DEPARTMENT OF TRANSPORT

RAILWAY ACCIDENT

Report on the Derailment that occurred on 16th February 1980 at Bushey

IN THE
LONDON MIDLAND REGION
BRITISH RAILWAYS

LONDON: HER MAJESTY'S STATIONERY OFFICE

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RAILWAY INSPECTORATE,
DEPARTMENT OF TRANSPORT,
2 MARSHAM STREET,
LONDON SW1P 3EB.
23rd October 1980

SIR,

I have the honour to report for the information of the Minister of Transport, in accordance with the Direction dated 26th February 1980, the result of my Inquiry into the derailment at high speed of a passenger train at 20.40 on 16th February 1980 at Bushey some 16 miles from Euston on the West Coast Main Line in the London Midland Region of British Railways.

The train, which was the 20.25 Euston to Manchester Piccadilly, and consisted of nine coaches hauled by an electric locomotive was travelling at 96 mile/h when the leading coach became derailed at a broken welded joint in the left hand (cess) rail some 180 yards short of Bushey Station. The locomotive remained on the track and came to rest with the first two coaches coupled to it but derailed some 164 yards beyond the station. The third coach came to rest alongside the Down platform on its offside, and the fourth and fifth coaches also on their sides and separated, across the Watford DC lines and the Down and Up Fast lines. The remaining four coaches were derailed but remained upright and generally in line, although the track beneath them was by then destroyed.

Of the estimated 150 passengers on the train 48 were injured and were taken to local hospitals mainly suffering from cuts, bruising and shock. 19 passengers were more seriously injured and were detained in hospital. Four members of the train crew were also slightly injured.

There was serious disruption to traffic and the Up and Down Slow lines and Down Local lines were not reopened to traffic until 17th February, the Up Local on 19th and the Up and Down Fast lines on 25th February. It was dark at the time of the accident and the weather was dry but with some quite thick fog patches.

DESCRIPTION

The Site and Signalling

1. As shown in figure 1 at the back of the report, the derailment occurred 181 yards before the commencement of Bushey Station platform on the Down Fast line. At this point there are six lines running approximately north and south. From the west there are the Down and Up Local (DC) lines which diverge at Bushey from the Main lines. To their east lie the Down and Up Fast lines and the Down and Up Slow lines. Approaching the derailment point the Down Fast line curves gently right handed on the level but it is straight and falling at a gradient of 1 in 337 through the point of derailment. (See Figure 4).

2. Track-circuit Block Regulations apply to all six lines. The local lines are electrified on a DC conductor rail system and automatic colour-light signalling is provided. The Main lines are electrified on the 25 kv AC overhead system and standard 4-aspect colour-light signals are provided controlled from Watford Junction (WJ) Signal Box. The maximum line speed is 100 mile/h. The signalling on the approach to the derailment point is illustrated at Figure 3 at the back of this report. All the signalling is automatic except where shown but the signalman is able to replace signals WJ 162 and 163 to Danger as well as the Controlled signals WJ 46 and 47 at Watford Junction. Although track-circuits on the Local lines at Bushey are indicated in the signal box the signalman is not able to replace signals to Danger—nor are the signal aspects indicated.

3. Because of the dual nature of the electrification, tuned reed track circuits have been used. On the Fast and Slow lines single rail track circuits in the offside (six-foot) rail are used, the 'cess' side or 'ten foot' side rail of each track being a common 'return conductor' earth rail through which traction current is also carried. Track circuit T37A, which operates at a frequency of 378 Hz, extends from the overlap of Signal WJ 171 at 15 miles 1,048 yards and is approximately 670 yards in length. Within this length there are twelve portal frames spaced about every 200 feet carrying the overhead electrification equipment which includes dual traction return current conductors on both sides of the railway; the structures are numbered G.15.23 to 32 and G.16.02, 04 and 05 travelling northwards. The first two are earthed to the common rail of the Up Slow line and between them the common rails of all four lines are bonded together. The next two are bonded to the Down Fast line, the fifth to the Up Fast line and the sixth and seventh to the Down Fast line. The tenth is also bonded to the Up Fast line but the remaining two as well as those beyond it are bonded to the Up Slow line. There is full cross-track bonding at structure G.16.07 within the following track circuit T37B.

The Track

4. The track through the point of derailment was originally laid in 1965 in 110A lb flat bottom rail on 24 concrete sleepers to the 60 foot length using Skull Hoop Clip (SHC) fastenings. Two 720 foot lengths of 113A lb rail were welded into the cess side (return conductor) rail on 16th October 1979 to replace rail which had developed defects, and it was the site weld between this new rail and the old rail at the northern end of the new rail at 15 miles 1,378 yards that failed.

The Weld

5. Three welds were made using the SkV 'Alumino Thermic' process and SkV-F moulds. This process involves cutting and cleaning the rail ends to achieve a specific gap between them for which a gauge is provided. The rails are then carefully aligned using a straight edge along the running edge and head of the rails. The rail ends are raised 1 mm over a 1 m length using, normally, four wedges and a 1-m long straight edge which has 1 mm 'nibs' on its ends. Moulds are then placed to enclose the gap and are held in place using metal shoes supported by swivel arms mounted on a universal mounting clamped to the rail head. A gauge is provided to check the rail-end gap and the position of the mounting. The moulds are then 'luted' using luting cards and sand, the sand being forced into the gaps by using a ramming bar. A luting tool is also provided to act as a 'stop' for the sand inside the mould riser and to ensure a clear and correct exposure of the rail end.

6. A crucible, which has previously been completely dried employing the standard pre-heating torch using an oxygen/propane gas mixture, is mounted on a separate arm and located centrally over the moulds. After the tapping pin has been inserted and adjustments made to ensure that the correct pouring position has been arranged, the crucible is swung clear of the moulds and charged. The head of the tapping pin is first covered with two refractory discs and these in turn are covered with some ground slag. The 'welding portion', consisting of finely ground aluminium, specially prepared iron oxides and the necessary alloying elements to match the rail steel, is then introduced into the crucible. The moulds and rail ends are then gas heated for a pre-determined time after which the crucible is swung into position and fired. Some 25 seconds after firing, the metal which is at about 2,000 to 2,100°C, is tapped. After 4 minutes the mould is stripped and the rail head riser is cut off using a nitrogen-driven pneumatic trimming chisel. When the weld is cool the side risers are broken off by knocking them towards the rail. The rail pads are replaced together with the fastenings after the wedges have been removed and the rail's running and head profiles ground using a grinding frame to achieve accuracy. Figure 5 shows pre-heat in progress.

7. The SkV 'Thermit' process was developed to reduce the variation in workmanship between one welder and another found with the SmW and AT processes which involved a lengthy pre-heating period and a relatively small welding portion. By increasing the size of the portion pre-heating could be reduced, and the rail gap increased. The following table illustrates the changes:

	SmW	*AT*	*SkV*
Rail gap (mm)	16–19	19–22	22–24
Pre-heat (mins)	7–10	6	1½
Portion (kg)	6	6	10

8. The SkV-F (flat) mould was designed for use with switches and crossings and enables a sound weld to be made with a single cut and replaced by a new weld without the need to remove a 15 ft length of rail. The collar of the weld, when made, is flatter which improves the weld's fatigue resistance, being 40 mm wide compared with 35 mm of the SkV mould. The mould also has two internal vents to the risers to facilitate the escape of gas. The SkV-F is the current British Railways standard mould having been in use some two years.

9. Instructions for making alumino thermic welded rail joints are contained in 'Civil Engineering Handbook No. 32 – General Instructions For Track Welding: Part I—Alumino Thermic Welding of Joints'. Part I(A) contains general instructions, and Part I(D) specifies the procedure for making welds using the SkV process. The following extracts are pertinent to my Inquiry.

A1.3 The work of all track welders shall be under the control of a Track Welding Supervisor.

A2.2 . . . rail butt welds of any kind must not be less than 4·57 m from another weld. (4·57 m is 14 ft 11¾ in).

A3.1 Freehand cutting is prohibited. Gas pressures must be correct for the type of equipment in use.

A4.4 When rails to be welded are of the same nominal section but dissimilarly worn, . . . a standard mould must be modified as in D4.1.

D4.1 (The use of 3 mm thick packing pieces of refractory material, and the necessity to rub down moulds from the bottom fishing angle to the outer edge of the foot on the most worn rail side - is described).

A4.5 For welding together dissimilar rail sections proper composite moulds as supplied for the particular sections concerned must be used.

A4.6 On completion of alignment, *datum marks should be made on the foot of both rails and on joint sleepers* in order to detect any longitudinal movement of rails during pre-heating.

A4.7 If sufficient longitudinal movement occurs during pre-heating, to produce a welding gap outside the prescribed limits for the process being employed, the welding operation must be terminated and corrections made.

