brake isolated (86 mile/mm from 8.2) a ratio of 11:1 block wear with rheostatic brake in operation to rheostatic brake isolated is obtained. It is realised that the Class 50 locomotives when on the LMR worked a slightly different service and over different routes than when on the WR but it is considered that an 11:1 ratio of block wear is a far truer indication of block wear as far as rheostatic braking is concerned.

Also by way of comparison brake block wear tests on a Class 45/1 locomotive produced a block wear rate of 75 mile/mm which compares well with the 86 miles/mm for the Class 50 locomotives involved in the test with rheostatic brake isolated, considering the higher brake percentage of the Class 45/1 locomotives and the nature of the services worked on the Midland lines from St. Pancras.

8.4 Western Region Modification Proposals

As a result of various unofficial experiments at Plymouth (Laira) Diesel Depot a series of modification proposals were introduced by WR CM & EE and these are as follows (reference No. 72/ML/MODS11/7/77) :-

8.4.1 Removal of the rheostatic brake and its associated electrical and mechanical control equipment, leading to possible savings of £78,160 per year in fault finding, work on exams, setting up etc. Also improvement in availability, decrease in casualties and decrease in down time.

8.4.2 Use of Rheostatic Brake Contactor DB4 as an extra motor contactor M6 in order to be able to isolate traction motors 3 and 4 if necessary. This proposal would result in possible savings of £6,864 per year with improved reliability and reduction in main generator flashover damage.

8.4.3 Isolation of current limit potentiometer. This is not dependent on the removal of the rheostatic brake.

8.4.4 Isolation of DCCT low speed wheel-slip control circuit. This is also not dependent on the removal of the rheostatic brake.

8.5 Filtration System

At present the Class 50 locomotives use inertia filters for primary filtration but these have not proved successful due to the fact that they are unable to filter particles below 10 microns in size allowing quantities of dirt to enter the locomotive and particularly when working in multiple for the trailing locomotive to suck in the leading locomotives exhaust emission.

A Dirt Working Party was set up in July 1971 and published a report in November 1971 detailing a considerable number of recommendations. Implementation of these has not cured the dirt problem and thus it was discussed and agreed at the Class 50 SPWG meeting to dispense with inertia filters subject to the rheostatic brake removal.

Dirt particles blow from the inertia filters onto the top of the control cubicle, causing layers of dirt to form on the resistance banks. Dirty air is also sucked in by the number 2 end traction motor blower and down into the traction motors and also through a duct up into the KV10 compartment of the cubicle causing contamination of the KV10 due to the removal of covers some years ago. Also over the years quantities of dirt have entered the rest of the cubicle through poor seals, when testing and setting up, through the trunking into the cubicle and also from the EP valves. This, due also to the fact that plastic interlock covers have become lost over the years, has led to dirt contamination of interlocks and a consequent unreliability of the locomotive due to spurious electrical faults.

Removal of the rheostatic brake would allow removal of the inertia filters and replacement by conventional filters. The intention is also to put a fan in the roof to draw cool air over the engine and install filters where the rheostatic brake resistances and fans are at present. This would provide filtered air for the number 2 end turbochargers, main and auxiliary generator cooling, number 2 end traction motor blower and KV10 compartment of the cubicle. There would also be a sealed bulkhead between engine compartment and the generator/cubicle/brake equipment compartment.

Thus any decision regarding the rheostatic brake has to be taken with very great consideration to the locomotive dirt problem as removal of the inertia filters requires the removal of the rheostatic brake to provide the extra air intake area required.

9. Conclusions of rheostatic brake on the Western Region

Conclusions reached regarding rheostatic brake operation on the Western Region are that, it is believed there has been no justification for the action taken regarding the implementation of unofficial modifications at depot level before the due modification process has been concluded. It is not regarded that the rheostatic brake was ever given a fair chance due to the reasons described in section 8.1.1 and that with sufficient effort problems with the rheostatic brake could have been overcome. It is conceded that the miles per casualty figures have shown a great improvement during 1977 but this could be due to the concentration of the majority of the Class at Laira depot and the increasing familiarity with the locomotives.

The question of loss of power after a brake application due to BRG not opening could have been alleviated by checking BRG more frequently on exam by noting the action of the shutters at opening and closing pressures. Other loss of power faults resulting from a rheostatic brake application are likely to have been caused by the general condition of the cubicle.

Rheostatic brake current setting is a problem and there would have been room for improvement in the design here, but the problems involved were not insuperable.

It is suggested, that the problem of water ingress whilst passing through carriage washing plants could have been alleviated if the drain holes in the floor of the locomotive were always ensured to be clear of debris.

The financial case put forward for the rheostatic brake removal is considered in the discussion in section 12.

10. Drivers dislikes of the Rheostatic Brake

A dislike common to both the LMR and WR was the fact that there was no indication of braking when braking rheostatically except on the ammeter which is remote from the position of the brake cylinder pressure gauge.

