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A COMPARISON OF WSP AND SCRUBBER BRAKE PERFORMANCE FOR ICM III STOCK.

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Author: J.Tunley.

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AEA Technology Rail
Jubilee House, 4 St. Christopher's Way, Pride Park
Derby, DE24 8LY
Telephone +44 870 190 1340
Facsimile +44 870 190 1516

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	Name	**Signature**	**Date**
Author	John Tunley		31-Mar-04
Reviewed by	Stuart Brown		
Approved by	Bill Poole		

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SUMMARY

The NSR ICM III stock is to have the scrubber brakes removed to reduce noise emissions. Also the existing Oerlikon WSP of both SGM III and ICM III fleets are to be replaced by a more modern Faiveley system. To allow the ICM modifications to be approved it is necessary to demonstrate that the vehicles will be at least as safe, or ideally safer, because of these modifications.

NedTrain Consulting (NTC) commissioned AEA Technology Rail to provide details of tests undertaken in the UK on the performance of scrubber brakes and to compare this with any improvement in WSP performance identified from WSP tests undertaken by Faiveley on the existing and new WSP systems for the SGM III stock. No WSP tests have yet been undertaken for the new WSP for the ICM III stock. It should be noted that any such comparison is only valid if:

1. The performance of the existing WSP on both the ICM and SGM stock is very similar.
2. The new WSP for the ICM stock is optimised to ensure that its performance is equal to or better than the new WSP for the SGM stock.

This report identifies limitations in both the Faiveley 'test bench' approach to WSP testing (see paragraph 2.1) and in the effectiveness of scrubber brakes in low adhesion conditions (see paragraph 4.1). However, it concludes that, within the confines of the available data and the assumptions made, in all except extremely low adhesion conditions the Faiveley WSP will contribute a similar or better level of adhesion improvement to that offered by the combined effect of the Oerlikon WSP and scrubber blocks currently fitted to the ICM III stock.

There is no numerical data for the comparison of scrubber brake performance and modern WSP under extremely low adhesion conditions (adhesion less than 0.02). Hence, it is not possible to make a critical judgement between block brakes and WSP under such extremely low adhesion conditions. However, it is generally accepted that, under such conditions, neither improved WSP nor scrubber blocks alone will improve adhesion or the utilisation of adhesion to a safe operating level. Other measures to improve adhesion, such as sanders, are required.

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1 Introduction

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2 Assumptions

NTC have suggested that the WSP test results for SGM III are representative of the likely WSP performance on ICM III. Such an assumption is only valid if:

1. The performance of the existing WSP on both the ICM and SGM stock is very similar.
2. The new WSP for the ICM stock is optimised to ensure that its performance is equal to or better than the new WSP for the SGM stock.

NTC have stated, and this report assumes, that the small percentage of total brake effort taken by the scrubber brake will be compensated by a similar increase in the disc brake effort such that the dry rail braking performance of the tread and no-tread brake fitted units will be similar.

3 Review of Faiveley WSP Test Report

The report to be reviewed (Ref. 1) is a comparison of the Faiveley AEF91ng WSP equipment, to be fitted to the SGM III vehicles operated by NSR, and the Oerlikon WSP equipment that it is to replace. The Oerlikon system is an old design utilising single stage dump valves that are not capable of holding a constant brake pressure. Because of this factor and other advances in WSP design, the Faiveley WSP should perform better than the Oerlikon design. However, as its name implies, the Faiveley WSP system design dates back to 1991 and there may well be other WSP systems available that make use of the subsequent advances in microprocessor technology to achieve a faster system response, allowing further improvements in axle speed control.

The following discusses the test technique and the test results contained in the Faiveley test report. Reference to other published work and relevant experience is made where appropriate.

3.1 The Test Method

The tests were conducted on the Faiveley WSP 'test bench', which was originally developed under UIC funding.

We understand that the bench was intended to allow an 'ideal' WSP to be developed based on the theories of Mr. M. Boiteux, at the time a senior engineer for SNCF and the chair of the ORE B164 committee. Mr. Boiteux's theory was that the shape of the adhesion/slip curve is modified by the slip energy and that a secondary adhesion peak, the â peak, can be generated to optimise the available adhesion. His aim, based on this theory, was to develop a WSP system that could better regulate the braking force to improve the available adhesion by making use of this â peak. This work is reported in Ref 2; however, it has not been developed further since the retirement of Mr. Boiteux. It is not referred to in the more recent UIC fiche on WSP acceptance (Ref. 3), soon to be issued, even though this working party was chaired by SNCF.

The work of Mr. Boiteux, and hence the adhesion characteristics of the Faiveley WSP 'test bench', was based on track tests where detergent is used to lower the adhesion between wheel and rail. Whilst the use of detergent as a means of assessing WSP performance against a known criterion is an accepted technique, the way that detergent behaves as a low adhesion contaminant may not be the same as naturally occurring contaminants such as rust and leaf film. In an addendum to the original reports of his committee (Ref. 2), a summary of new knowledge (Ref. 4) said 'even a modern WSP, providing sustained slide, could do little to improve adhesion on fallen leaves'.

From the above it is concluded that the Faiveley WSP ‘test bench’ may not provide an accurate representation of naturally occurring adhesion conditions or the wheel and rail cleaning effects that result from WSP controlled wheel slip. Detergent produces a uniformly sustained moderately low adhesion level and is not representative of the range of variable adhesion conditions encountered on damp leaf film and other contaminants. However, it is perhaps reasonable to assume that the results from this test bench may be used to compare the relative performance of one WSP system against another, in much the same way as the UIC detergent track test is employed. It should also be borne in mind that the Faiveley WSP has been developed on this test bench and should be expected to perform well on it.