A8.1 All gas connections, particularly that between the stem and pre-heating attachment must be checked for tightness. *Neglect of this precaution will result in reduced pre-heating efficiency.*

A8.2 All gas equipment must be properly maintained to ensure correct pre-heating and the accuracy of gas regulators is to be checked by gauges fitted to the supply pipes.

A13.1 Every authorised welder will be provided with an identification stamp which he will apply to the workpiece on completion of the welding (unless he believes the weld to be defective).

D4.2 The first mould and shoe is placed *centrally and vertically to the gap. . . .* The two moulds must fit flush to each other at the top and the bottom and must be central to the gap. *This can be checked by looking down the riser aperture.*

D7.5 It is essential that the crucible is vertical and central to the mould.

D16.1 *The surplus sand around the weld must be removed so that the weld can be inspected* and passed if satisfactory.

Note: (the italics are mine).

The Train

10. The train was 1H24, the 20.25 Euston to Manchester passenger train consisting of nine coaches hauled by electric locomotive No. 87 007 'City of Manchester'. The leading coach was a Trailer Second Open Mk IIe; the remaining coaches being of Mk I, Mk IIf and Mk IIIa construction. It was buckeye coupled throughout and screw coupled to the locomotive. The train, which was fully air braked, was 698 feet long overall and weighed about 300 tonnes with a brake force of 153 tonnes.

The Course of the Derailment and Accident Damage

11. The locomotive passed over the broken rail safely and it was probably the leading bogie of the first coach that became derailed to the right when its leading left-hand wheel flange struck the end of the running-on rail which had become displaced into the 'four-foot'. All the remaining bogies became derailed to the left. The locomotive and first two coaches remained coupled although derailed but the following three coaches became completely uncoupled and detached from their bogies coming to rest on their sides in the positions shown in Figure 1. The rear four coaches remained coupled together and their bogies were intact but the track had, by then completely disintegrated under the train.

12. The locomotive came to a stand some 720 yards beyond the broken weld. Approximately 760 yards of main-line track and 140 yards of the DC lines were destroyed and there was considerable damage to the Down Fast platform at Bushey Station which was struck by the third coach. Most of the sleepers beyond the point of derailment were broken up by succeeding impacts from wheels of the train but the first sleeper immediately beyond the broken weld had failed from attrition in an entirely different manner, as shown in Figure 6. Four of the overhead electric traction structures were knocked down as shown in Figure 1 and the foundation of one mast of structure G.15.26 was lifted three feet out of the ground. The overhead equipment was torn down from structure G.15.24 to G.16.11 and wires were wrapped around the locomotive. Only on the Up Slow line was the catenary intact although it required adjustment due to the damaged structures.

13. The pantograph on the locomotive was destroyed but the only other damage was minor. There was no interior damage to the leading coach although the door was missing at the nearside trailing end. This coach may have struck the platform and also the brick parapet wall to underbridge No. 59 to the north of the station. The second coach, a Mk IIIa TSO, came to rest leaning at 20° to its offside with its leading bogie displaced and its trailing bogie on the track 225 yards to the rear. Its underframe and underfloor equipment was badly damaged but inside it, only two tables were displaced and 8 arm rests bent. Although 7 outer panes of its double windows were broken only 2 inner panes were broken.

14. The following three Mk IIIa TSOs which came to rest on their sides and displaced from their bogies, were much more seriously damaged where they had struck lineside structures and, in the case of the third coach, Bushey Station platform. They all remained, however, structurally intact and between them only two inner panes were broken although each had three outer panes broken. The rear four coaches suffered minor damage only and little or no interior damage.

Evidence Concerning the Derailment and Events on 16th February

15. *Leading Trackman D. Moio* walked the track four times every week and last did so on the morning of the derailment. He had passed the weld that broke at about 10.00 and noticed nothing untoward. He had served on the railway for 29 years. He had last found a broken weld in the Up Fast line near Bushey in November 1979; the rail was broken right through and the two ends had drawn well apart but trains were still passing safely over the break.

16. *Clerical Officer K. A. Pitt* who was employed in the travel centre at Charing Cross Station was a regular commuter to Birmingham and was travelling in the leading coach of the 19.40 train on the evening of the derailment. Approaching Bushey Station when the train was travelling at its normal speed of about 100 mile/h, he both heard and felt a bad bump under the coach. It appeared to start underneath the locomotive and pass from front to rear under the coach. The coach was almost fully occupied and it was bad enough for some people to remark on it but not bad enough for him to consider stopping the train, nor even to tell the guard. On arrival at Birmingham he heard about the derailment and reported it there.

17. From the signal box records the 19.40 (Mr. Pitt's) train passed Bushey at about 19.52 some 48 minutes before the derailment occurred. The driver of the train said that he felt nothing and the driver of the following train which passed 17 minutes before the derailment also felt nothing. A parcels train for Lairg passed some 8 minutes before the derailment and its driver has said that he felt a "slight bump but nothing very much". None of them and no other passenger made any report.

18. The driver of the derailed train, 1H24, was *Driver R. G. Gallagher* assisted by *Driver's Assistant G. L. Nuthall.* Gallagher told me that he had worked on the West Coast Main line for some nine years, first as a fireman and then as a driver and had driven all types of locomotive. His locomotive was a Class 87 which he described as having a very good ride. Approaching Bushey at about 96 mile/h he felt an irregularity in the track but nothing that would really cause alarm. He thought that it was probably a 'wet patch' of which they had "more than our share this year" but because it was dark and they were passing through a fairly dense patch of fog, he could not see it. Almost immediately there was an automatic application of the emergency brake and the light indicating overhead line voltage to the locomotive went out. He lowered the pantograph and both he and his assistant lay down on the floor to be safe from 'flying' insulators. When they came to a rest he sent Nuthall ahead to telephone the signalman telling him that the overhead wires were down and the lines would be obstructed. He, Gallagher, placed track-circuit clips on the Up Fast line. He could see only two coaches and one was at an angle of 45 degrees and no lights were visible. He then ran along the Up Fast line with a lamp and detonator and met Nuthall at a signal-post telephone talking to the signalman. He told him that it was a very serious accident and to call the emergency services. He noted the Up Fast signal displaying a red aspect so he placed his detonators on the approach side of it. (The signal was WJ 177 an automatic signal). Nuthall also noted that the signal was at Red.

19. *Relief Area Supervisor B. Porter* was on duty as regulator with one signalman in Watford Signal Box. At 20.40 he received a telephone call from the Electrical Control Officer who told him that the power had been cut off from both the DC (Watford Local) and AC (Main) lines. He immediately saw that the track circuits on all the lines except the Up Slow line were showing occupied. Prior to this time the signalling had been working correctly and there had been no track-circuit faults indicated. Shortly afterwards the driver telephoned and he asked him to go back and look at his train and to report back. There were no diesel-hauled trains about and because the traction power was off he knew that all lines were safe. The signalman replaced signals on all lines to Danger to protect the area of the derailment, and he called the emergency services.

Evidence Concerning the Course of the Derailment

20. *Mr. M. McLoughlin* of the Railway Technical Centre Derby arrived at the scene of the derailment shortly after midnight on the night of 16th/17th February. He has recorded his findings on the drawing at Figure 2 at the end of this report. From the derailment marks on the rails and the positions of the coaches he concluded that the rail had fractured under a previous train. The 'six-foot' rail was still generally intact but the running-on cess rail was lying in the 'four-foot' and its end was badly battered. One wheel flange had obviously bit the rail end which had caused this axle to become derailed to the offside; he thought this was the leading axle of the first coach. The impact must have displaced the rail and all the following axles had become derailed to the nearside and he counted 26 to 28 marks on the 'six-foot' rail over a length between 10 and 27 sleepers forward of the broken weld. It was the fact that the sleeper immediately beyond the broken weld was pulverised and completely destroyed that led him to conclude that the weld had been broken for some time. The type of damage was quite different from the impact damage to the other sleepers caused when they were struck by passing wheels. He had seen this on a previous derailment of a freightliner train in Tring Cutting in 1977. The type of damage inflicted is clearly seen in the photograph of the sleeper at Figure 6.

Evidence Concerning the History of the Track and the Making of the Weld

21. The Assistant Permanent Way Supervisor for the section extending from 15 miles to 18 miles from Euston was *Supervisor J. Martin*. The cess rail in the area of the derailment had been laid in 110A lb rail in 1965 and had been destressed, to be free of stress at a temperature of 80°F, on 29th November 1972. Because the rail was worn it was due to be changed at the end of 1979 and 720 foot lengths of new rail had been laid out for the purpose. On about 13th October 1979 a rail-flaw detection gang had inspected the rail using hand-held ultrasonic rail-flaw detectors and had marked the rail with 10 red marks to indicate serious flaws and 13 white marks to indicate minor flaws. He therefore told *Mr. Davis* the Permanent Way Supervisor that he thought it was dangerous and the rail should be replaced. This work was done on 16th October 1979.