There is also a lack of being able to feel the action of braking whilst braking rheostatically. When the Class 50's were on the LMR many drivers were already familiar with rheostatic brake fitted to the a.c. electrics, but Scottish Region drivers were not familiar with rheostatic braking and it is suggested that it was these drivers who disliked the brake most when the Class 50's were in use on the LMR. The Class 50's also used to have some unfitted freight duties which rheostatically braked electrics did not tend to have and when working this type of train, drivers considered the rheostatic brake (particularly on ScR) as an unnecessary complication. Furthermore when working vacuum braked trains it was possible to get shocks (although not severe) due to the more immediate brake response on the locomotive than on the coaches. Finally any driver "fanning" the brake handle would cause shocks due to the response of the rheostatic brake.

Another dislike stemmed from the removal of the Brake Timing Relay which then required the drivers to pause between shutting off power and making a brake application. Severe shocks could be set up if this procedure was not adopted due to overloading and suspension of the rheostatic brake.

The final cause for dislike amongst drivers was the question of loss of power on the second locomotive when working in multiple. This resulted in difficulties keeping time and was a problem by no means as prevalent on the Western Region due to the small amount of multiple working there.

11. <u>Hysteresis tests - RACV</u>

Any weakness in this component was investigated on a Westinghouse brake rig at the Railway Engineering School, Derby. Rheostatic Braking was simulated by applying a voltage to the Brake Modulating Valve coil. Any hysteresis effects were looked for by applying the proportional air brake to full service and then voltage applied to the BMV coil was gradually applied to vent the brake cylinder. At a brake cylinder pressure of 0 psi the voltage was gradually reduced until the cylinder pressure was again at maximum.

The results obtained are shown in Graph 2 and demonstrate that few hysteresis effects were apparent and in fact on a loco any effects would be reduced further due to general vibration and the results are a combination of hysteresis effects in the RACV and the RARV.

The results were also extrapolated to the Westinghouse characteristic for the RACV of putput pressure against coil current (see graph 3) and this was done bu dividing the brake cylinder pressure by 1.2 to discount the effect of the RARV and equating the rheo brake reading to coil current. The graph shows that the slope of the characteristic is correct and it does not fall into the Westinghouse limits due to the arbitrary scale used to measure BMV voltage at the Railway Engineering School.

From these results it can be concluded that there are no inconsistencies in the RACV and this was borne out by discussion of experience with the actual locomotives in service. In fact the bulk of the problems have been on the electrical control side.

12. Discussion

All things considered, it is difficult to come to a firm decision regarding the rheostatic brake on the Class 50 locomotives. On the plus side there is the reduction in block wear and it is concluded that a rheostatically braked Class 50 could have a block life of 11 times longer than a non-rheostatically braked Class 50, although it is difficult to be absolutely certain about this as satisfactory test results have never been obtained and it is not possible to trace back brake block consumption. However it is clear, that with the rheostatic brake in use, a substantial amount is saved in brake blocks and in the actual process of blocking. This can be quantified as follows using the 11 to 1 ratio of block wear :-

Cost of BRL5 brake blocks = £2.15 per block.

Scrap value of brake blocks = £31 a ton - scrap brake blocks are disposed of to various scrap dealers.

Labour costs incurred in blocking one Class 50 locomotive = £16.50 on the basis of costs of £5.50 per hour wages and a blocking time of 3 hours for one man.

Assume brake blocks wear 1.5 inches = 38.1 mm before changing.

Using an average mileage per Class 50 locomotive of 93 000 miles per year, and taking the wear rates quoted previously of 947 miles per millimetre with the rheostatic brake working and 86 miles per millimetre with the rheostatic brake isolated, this gives a block life of 36 081 miles with the rheostatic brake working and 3277 miles with the rheostatic brake isolated, working out at 2.6 and 28.4 block changes a year respectively.

Therefore taking a brake block cost of £2.00 allowing for scrap value, the total cost of re-blocking a Class 50 locomotive is £64.50 or the yearly costs are £166 per locomotive with rheostatic brake working and £1831 with the rheostatic brake isolated, amounting to savings of £83,000 per year for the complete fleet of 50 locomotives.

Further small savings with the rheostatic brake in use, and this is an important point, are in the pulling up of slack in the brake rigging due to worn blocks. This work is substantially reduced and safety consequently increased by eliminating the possibility of a locomotive with reduced braking effectiveness. In 1968 an experiment (number M/C/L 1721) was applied to 6 Class 50 locomotives to determine the difference in tyre wear between those with the rheostatic brake operative and those with the rheostatic brake isolated. With the rheostatic brake isolated the conclusion was that piston strokes would need adjustment every 33 engine hours on the basis of a maximum brake cylinder stroke of 4 inches and blocks changed when the thickness is reduced to 1 inch ($2\frac{1}{2}$ inches originally) with a block life of 100 engine hours. On this basis there should be 2 slack adjustments per block life. The cost of pulling up the slack is about £1 per locomotive working out at £5.15 per year per loco with rheostatic brake and £56.77 per year per loco without rheostatic brake giving savings of about £2000 per year on the basis of 40 locomotives in traffic at any one time.

Thus on the basis of this analysis, use of the rheostatic brake could lead to savings of £85,000 per year.

On the debit side there is firstly the question of tyre damage. No firm conclusion s seem ever to have been reached as to whether the presence of the rheostatic brake causes tyre damage, the conclusion is that it does, but on the Class 50's this may have been substantially reduced with a reduction in brake cylinder pressure which is proposed for the Class. Secondly there is room for improvement in the design of the resistances on the CU1 board, to enable them to be set more easily and locked easily. Thirdly there is the question of whether rheostatic braking has magnified any of the problems experienced with traction motors. In October 1974 the Traction Motor Working Party produced a report to the effect, that there was no evidence to suggest that the rheostatic brake caused traction motor problems - the maximum armature current when braking is less than the continuous rating of the motors and is a value not reached very often. Also the worst condition of commutation when braking is comparable to that when motoring. The rheostatic brake should not worsen the motor performance in service and this was borne out in comparison trials between locomotives with and without rheostatic brake during the first years of Class 50 service on the London Midland Region. Fourthly drivers dislike of the rheostatic brake could be eliminated by improved driver training, use of a gauge solely to indicate rheostatic braking and reinstatement of a brake timing relay. Fifthly it had been frequently alleged that even if the rheostatic brake was set up properly, the settings would wander after a time. However it is regarded that this would not be the case if the rheostatic brake was set properly initially and the CU1 board resistances secured properly, then the system would not alter out of adjustment. Finally, it appears that the urgent need of improving the locomotives filtration requires the removal of the rheostatic brake.

13. <u>Conclusions and Recommendations</u>

The conclusion reached is that if the dirt problem is ignored for the moment, the rheostatic brake should not have been isolated by the WR and unofficial modifications should not have been carried out. However, the following improvements could have been made :-

(a) Reinstate some sort of brake timing relay to greatly reduce the problem of overloading. There is no evidence to suggest that reduction in the time of initial friction braking improved the tyre situation.

(b) Install a gauge in the cab to give the driver a measure of rheostatic braking used solely for measuring braking. This could be done by taking a measure of distributor output pressure and using this as brake pressure for both friction braking and rheostatic braking.

(c) Make it more difficult for the driver to isolate the rheostatic brake by for example putting a seal on the shutter air cock.

(d) Replace the potentiometers on the CU1 board with an improved type not so liable to breakage and alter adjustment through vibration. The conclusion reached is that this was the main weakness on the rheostatic brake set-up on the Class 50 locomotives.

Although the filtration proposals alone should not be used as a basis for removing the rheostatic brake, the fact that so much work has already been done at Laira Depot in so far as removal of the rheostatic brake goes, and also the large amount of opposition that there would be to any proposal to reinstate the brake on the WR, the only practical course of action now seems to be to remove the rheostatic brake completely and go ahead with the filtration proposals.

Therefore to summarise :-

(1) Due to the large savings which appear to be possible, the rheostatic brake should not have been permanently isolated.

(2) Continue with its removal if there is absolutely no other way of improving the filtration system without removing the rheostatic brake.