22. In addition to his own gang of about 4 men he had 17 or 18 men the remainder being from Northampton. He took an engineering possession of both the Up and Down Fast lines from Harrow to Watford commencing at 10.15, and he handed back both lines for traffic at 16.00. After discussing with Senior Technical Officer Schofield and his Permanent Way Supervisor Davis, how much rail could be changed it was decided to cut in two 720 ft lengths, extending from 15 miles 1,378 yards in the north to about 15 miles 898 yards in the south but because of an existing weld within 10 feet of the southern end of the rail it was decided to cut the rail further to the north to allow at least 15 feet from the weld. He had two welders on site and Mr. Schofield asked him to ask for a second team which would have enabled them to put in a further 720 foot length but when he telephoned 'Mr. Tony' one of the welders in the store at Watford he was told that none was available.

23. He knew the two welders Courtney and Goodwins well, as he had worked with them many times. His gang loaded the welding equipment onto their trolley at Bushey and the welders pushed it down to the northernmost weld at 15 miles 1,378 yards where the rail was cut. His men then harred out the old rail and began moving in the new rail. He was fairly sure that the welders cut the new rail to length and made the weld before moving to the centre position to cut the rail there and then to the southern end of the job at about 15 miles 900 yards where they cut the two rails and made the weld. The final weld was made at the centre location.

24. Mr. Martin assured me that he had replaced all the pads on the sleepers and had personally checked that the pads each side of each weld had been properly replaced. The old pads that they took out had worn very thin and some had broken up. After the welders had finished grinding the head of the rail at each weld he checked it by eye and each looked a good job to him.

25. Mr. Martin had served on the railways for 25 years but he had never attended a welding appreciation course. Although he had seen welds made on numerous occasions it was not his duty to check on the work done other than to check that the rail was well ground and there were no cracks. When it was pointed out to him that the collar of the weld that failed was not vertical to the head of the rail, he said that he had "seen quite a few like it in my Watford area". Prior to the derailment occurring some packing had been done under two sleepers some 10 sleepers beyond the weld and a much more serious wet spot some 300 yards north of the weld had also been dealt with. On Friday 15th February, the day before the derailment, he had visited the site, and in his opinion all the sleepers in the area were well supported.

26. His gang had found broken welds on several occasions. In August 1976 one had occurred in the Up Fast line near the 18 mile post and another had occurred on the Down Fast line in 1979; the weld had been porous with many tiny bubbles in it. The pieces of rail had been sent to the Derby Research Centre. He always recorded when he took a possession of the track, noting the times, the mileages, which track was affected and the type of break in the rail but he did not note the names of the welders who made the repairs. He had seen broken rails and broken welds in the track and thought that trains could run over them quite safely but he did not think that they would survive for two days. He sometimes saw the Welding Supervisor on Sundays but he very rarely saw him on the track during the week. He stressed that he knew nothing about welding and he could not therefore supervise the welders' work.

27. *Senior Technical Officer T. R. G. Schofield* had been Senior Technical Officer at Watford since 1971 and attended the work on 16th October 1979; he described his main task as being "to lend technical assistance to the supervisor for restressing purposes". He agreed with Mr. Martin that the two welders had first cut and then made the northern weld at 15 miles 1,738 yards, had then cut the old rail at the centre of the site, then cut and made the southern weld before returning to the central point to cut and weld the new rail there. He remembered discussing the precise point at which to cut the rail at the southern end. He had recorded the rail temperature as being 60°F when it was being 'barred in', 62° as it was being clipped down at the northern end and finally as 63° as the last of the rail was clipped down. He had decided not to destress the rail at the centre point before welding because winter, with its lower temperatures, was approaching and he did not want to over-tension the existing rail which was known to contain some defects. He was certain that, although they had tried to obtain more welders, none had arrived and Courtney and Goodwins, whom he recognised, had made all three welds.

28. Mr. Schofield had attended a welding appreciation course some five years previously and he knew the difference between an SkV and an SkV-F mould. He had instructed the welders where to cut and assumed that the "welders would make a satisfactory job". The only weld he saw being made was the central one but even then he did not see them using the cutting guide. When he examined the welds after they were made the collars were still partly obscured by sand. He was not directly responsible for welds but he did observe them and had commented on the fact that the southern weld had been trimmed too deep but the dip in the rail head after grinding was not in the running surface of the rail and he was finally satisfied with it. He had checked it by eye only and had not used a straight edge.

29. *Track Machineman (Welder) F. H. Courtney* was allocated the welding task on 16th October by the storeman on duty in the welder's office in Watford yard. The kit was loaded in a van or lorry and delivered to the Bushey goods yard where it was unloaded by the gang. He had been told that morning that he was to weld a broken rail which would have entailed welding in a short section of rail but after arrival it was decided to rerail using 1,440 feet of rail which was already lying on site. He had no precise memory of the job but he agreed that he had probably cut the rail and made the weld at the Bushey end before going down to the southern end, finishing up at the centre weld which would normally be the destressing point.

30. Courtney told me that the kit provided was sufficient to make the three welds and that everything was complete. They marked the rails using the 22 mm distance piece and gas cut them using the cutting guide provided. They used a 1,000 mm straight edge with 1 mm nibs on either end to ensure that the rails were sufficiently raised, and fitted the SkV-F moulds to the rail ends. He had not measured nor compared the depths of the rail sections, and he had no idea how much wear there was on the old rail and nothing with which to measure it. By rubbing the mould along the two rails he could see where they had to be cut and he then scraped away the excess on one side using the luting tool provided. He had been taught this in the school. He said "Sometimes if you give them a little rub along the two rails they fit in perfect." He always fitted the first mould and his assistant fitted the other side up to his. He usually checked that it was in the correct position on the rails by feeling the fit under the rail, and he could also look down into it. He generally left the pre-heating to his assistant and they took it in turns to do the other jobs such as knocking off the risers, chipping off the head and grinding.

31. Having made a weld he had no way of knowing whether it was a sound one or not except on one occasion when the weld metal had simply run through; nor did any of the welders stamp their welds with their number. "It is the responsibility if anything happens and no way of knowing that you have done bad work" that caused them to take this line. "It would have been putting too much responsibility on an ordinary bloke doing the job" he said. "We're not really proper welders, are we?" By this he meant that he had not been trained as an electric arc welder.

32. Mr. Courtney had been trained as a thermit welder at the London Midland Region welding school at Northampton and passed out on 27th September 1978. This fact was recorded on his welder's card that he carried. He had not seen the yellow copy of the welder's handbook which had been in short supply but had been given a copy of it on roneo sheets. The course had lasted three weeks and he had worked with a welder on the track for a further three weeks before returning to the school for testing. He knew that he should be tested every six months and he had seen the welding supervisor Mr. Stanton on several occasions but he had never marked up his card. He told me that they were very busy and he always volunteered to work during the weekends when most of the work was done; he worked seven days a week.

33. *Leading Trackman F. C. Goodwins* had worked as a temporary welder for about one year and generally with Courtney. He could only remember doing two welds at Bushey and told me that they had begun work at the southern end of the job. Mr. Courtney had done the cutting and put on the first mould and he had lined the other mould up with his. He had trimmed the head of the weld using the nitrogen driven gun and they had taken it in turn to grind the rails. He had also attended the three weeks course at Northampton and had passed out on 20th February 1979. He had seen the welding inspector from time to time but he had never signed his card. I asked him whether he or Courtney had replaced the rail pads at Bushey and he replied "I presume they put them back in when they come and clip it off—I always try and get the bloke to put them in before the wedges come up". From this I understand that the gang, not the welders, normally replaced the pads. Goodwins told me that he also usually worked at weekends.

34. The welding supervisor in the Watford area was *Welding Supervisor C. J. Stanton*. He was in charge of 31 full-time welders and two men who worked at weekends only. He thus had sixteen gangs for whom he planned the work. One of the welders worked as his assistant in the welding store in Watford yard. He kept no record as to who was employed on which job but the time sheets that the men prepare showed that Courtney and Goodwins were on the site at Bushey on 16th October 1979. He normally spent all his time at the Divisional Headquarters in Watford and the request for additional welders on that day was dealt with by his assistant.