Date 31-3-78

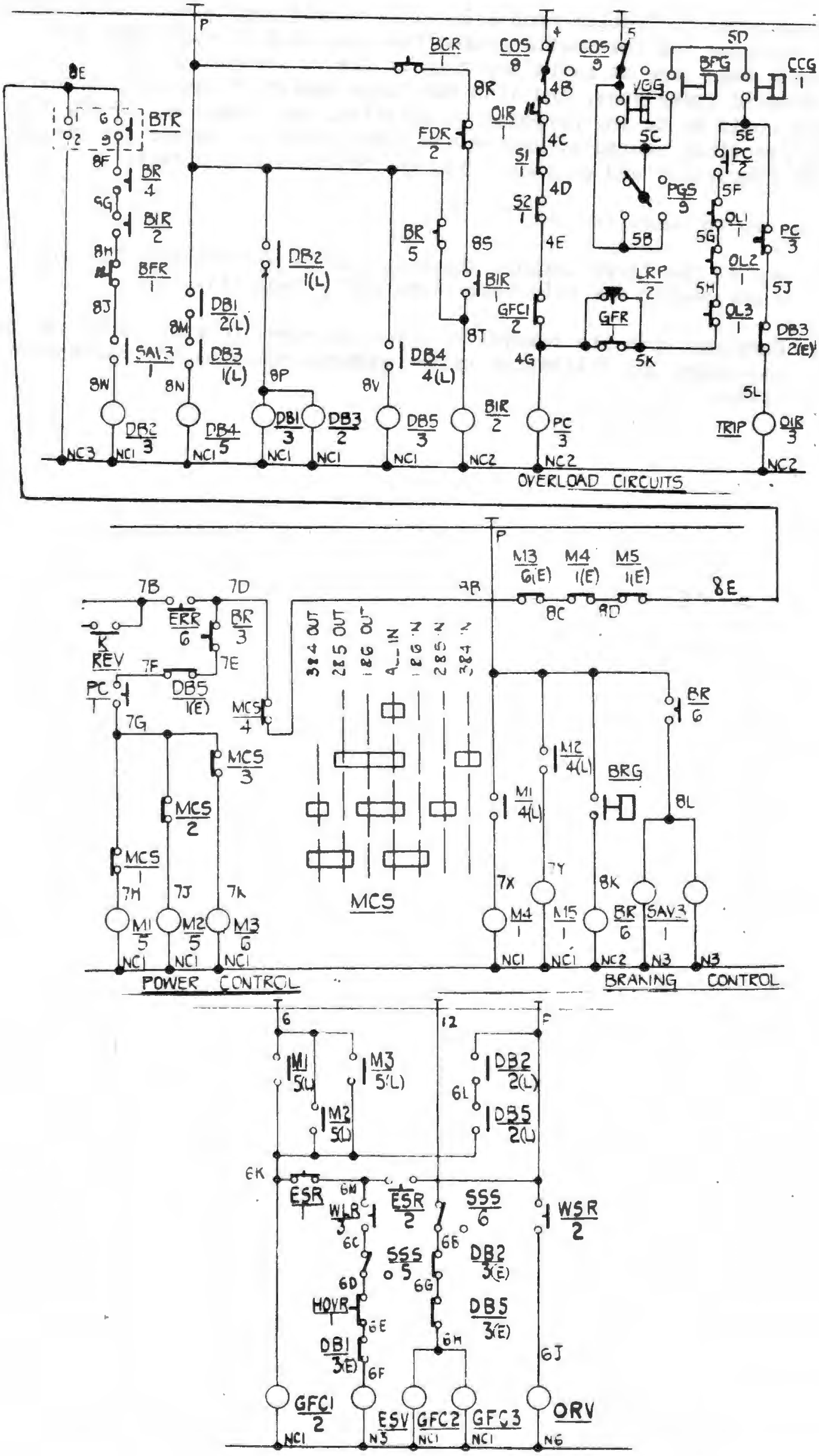


FIG 1 SCHEMATIC DIAGRAM OF ELECTRICAL CONTROL FOR RHEOSTATIC BRAKE