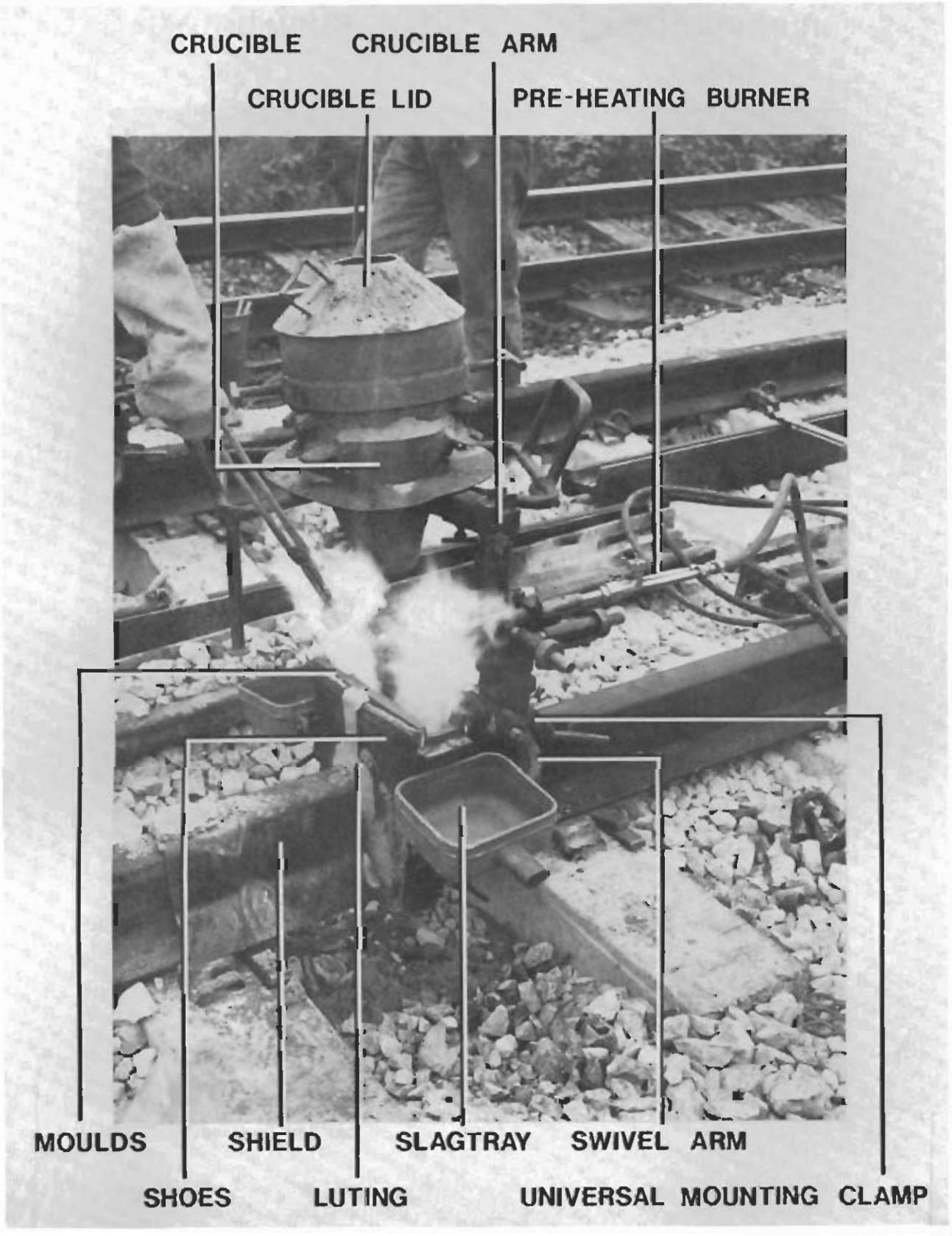


Figure 5 The SkV alumino-thermic welding process

Figure 6 'Running-on' sleeper

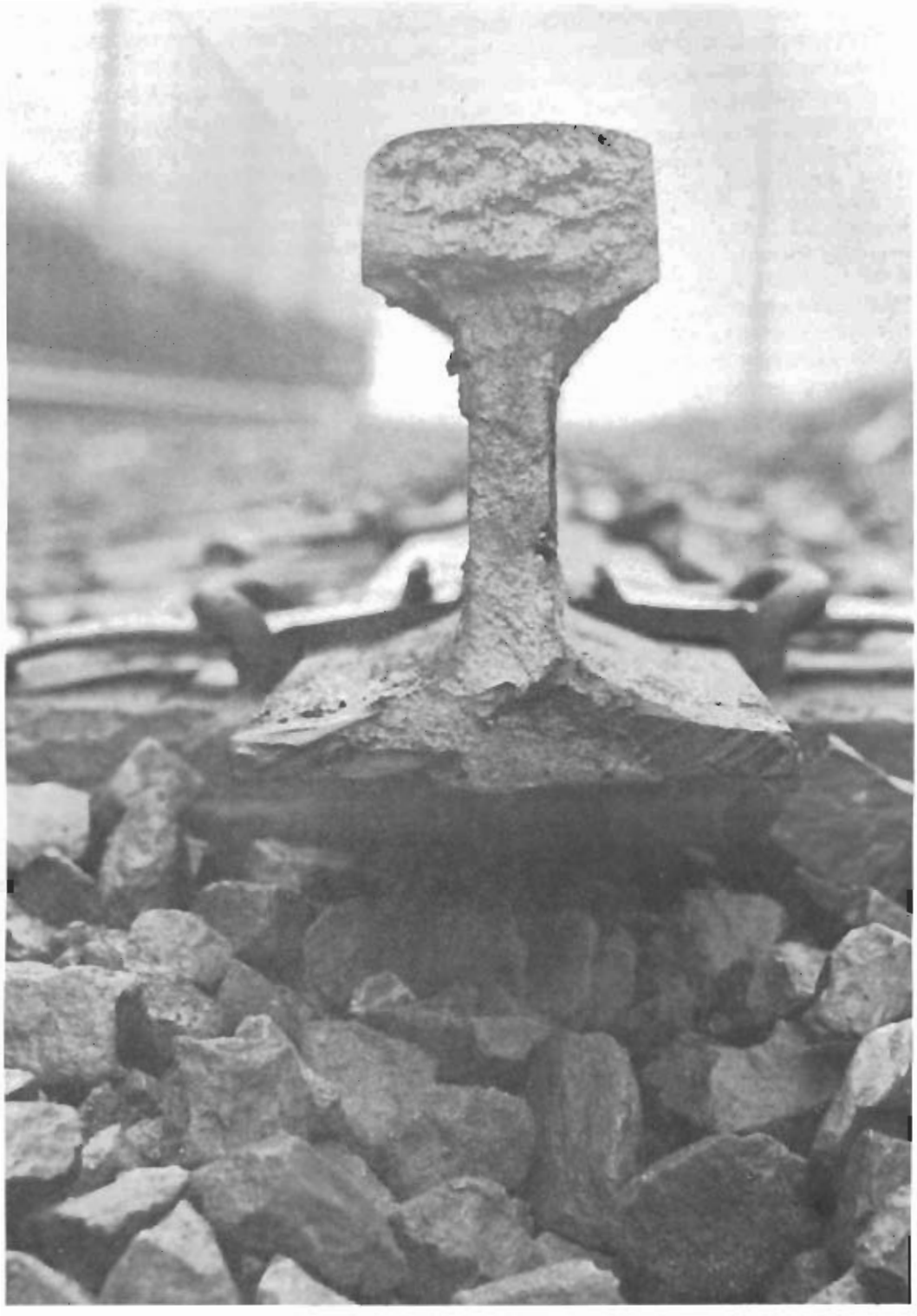


Figure 7 'Running-off' rail end

Figure 8a, Figure 8b
Longitudinal section through centre of weld

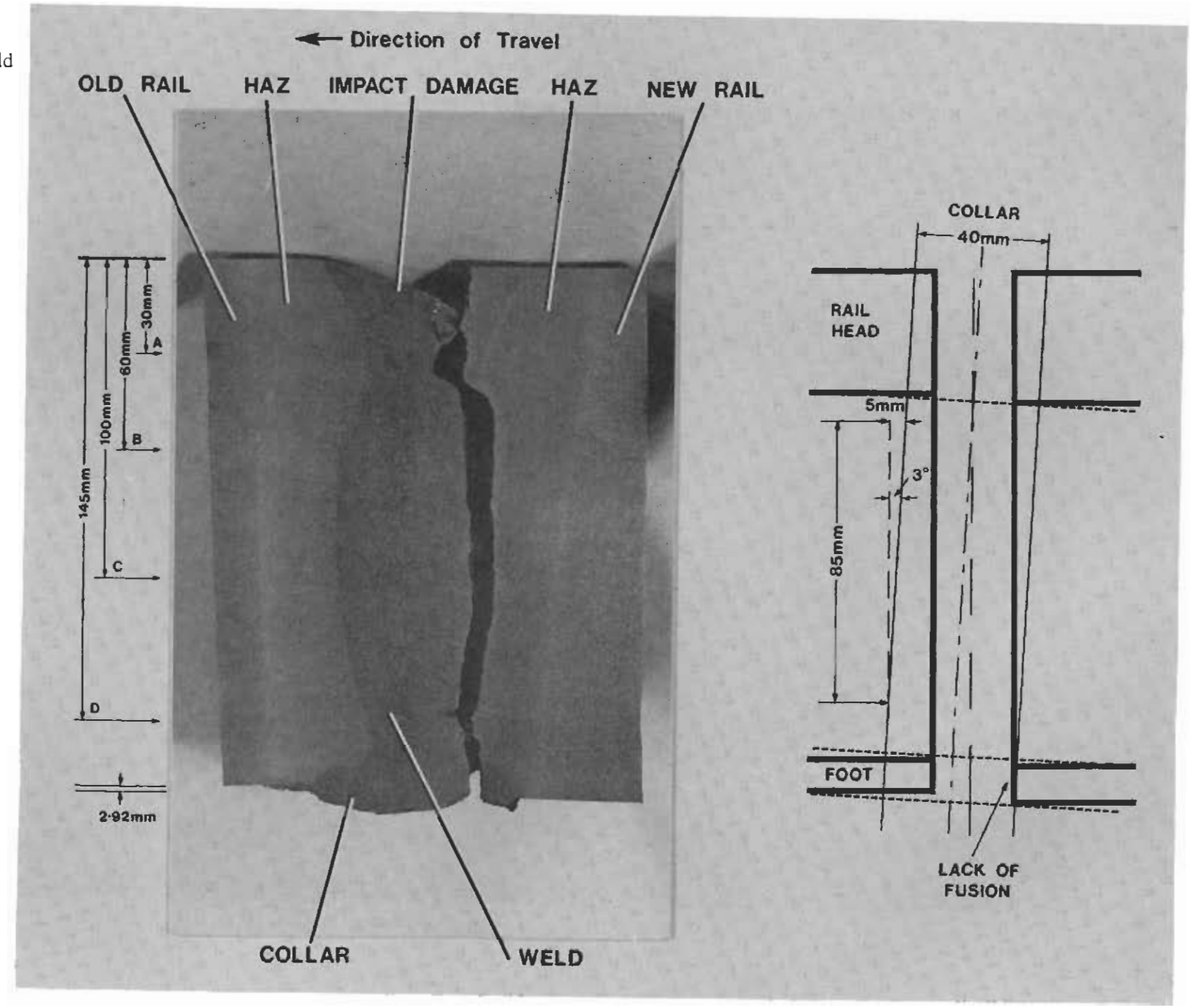


Figure 9 Annual failure rates of alumino-thermic welds per 100 miles of CWR in passenger lines

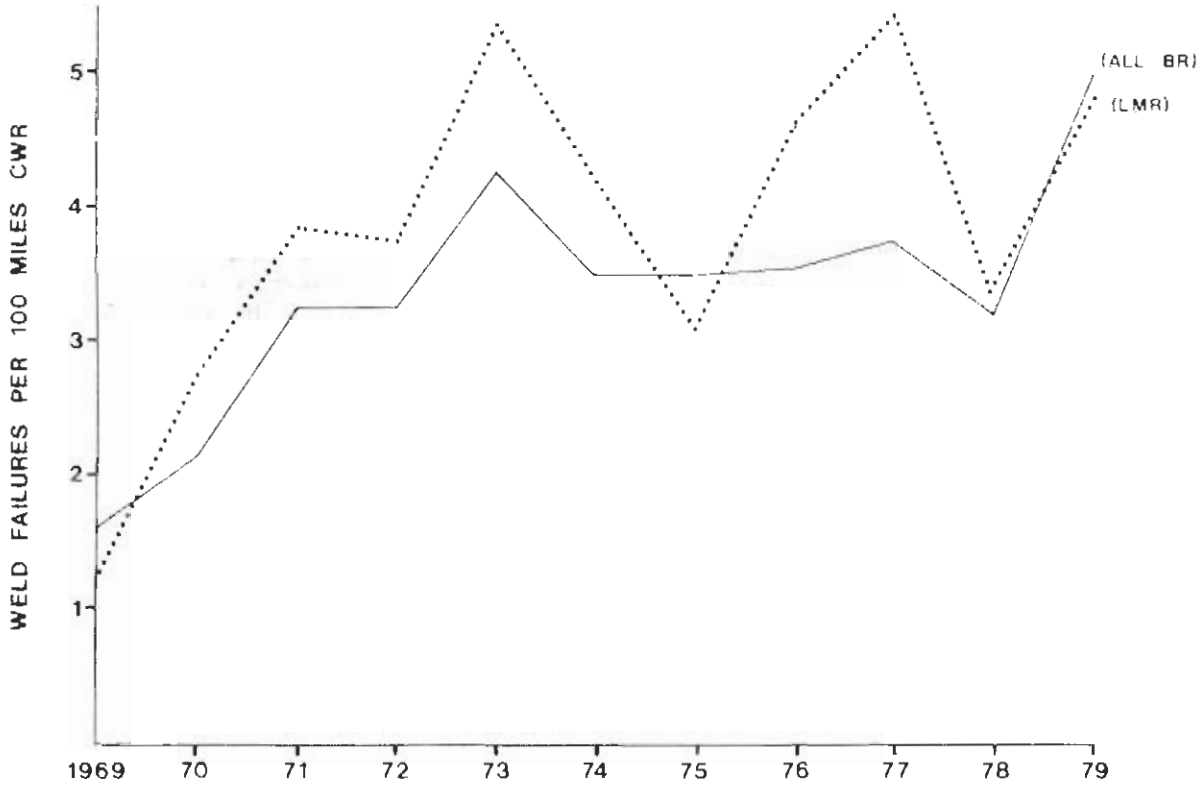
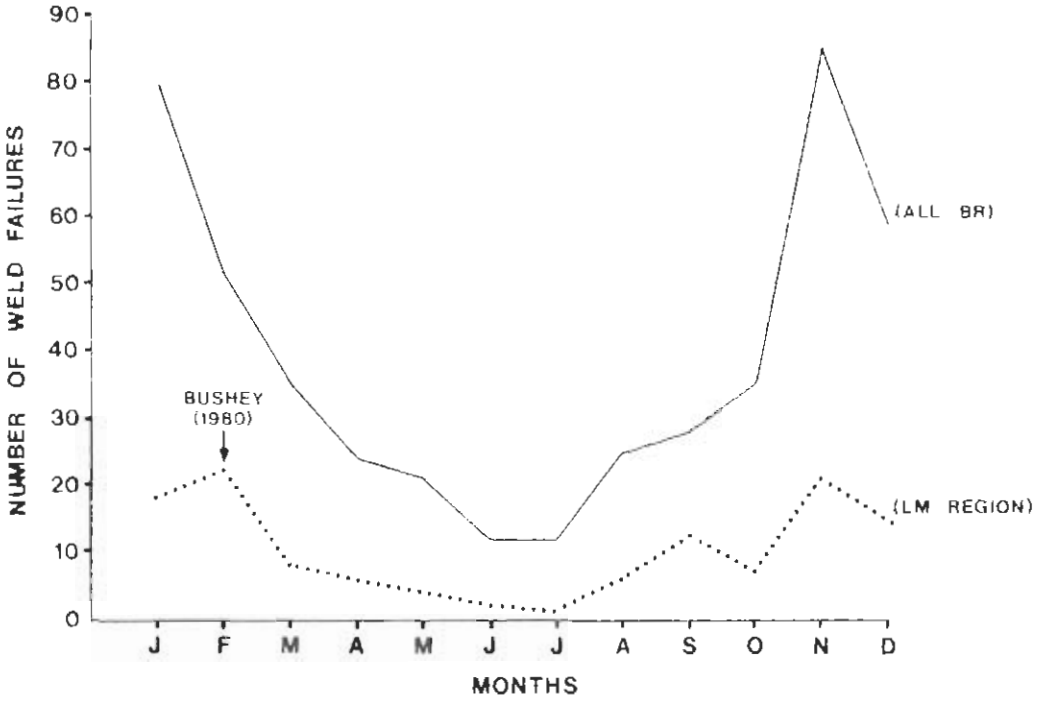


Figure 10 Monthly failures—1979



35. It was his responsibility to recheck all his welders every six months. He had two assistant supervisors, one helped train the trainees and the other came into his office twice a week to help with the time sheets. He had no office staff as such. His assistants visited the welders on site more than he did because he was fully employed during the week in the office and he usually visited his welders wherever they were working, on Sundays. He believed that he visited all his welders more than the required once every 6 months and he noted the dates in a book he kept; he had last inspected Courtney's work on 18th August 1979 and 16th November 1979. He did not however tell the welders he had checked them nor did he sign their cards. He had checked his men for not wearing goggles and for such failures but never for bad workmanship.