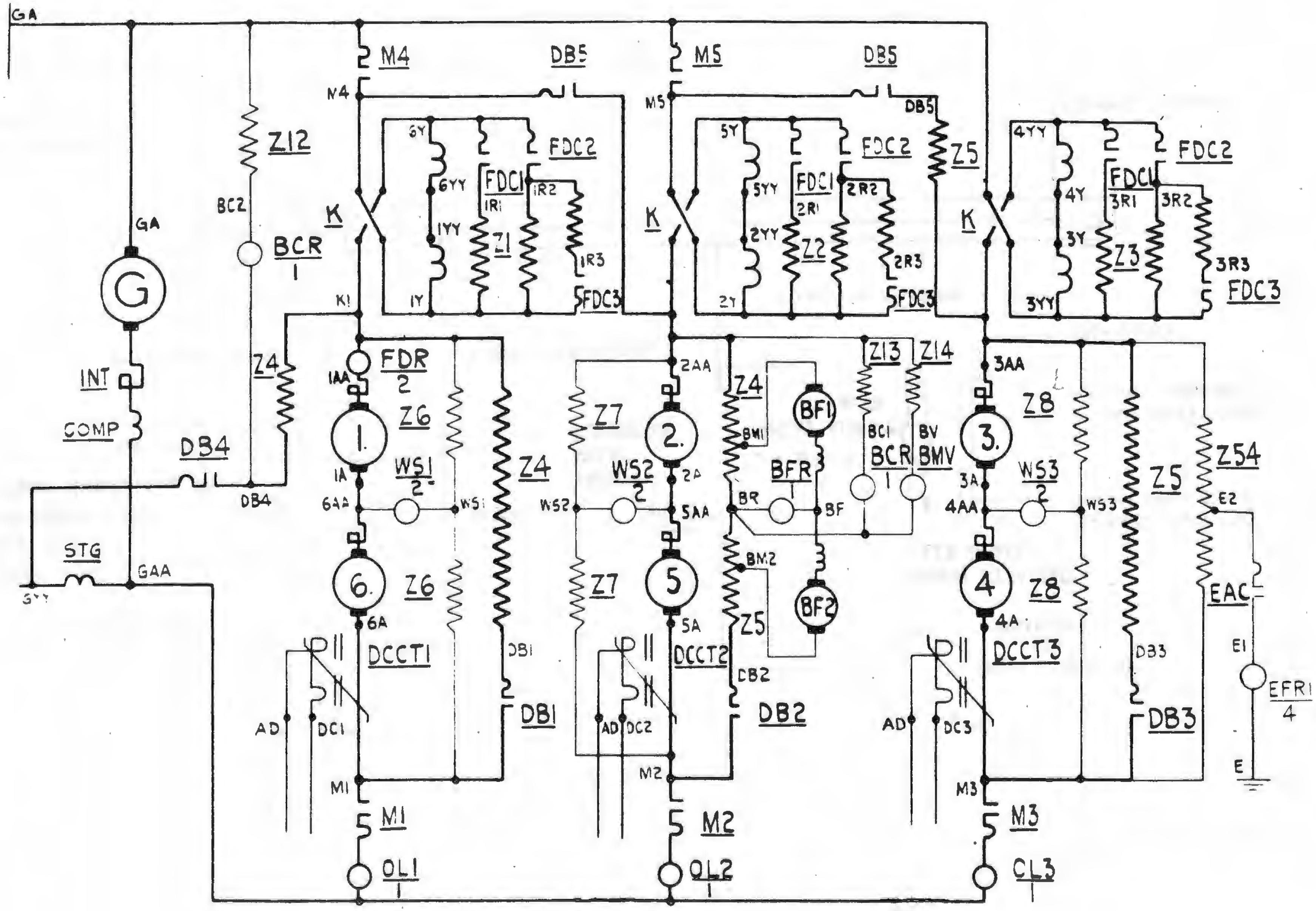


FIG 2

SCHEMATIC DIAGRAM OF LOCOMOTIVE MAIN POWER CIRCUIT