36. In his opinion one of the most likely reasons for a bad weld was that a rail already in tension tended to pull back, sometimes by as much as 4 inches, and even during the pre-heating stage could continue to creep back. This creep could pull moulds out of line. He knew that Section A.4.6 of the welder's handbook requires welders to make datum marks on the foot of both rails and on joint sleepers to detect any longitudinal movement during pre-heating but he admitted that he had never seen any of his welders do this and to his knowledge it was not taught in the schools.

37. He considered the workmanship of Courtney and Goodwins to be very good and he had been very satisfied with them. He had seen most of the failed welds and thought that misalignment of the moulds was the most common cause but he was not able to tell from his records whether the failed welds had been made by certain welders or whether it was just a matter of chance.

Evidence on the Examination of the Failed Weld

38. The London Midland Region HQ *Regional Welding Assistant J. K. Milne* was called to inspect the broken weld at Bushey. The two lengths of rail each about 8 feet long had been laid aside for inspection and he measured the vertical depth of each rail near the weld and some 6 feet from it and found the new (running off) rail to be worn 1 mm and the older 110 lb rail 3 mm. He borrowed an engineer's square and found that over a height of 85 mm between the head and foot of the rail the weld was 5 mm out of vertical. On the running-off rail he could see, through lack of fusion, the flank of serrations on the rail foot. This is clearly seen in the photograph at Figure 7. He also noted that there was no weld collar visible on this rail which indicated to him that the moulds had not been correctly aligned. He believed that a welder having made the weld could have seen that the collar was not vertical had he cleared away the luting sand and examined his work carefully. (The angle is illustrated in Figure 8(b)).

39. Mr. Milne began his railway career at Wolverhampton in 1961. He worked in the civil engineer's drawing office until 1966 and then became a Professional and Technical Grade B and later a Senior Technical Officer on Western Region. He told me "In 1968 when the person who was involved in welding at that time got a promotion I simply asked my boss if I could do that job, and I did". He then became responsible to the Divisional Civil Engineer at Bristol for all track welding and ultrasonic testing. Later he was put in charge of a rail welding depot (where long welded rails are produced by the flash butt process) and was promoted to Workshop Supervisor 'D'. He had applied for his present appointment in 1977.

40. He told me that his Region made about 15,000 thermic welds every year; the majority of welds were made during weekend 'occupations' of the line. He was in charge of the Regional welding school in Northampton where all new trainees attended a three-weeks course. In addition to the seven Divisional Welding Supervisors who were responsible for testing and assessing at six monthly intervals all his welders, he had two instructor supervisors whom he had also employed for assessment duties. All his welders attended a two-yearly Regional Refresher course in the school, to bring them up-to-date with developments. He also spent most weekends visiting welders on the track. He always used a mirror to check the undersides of welds but welders were taught to fit moulds correctly by feel.

41. The two lengths of the new (running-off) and old (running-on) rails that were cut out of the damaged track after the accident were sent to the Research and Development Division at Derby for metallurgical examination. The new rail was 113A lb made in 1974 by the basic open hearth process whereas the old rail was 110A lb made in 1965 by the acid bessemer process. The new rail was 2·92 mm deeper than the old, and was found to have a dip at the weld of about 1·5 mm over a 1 m length. No weld identity stamp mark was found.

42. The weld was sectioned and etched along the rail's centre line as shown in Figure 8(a) which shows that it had failed within the heat affected zone (HAZ) of the (running-off) new rail. The moulds had been set up at an angle of 3° to the vertical (see Figure 8(b)) but they were square across the rail. The weld had been made vertical to the rail head indicating that the rail ends had been cut vertically, but a metallographic examination showed that the HAZ varied on the two sides of the weld as shown in Figure 8(a). A number of Standard SkV-F welds were made both with inclined and with straight moulds and similarly sectioned, and the following table records the widths of the HAZ at four points below the running surface of the rails in each case.

Widths and Depths in mm

		THE BUSHEY WELD			*TEST WELDS*		
At Depth	Marked	HAZ Running Off	Weld Width	HAZ Running On	HAZ (a)	WELD WIDTHS Angled Moulds	Straight Moulds
1	2	3	4	5	6	7	8
30	A	30	28	32	24–25	36	34–35
60	B	22	38	24	18–22	47	44–45
100	C	20	39	24	17–20	53	42
145	D	17	27	30	18–22	56	32–34

(a) HAZ widths same on both sides of weld.

43. By comparing columns 4 and 7 it can be seen that the Bushey weld was some 8 mm narrower than a normal weld. In addition, because of the angle of the mould to the vertical, the centre of the collar at the foot of the rail was displaced by 8 mm from the centre line of the weld which gave rise to variations in the widths of the HAZ particularly at the foot (see columns 3 and 5).

44. A chemical analysis of the rails and weld showed them to be normal except that the mean aluminium level was found to be 0·69 per cent whereas in quality control tests over the previous 14 months the mean had been found to be 0·33 per cent (0·2 per cent to 0·70 per cent is specified). This led to higher than normal Brinell Hardness figures (276 to 317 compared with 227 to 293 specified using a 3,000 kg load and 10 mm ball).

45. In discussing their observations the metallurgy section at Derby came to the following conclusions:

(a) Lack of corrosion on the fracture faces indicates that the fracture had only occurred a short time before the derailment.

(b) One of the two unfused areas had initiated the fracture which had been instantaneous.

(c) Some fitting of the mould had been done, but it had been inadequate: (had no fitting been done the mould would have been at 4° to 5° to the vertical whereas it was 3°). Some flashing found around the weld confirms that the mould had been badly fitted.

(d) Such an angled mould can lead to 'lack of fusion' defects but not as large as those on the Bushey weld, and "it appears likely that additional procedural deficiencies may also have been involved".

(e) The weld chemical analysis indicated that the 'welding portion' used was satisfactory.

(f) The narrowness of the weld may have been due to the initial cut gap being some 6 mm less than the required 22 mm minimum, or delayed tapping or blocked vent risers may have prevented the molten steel from washing away the rail ends to the normal degree.

(g) The high aluminium content could have been due to:

(i) premature tapping of the crucible;

(ii) lack of crucible deslagging;

(iii) excess aluminium in the portion used.

The Incidence of Broken Welds

46. The mileages of CWR on the whole of B.R., on the London Midland Region and on the Watford Division of that Region are given in the following table. Also shown are the number of alumino-thermic welds which broke in 1979 and the rates per 100 miles of CWR at the end of the year.

	B.R.	*L.M.R.*	*Watford Division*
Miles of CWR Track (Dec '79)	9,982	2,592	553
No. of Broken Welds (1.1.79–31.12.79)	504	126	30
Broken Welds/100 Miles CWR	5·05	4·82	5·42

47. If all CWR was installed by laying into the track 720 ft lengths of rail, each having 11 flash-butt welds and one alumino-thermic weld there would be 15 alumino thermic welds in each mile of CWR track. But there are many more alumino-thermic welds per mile than these figures suggest. Some 190,000 alumino-thermic welds have been made on LM Region and it is estimated that some 40,000 have been removed leaving an estimated 150,000 in the track. Whilst the majority of alumino-thermic welds are installed in plain line in CWR, a not inconsiderable number are made in switch and crossing layouts, sidings etc., and to eliminate unwanted joints in conventional jointed track. It may be assumed, therefore, that on the L.M.R. there are overall some 50 alumino-thermic welds per mile of plain line CWR of all categories. Of these 150,000 alumino-thermic welds, 15,300 are thought to be SkV–F, of which there were 21 failures in 1979 which is a rate of 1·37 per 1,000 welds installed in track.

48. Whilst some welds break within 1 or 2 years of the date on which they were installed, and others fail subsequently from fatigue fracture, most alumino-thermic welds outlive the life of the rail in which they have been made. The current rate of failure for alumino-thermic welds made by various processes is illustrated by the following table which shows, for the whole of B.R., the years in which they were first introduced and the estimated number of broken welds per 1,000 welds in the track in 1979. The figures are approximate only because, in the past, failed welds have not all been identified by welding process but their years of introduction and the areas in which they were used enable fair estimates to be made.

Type of alumino-thermic weld	*SmW*	*AT*	*SkV*	*SkV–F*	*Total*
Introduced	1954	1970	1976/7	Oct '78	
No. in B.R. × 1,000	575	30	40	45	690
Broken on B.R. in 1979	277	20	111	96	504
Broken Welds/1,000 in track	0·48	0·66	2·78	2·13	0·73

Although no firm conclusions can be reached in comparing the SkV and SkV–F welds with SmW Welds, it does show that the London Midland Region's rate of 1·37 broken SkV–F welds per 1,000 installed is below the average figure of 2·13 for B.R. as a whole.