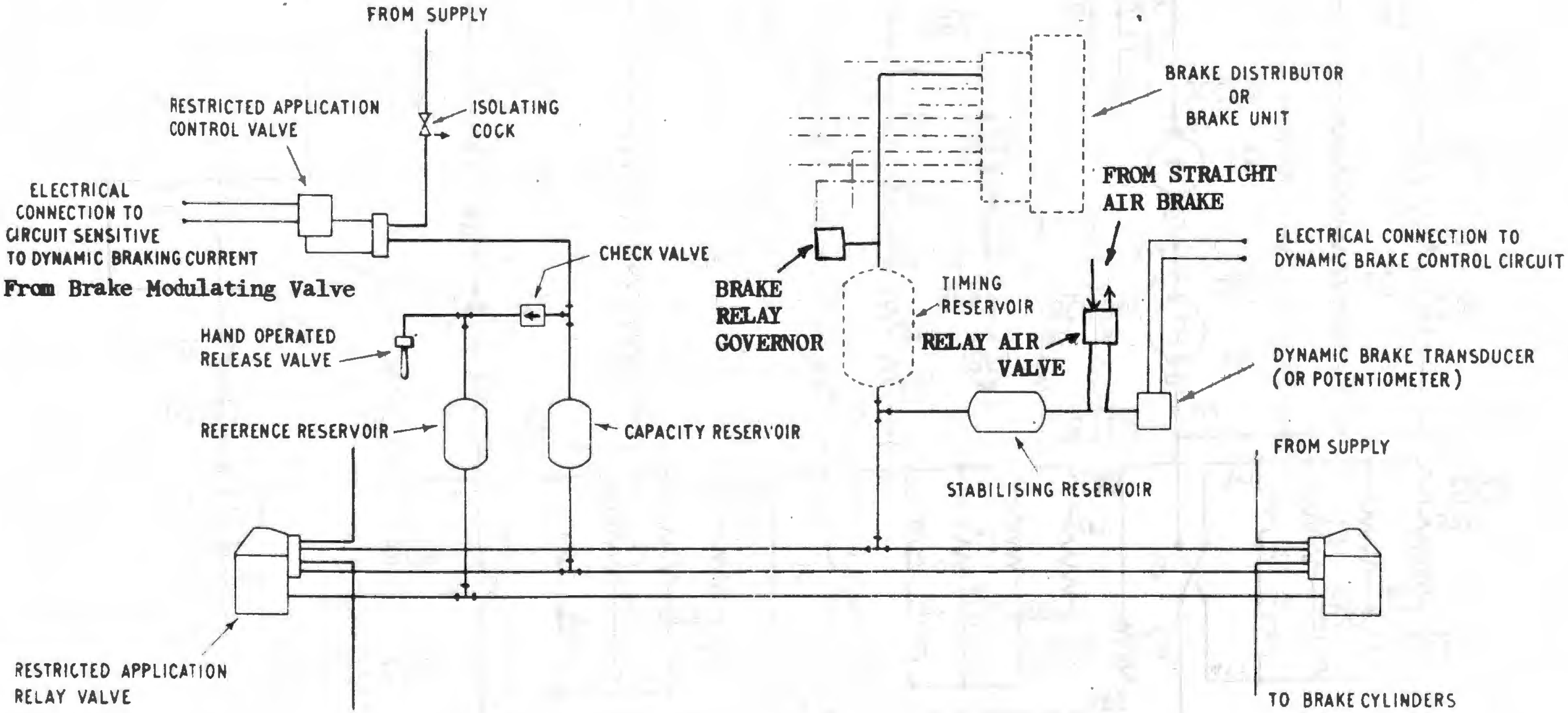
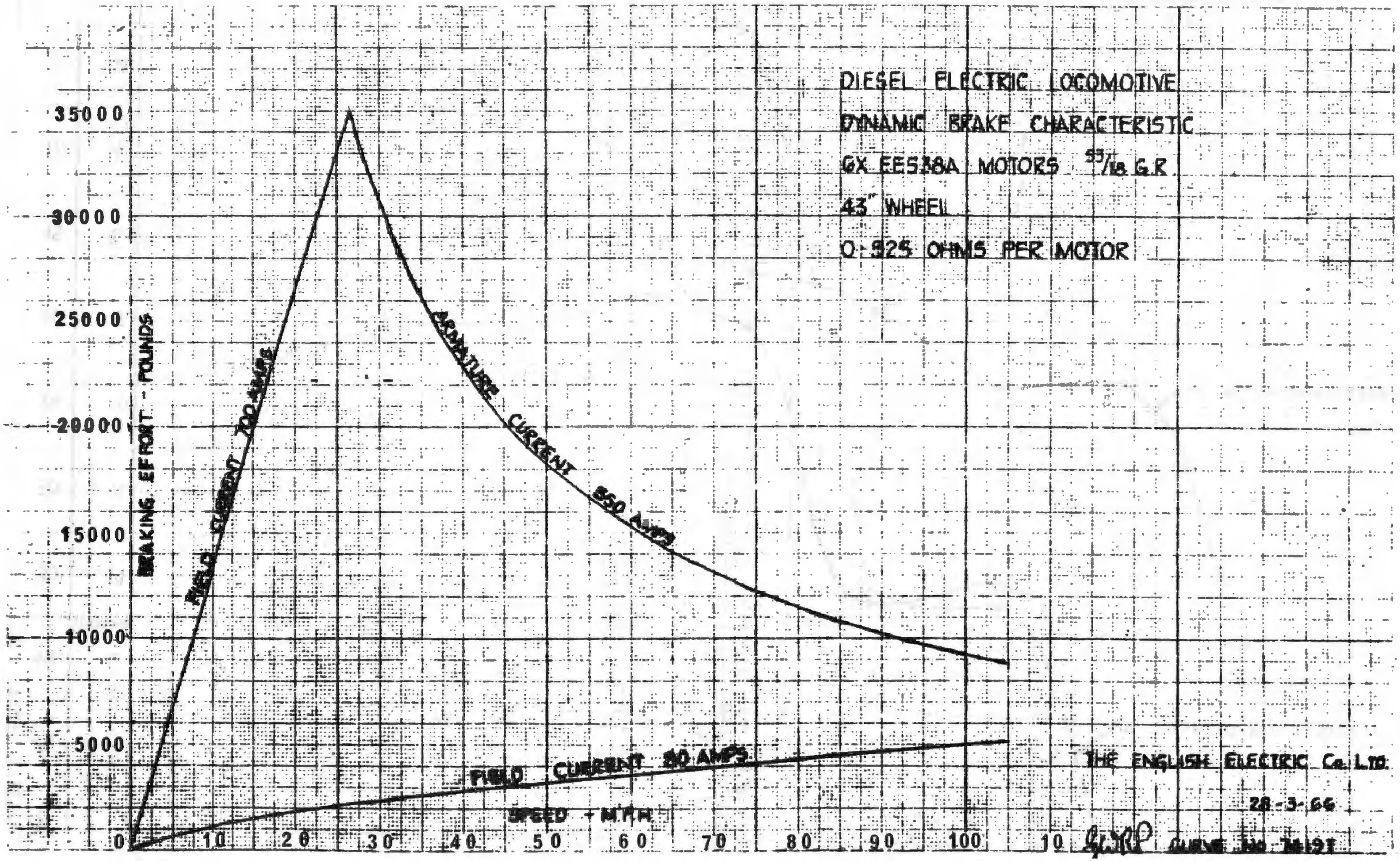
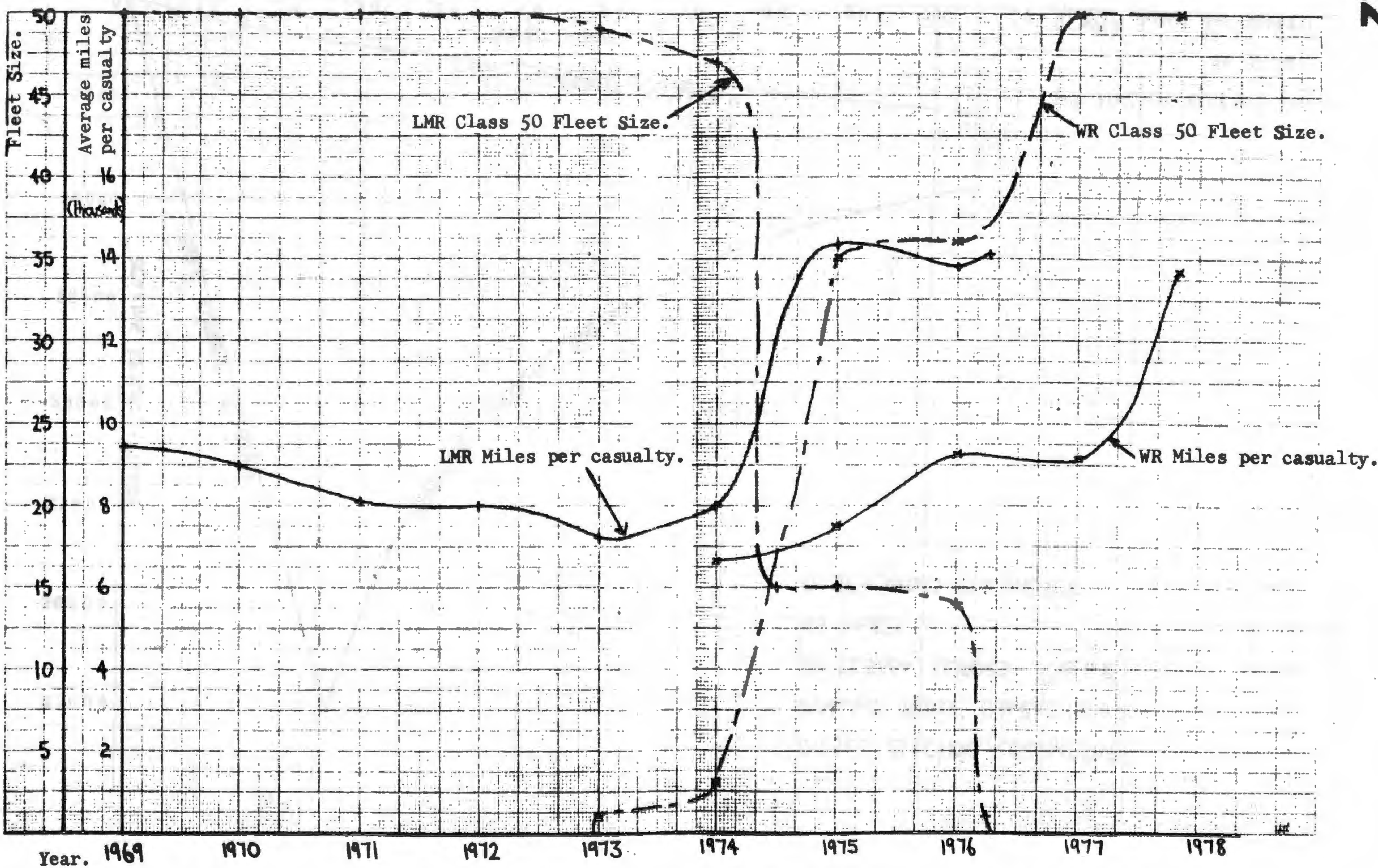