49. In a study of 55 broken alumino-thermic welds made by the SkV process, of which only a few were of the SkV–F type, the Research and Development Division at Derby found that in 64 per cent reason for failure was lack of fusion defects, with hot-tearing being the reason in 16 per cent and porosity in 11 per cent. Most of the welds containing lack of fusion defects also showed narrower weld fusion zones than normal and a small proportion of these appeared to have been made with a too narrow initial welding gap.

50. Figure 9 plots the failure rate of alumino-thermic welds as a whole over the last ten years. The rates are 'per 100 miles of CWR track', the mileages being the average between that at the beginning and end of each year. Whereas over the whole of British Railways the rate was steady at about 3·7 from 1974 to 1977, it fell significantly in 1978 but rose suddenly in 1979. London Midland Region's figures fluctuated about this figure rising to 5·56 per cent in 1977 but the figures for 1978 and 1979 were about average. The 53 per cent increase for the whole of British Railways in 1979 over the 1978 figure must cause some concern.

51. Figure 10 shows the monthly distribution of weld failures in 1979. It is normal for about 75 per cent of all weld failures to occur between October and March each year. Very few occur in June and July. London Midland Region made a special study to determine how the 57 failed alumino-thermic welds on the West Coast Main Line in 1979 came to be detected. Four Divisions were involved: on the Watford Division 25 per cent were detected because they caused track-circuit failures, on the Crewe Division it was 30 per cent, and on the Liverpool and Preston Divisions it was 50 per cent. The average rate of detection because of a track-circuit failure for the line as a whole was 40 per cent, the remaining 60 per cent being found visually by permanent-way staff except for 2 weld failures out of the 57 which were reported by locomotive drivers. During 1979 on British Railways as a whole the proportions found by track-circuit failure or the S. & T. staff were 31 per cent on electrified lines and 37 per cent on non-electrified lines, but on the non-electrified lines of Western Region much of which are equipped with double-rail track circuits the figure was 52 per cent.

Conclusions

52. The derailment was caused by a type 4212.2 (a) failure of an alumino-thermic weld made using the SkV–F process on 16th October 1979. The weld was obviously broken some 48 minutes before the derailment and may have been broken earlier but it was not broken when Trackman Moio passed the site at 10.00 some 10½ hours before the derailment occurred. At least three trains passed over the broken weld safely. It was the failure by repetitive impact loading of the running-on concrete sleeper that led to this sleeper crumbling and finally releasing the rail end that led to the derailment occurring.

(a) See Appendix "A".

53. The mould had been incorrectly fitted to the rails at an angle of 3° to the vertical which, by observation, was quite obviously crooked. It should also have been easily detected had the welder looked down the riser aperture as required in Clause D4.2 of Civil Engineering Handbook No. 32. The metallurgical study showed that the weld was narrower than it should have been. It is possible that the gap between the rail ends was less than the 22 mm minimum required and that this prevented the pre-heating flame and then the molten metal flowing properly around the foot of the rail resulting in parts of the parent metal near the outer edges of the rail foot failing to melt properly. In consequence, the mixing of the liquid Thermit steel and the molten rail end that takes place in a properly made weld did not occur and the 'lack of fusion' defect, subsequently revealed, was created. On the other hand delayed tapping of the crucible coupled with a lack of crucible deslagging may have produced the same results.

54. Had the gap been less than the prescribed 22 mm minimum, this may have been connected with the procedures adopted by the welders. The rail temperature at the time the cuts were made would have been such that the rail would have been in tension, and, therefore, the gap would have been expected to open. It is possible that the welder attempted to make allowance for this by cutting the gap too narrow and that the expected movement failed to materialise. Alternatively, he cut the gap to the standard opening and the gap closed as the sun came on the rail. Any movement went unnoticed because it was not the practise of the welders to mark the rails and sleepers as required by Clause A4.6 of Handbook No. 32. It is not possible to say whether the gas pressures were correct nor whether the timing of the various operations in making the weld were correctly applied, but there is evidence to suggest that, even with a too narrow gap, other factors played some part in the failure.

55. There has been little or no quality control of welder's work other than visits by the Welding Supervisor at intervals of not more than six months. Permanent Way supervisors have not generally attended welding appreciation courses and Mr. Martin felt that overseeing the welder's work was not at all his business. Finally, the welders themselves felt that they had no way of knowing whether they had made a good weld or a bad one, although strict adherence to the requirements of Handbook No. 32 would have given them no cause to suppose that an unsatisfactory weld would be produced. Had the sand been cleared away and the weld examined after making, as required by Clause D16.1 of the Handbook, they could at least have seen the crookedness of it. Senior Technical Officer Schofield had not been trained to supervise the actual welding operation and, therefore, was not in a position to contribute to that aspect of the job. Whilst he could have suggested the use of destressing clamps to hold the rails, their use, in this case, might not have led to the production of a sound weld.

56. In summary, a sequence of events led to the production of a weld which subsequently failed. It began with insufficient supervision and quality control of the welders. In cutting the rails the prescribed gap between the two rail ends was probably not created. The moulds were then incorrectly positioned and, in consequence, when the liquid thermic steel was introduced into the moulds the designed requirements for making a satisfactory weld between two rail ends could not be achieved.

Discussion and Recommendations

57. The British Railways Board have undertaken a thorough and detailed investigation into the organisation responsible for track (rail) welding and made many suggestions to eliminate the shortcomings found. I have had detailed discussions with the Board's representatives regarding their proposals, most of which are already being initiated. These proposals may be summarised under five headings, as follows:

58. ***Organisation***

(a) In those areas where this does not currently apply it is proposed to increase the number of Welding Supervisors so that there will be a ratio of one to not more than 10 welders.

(b) Where at present not provided for, it is proposed that arrangements will be made for the keeping of records, ordering materials and handling messages, etc. to be dealt with by other than the Welding Supervisor. This will enable the Welding Supervisors to devote more time on site, supervising welding operations.

(c) It is proposed to step up technical supervision and control on the Regions by:

(i) the appointment of additional Technical and Supervisory Welding Staff at Regional level. Some staff will be encouraged to attend specialist courses leading to an appropriate technical qualification.

(ii) ensuring that all Technical and Supervisory Staff associated with track work where welding is involved are given appreciation courses in alumino-thermic welding techniques.

(d) It is proposed to make an additional appointment at B.R. H.Q. level specifically to establish training standards, to ensure a uniformly high standard is maintained in training at all levels throughout the system and to review attainments in the field. The welding organisation at Regional level will be reviewed to ensure the highest standards of organisation, quality control, training and supervision in the rail welding field.

59. ***Equipment***

(a) It is, in my view, essential to engender a greater sense of craft pride and skill in track welders trained in the alumino-thermic processes. The kit of authorised tools provided to each welding team should include a suitable gauge for measuring rail depths and, also, a robust torch to enable the welder to see into the riser apertures to check that the moulds are positioned centrally at the foot of the rails. In addition a large-faced laboratory type timer would enable both men to check progress and I recommend their use.

(b) The accommodation for welding equipment and consumables that I saw at Watford was deplorable. However, the construction of a new store was already being progressed prior to the accident at Bushey. Work is now in hand and, when completed, satisfactory storage facilities for all items of welding materials and equipment will be provided.

(c) The provision of dedicated road transport for the conveyance of track welders and their equipment is proposed. The use of such vehicles should lead to a reduction in damage to equipment and consumables and result in an improved standard of work being attained on site.

(d) Development of suitable overhead protection, not only for welding stores and equipment, but also for the actual site of the welding operation, is in hand.

60. ***Training***

(a) The re-examination of welders at intervals of not more than two years will continue on all Regions as at present, but with more formal arrangements being established on the Southern and Scottish Regions.

(b) The training of all Welding Supervisors will be carried out under B.R. H.Q. control, and I recommend that the training includes up-to-date advice on the reasons for welds failing and the causes of defects in welds.

(c) All technical staff directly involved with track welding will attend further courses in the appropriate track welding techniques (see also Para. 58(c)(ii)).

(d) It is essential that all Permanent Way Supervisors understand the problems connected with successful track welding and that they appreciate that lack of assistance, insufficient time and undue duress to complete a weld may lead to short cuts being taken and unsatisfactory results. All Permanent Way Supervisors and also technical staff responsible for restressing operation etc., will attend courses to give them an awareness of the potential difficulties, and emphasis is already being given to these aspects in courses which are provided at the Civil Engineering Training School at Watford.

(e) Stress must continue to be placed on the necessity to comply absolutely with the requirements of Handbook No. 32.

(f) As explained by Welder Courtney, welders have refused to apply Clause A13.1 of the Civil Engineering Handbook No. 32, and stamp their welds. This is the only positive way in which any particular weld may be identified, and Board representatives have discussed this requirement, further, with the Union concerned. I am glad to be able to report that, subject to certain safeguards being introduced, agreement on its full implementation throughout B.R. has been obtained.