FIG 3 LAYOUT OF AIR/DYNAMIC BRAKE BLENDING SYSTEM.

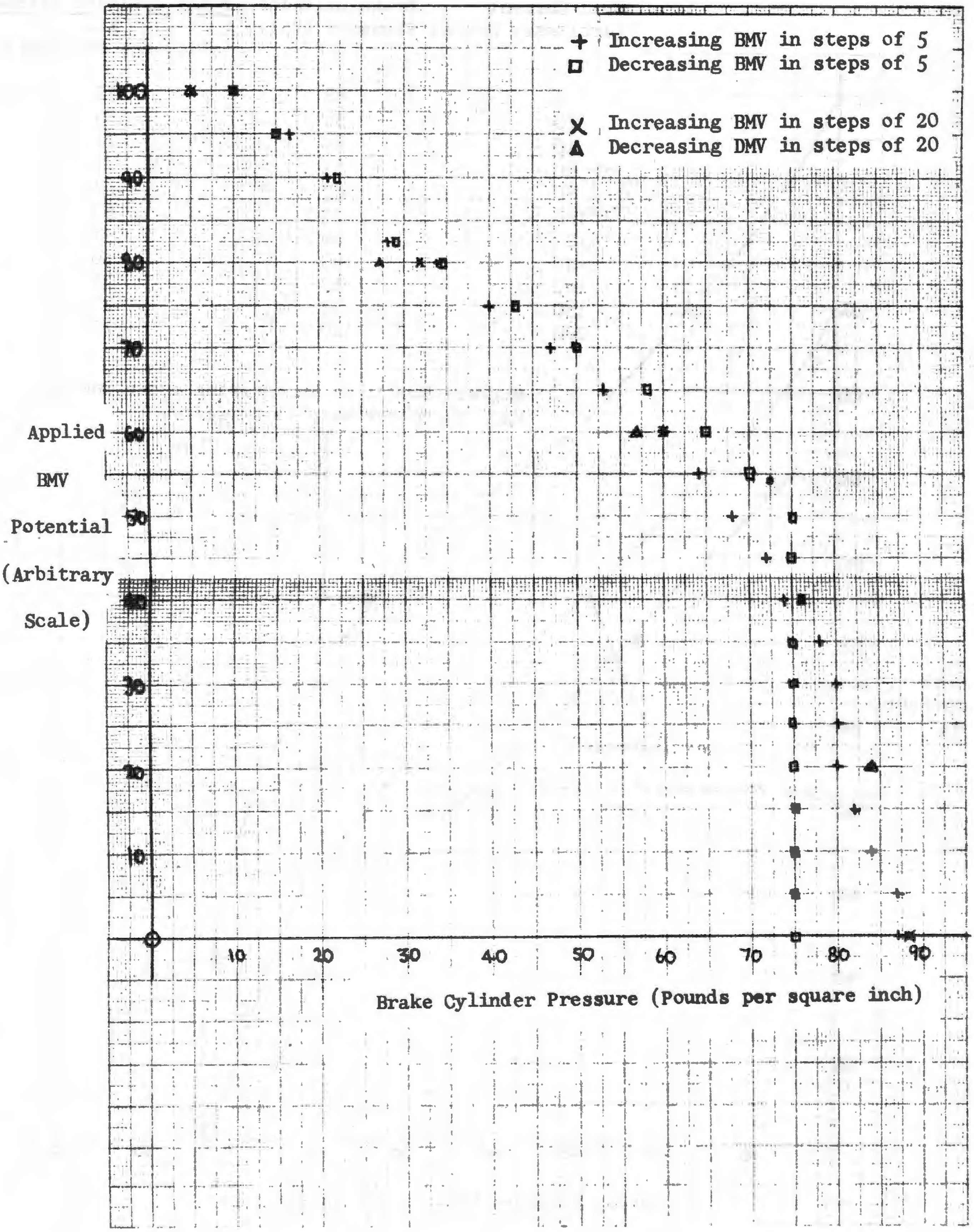


DIESEL ELECTRIC LOCOMOTIVE
DYNAMIC BRAKE CHARACTERISTIC
6X EE538A MOTORS 53/18 G.R
43" WHEEL
0·525 OHMS PER MOTOR
BRAKING EFFORT - POUNDS
35000
30000
25000
20000
15000
10000
5000
0
10
20
30
40
50
60
70
80
90
100
10
SPEED - M.P.H.
FIELD CURRENT 700 AMPS
ARMATURE CURRENT 850 AMPS
FIELD CURRENT 80 AMPS
THE ENGLISH ELECTRIC Co. LTD.
28-3-66