61. ***Supervision***

I recommend that a Permanent Way Supervisor on site should play some part in the supervision of welders, and this will be aided by his awareness of the basic necessities following an appreciation course. Where a Welding Supervisor is not present during the actual welding operation, then a Permanent Way Supervisor who is present should, subsequently, advise the Welding Supervisor of any matters he considers to be noteworthy. In particular he should check that the mould is vertical to the rail head, that marks are made to detect any rail creep and that the welders are not in any difficulties on this score. Finally, he should check that the rail head has been well ground and the weld stamped. The use of restressing clamps should be considered if the rail is likely to creep.

62. *Ultrasonic Examination of Welds*

Neither the Rail Flaw Detection train, nor any of the hand-held detectors in use prior to this accident could satisfactorily detect a vertical transverse fracture within a rail weld. The problem is in two parts:

(a) To detect such fractures in the head, web or central part of the foot of the rail.

(b) To detect similar fractures or lack of fusion defects in the flanges of the foot of the rail.

Rigs and probes for use with existing detectors have been manufactured and teams of operators (one from each Region) have been trained. Doubtful welds are being cut out and sent to the Research and Development Division, Derby, for detailed examination, but it is as yet too early to assess the effectiveness of the procedure.

Detection of Broken Rails by Track Circuit

63. The matter which must cause the greatest concern is the speed with which the running-on sleeper disintegrated under the repetitive axle loading of high speed trains as described by Mr. McLoughlin. In the Watford Division where single-rail track circuits are used only 25 per cent of broken welds are being detected by track circuit, the remaining 75 per cent being found when the patrolman walks the track at 48-hour intervals. At Bushey, the track disintegrated within 10 hours 40 minutes of his visit, and the sleeper must have disintegrated within this time and possibly after only a few hours traffic for, once the weld had failed, the impact load on it was very considerably increased.

64. The use of a single-rail track circuit on an electrified line enables one rail to be used to conduct traction current. In the United Kingdom the traction rail cross bonding as described earlier is designed to restrict peak 'rail to earth' 50 Hz RMS voltages to 60 volts under normal conditions and to 430 volts under fault conditions to a CCIT specification. In France one of two types of double-rail track circuit is used on all lines electrified at 25 kV and where the line speed exceeds 60 Km/h. An impedance bond is provided at the mid points of each track circuit with cross bonding between tracks. Overhead structures are connected by an earth conductor, itself connected to the rails via the impedance bonds. The arrangement is a compromise between limiting the rail voltage and providing a satisfactory earth return for traction currents, and track circuits must be limited in length to function reliably. They will, however, detect a break in either rail. I am told that they have been in use on the SNCF for several decades and, so far as is known, have not led to any dangerous voltages affecting railway personnel working on the track or on fixed equipment.

65. I have been informed that to provide impedance bonds, and a structure earth return cable and to alter the cross bonding on our 25 kV electrified lines would be extremely costly and would absorb such a high proportion of available railway and industrial resources that future modernisation schemes would be affected. Because of the potential safety advantages on our high-speed lines however, I recommend that a study be made into how a complete fracture of the rail which is at present used to carry the return traction current, could be automatically detected.

Other Matters

66. Most of the casualties occurred in the 4th, 5th and 6th coaches which, having become completely uncoupled, swung round and rolled over onto their sides off their bogies; one coach fell onto a bogie and its side was stove in by it. Had the Buckeye couplings remained coupled, as they often do, casualties and damage must have been less. I therefore recommend that means should be found to prevent the vertical disengagement of these couplings.

67. It has been widely asked, and the question was echoed in a Sunday National newspaper on March 16th, whether the West Coast Main Line is too rough for safety. The heaviest load on the track was applied by the Class 86/0 locomotives under which impact loads approaching 100 tons have been measured. The loads under other classes of electric locomotive, including the modified Class 86/1, and 86/2 locomotives are far less and it is for this reason that Class 86/0 locomotives have now been limited to a maximum speed of 80 mile/h. In comparison, the lateral load on the rails under a very badly hunting coach bogie is not likely to be more than 2 or 3 tons and I am satisfied that the well-known rough riding characteristics of certain types of rolling stock was not the prime cause of the weld failing.

Acknowledgement

68. I wish to acknowledge the help I have received in carrying out my Inquiry from Mr. A. J. Key of Thermit Welding U.K. Ltd., who had a demonstration weld made for me.

I have the honour to be,
Sir,
Your obedient Servant,
A. G. TOWNSEND-ROSE,
Lieutenant-Colonel.

The Permanent Secretary,
Department of Transport.

APPENDIX A

Extract From BRB Civil Engineering Department Handbook No. 1

RAIL FAILURES—DESCRIPTION, CLASSIFICATION AND REPORTING
THIRD EDITION 1968

4 Welding and building up.

42 Thermic welding.

421 Transverse cracking.

4211 Transverse cracking of the rail head.

(Characteristic appearance)

This crack occurs in the weld near the gauge corner or in the side of the rail head. It may lead to total fracture of the rail.

4212 Contraction cracks or incomplete fusion.

(Characteristic appearance)

This relatively flat crack in the weld arises from contraction stresses or incomplete fusion of the foot. It leads eventually to fracture of the section.

After fracture, the contraction crack shows a dark discoloured zone in the rail foot (4212.1). In the other case it is possible to find the unfused region in the foot (4212.2).

4213 Cracking at the change of section.

(Characteristic appearance)

This crack starts at the foot due to a change of section introduced by the weld collar (4213.1). It leads to total fracture of the rail (4213.2).

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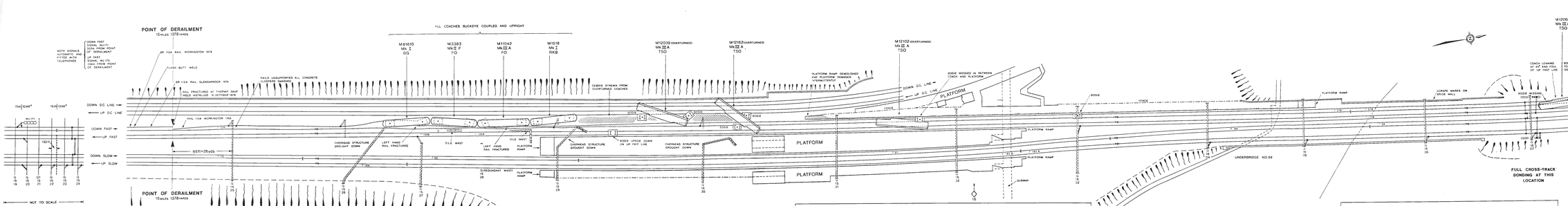
[illegible] 3/81 (177337)



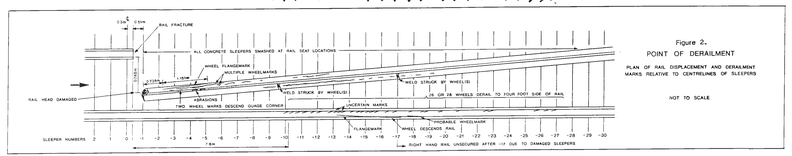
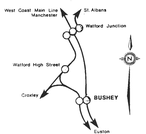


Figure 2.
POINT OF DERAILMENT
PLAN OF RAIL DISPLACEMENT AND DERAILMENT MARKS (RELATIVE TO CENTRELINES OF SLEEPERS
NOT TO SCALE



LOCATION DIAGRAM

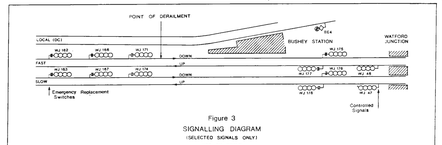


Figure 3
SIGNALLING DIAGRAM
(SELECTED SIGNALS ONLY)
NOT TO SCALE

Note:-
TRACK CIRCUIT INSULATED RAIL IS THE RIGHT HAND RAIL IN DIRECTION OF TRAVEL ON FAST AND SLOW LINES

TRACK CIRCUIT JOINT
EARTH RAIL
RAIL
FASS
EARTH RAIL
TRACTION BONDING SHOWN THUS

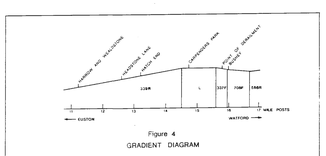


Figure 4
GRADIENT DIAGRAM

Figure 1

DERAILMENT AT BUSHEY 16th FEBRUARY 1980 GENERAL SITE PLAN

0 10 20 30 40
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Railway Accident—Report on the Derailment that occurred on 16th February 1980 at Bushey

HMSO