GRAPH 1



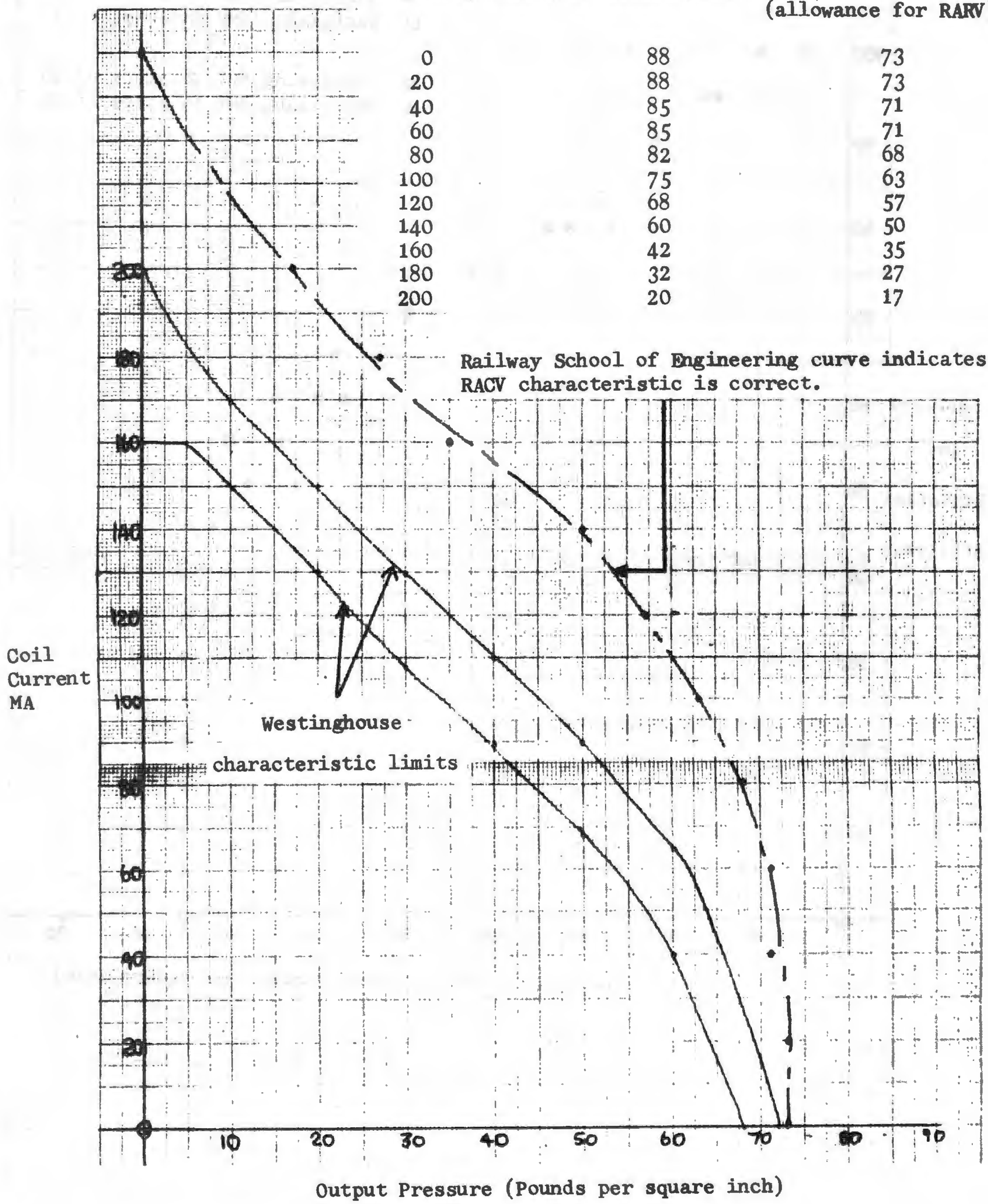
GRAPH 2 CLASS 50 VARIATION OF MILES PER CASUALTY, AND FLEET SIZE
(Average over the year)



GRAPH 3

VARIATION OF BRAKE CYLINDER PRESSURE FOR CHANGES IN BRAKE MODULATING POTENTIAL
(Railway Engineering School)

Coil Current (Arbitrary Scale)	Brake Cylinder Pressure (PSI)	Brake Cylinder Pressure / 1.2 (allowance for RARV)
0	88	73
20	88	73
40	85	71
60	85	71
80	82	68
100	75	63
120	68	57
140	60	50
160	42	35
180	32	27
200	20	17



GRAPH 4

GRAPH SHOWING WESTINGHOUSE LIMIT CURVES FOR VARIATION IN OUTPUT PRESSURE WITH BMV CURRENT TOGETHER WITH CURVE OBTAINED AT RAILWAY ENGINEERING SCHOOL, DERBY