3.2 Braking Distance Test Results

A range of WSP tests was conducted at different levels of constant adhesion and at three speeds. Each test was repeated three times, with some variability in results. The average stopping distances for each test condition is tabulated below:

Initial Speed	Adhesion	Oerlikon (m)	Faiveley (m)	Difference
120 km/h	8%	760	661	+15%
	6%	1046	769	+36%
	2% (300m)	1753	952	+82%
80 km/h	8%	347	322	+8%
	6%	425	404	+5%
	2% (200m)	544	528	+3%
40 km/h	8%	101	97	+4%
	6%	146	141	+3%
	2% (50m)	175	189	-8%

Averaged over all the tests the Faiveley WSP gave a 30% predicted reduction in stopping distances compared with the Oerlikon WSP. However, this result is greatly influenced by the very large extension in stopping distance of the Oerlikon WSP at 120 km/hr on 2% adhesion.

Reference to the relevant test plot (Ref.1, page 23) shows that three of the four wheelsets remain at a high level of slip for 50 to 58 seconds. On this particular test the simulated very low adhesion section is only of 300m length and at an initial speed of 120km/hr it would take only about 10 seconds to traverse. The fact that the wheelsets controlled by the Oerlikon WSP remain at high levels of slip for so long is probably a function of the poor control of wheel speed, but it could also be a function of the design of the test rig. If this particular test result is discarded, the Faiveley WSP still gives a 14% overall predicted reduction in stopping distances compared with the Oerlikon WSP over a wide range of operating speeds and adhesion levels.

Contrary to the above, at low speed in very low adhesion conditions (40 km/hr, 2% adhesion for 50m), the Oerlikon WSP performed 8% better in terms of stopping distance than the Faiveley system. The wheel slip control of both systems was not particularly good (see Ref. 1, pages 20 and 29), although the Oerlikon system is more likely to result in wheel damage.

Averaged over all the tests conducted at adhesion levels of 0.06 and below that are likely to cause the greatest problems in normal operation, the Faiveley WSP gave a 37% predicted reduction in stopping distances compared with the Oerlikon WSP. This reduces to 15% when the 120km/hr, 2% adhesion results are discarded, as discussed in the paragraph above.

3.3 Comments on Faiveley Synthesis of Results

The following are the author's comments on the Faiveley conclusions (Ref.1, Section 4):

Sliding speed regulation: Agreed, the sliding speed regulation of the Faiveley WSP is better than that of the older Oerlikon design.

Adhesion regeneration: The Faiveley WSP test results do indicate an increase in adhesion along the track, but please note the author's reservations about the validity of the test bench adhesion data (see Section 2.1 above) for naturally occurring low adhesion conditions.

'Bogies Rearing up effect': The weight transfer during braking causes an axle unloading effect on some axles which will depend on the effective mass and the vertical and longitudinal positions of the centres of gravity of the vehicle body and bogies, together with the applied force. A low deceleration resulting from low adhesion will reduce the weight transfer effect. The Faiveley simulation assumes a constant 10% weight transfer that is not accurate, although any error will apply equally to both WSP systems. The Faiveley WSP maintains better axle speed control under these conditions. In reality, particularly in the low adhesion tests, the unloading may be less and the Oerlikon WSP system may not perform quite so badly.

Air consumption: Agreed – the single stage dump valves and longer stopping distance of the Oerlikon WSP test results will all contribute to the increased air consumption.

Extension of the braking distance: See the review of braking distances above. The comment by Faiveley that their WSP achieved a 7.3% extension in stopping compared with a 22.8% extension for the Oerlikon WSP under simulated UIC detergent test conditions raises the following important question: Was the Oerlikon WSP fitted to SGM III stock tested and approved according to the UIC test method? If it was, and assuming it passed, then why is there such a significant extension in braking distance on the Faiveley rig test compared with the UIC track test result?

Very low adhesion conditions: Agreed – the Faiveley WSP generally performs better than the older Oerlikon design, although the single test result where the Oerlikon WSP performed best is not mentioned or explained.

Reference speed calculation: Agreed, the development of an accurate reference speed calculation, particularly in very low adhesion conditions is critical to the success of a WSP design and to any train systems that may use this signal.

3.4 Comments on Faiveley Conclusions

The stopping distance and the air consumption of the Faiveley WSP was better than the Oerlikon system under the applied test conditions and within the limitations described in the previous section of this report. However, these two factors do not 'demonstrate that Faiveley's WSP system will significantly reduce the wheel damage', as stated in the second paragraph of the conclusions.

Wheel damage is a prime reason for the WSP upgrade and a review of the graphical test results does reveal that there were a number of wheel lock events with the Oerlikon WSP. These occurred at sufficiently high vehicle speeds to result in wheel damage. There were no such problems with the Faiveley WSP.

When an earlier version of the Faiveley WSP was first introduced on UK stock, in common with other manufacturer's systems, it did not perform very well in service even though it had previously been optimised on Faiveley's test bench and had passed the UIC test. The WSP was subsequently optimised on the AEA Technology Rail's WSP test facility, the WSPER®, and Faiveley engineers developed the 'software module for low adhesion conditions'. However, in the light of UK experience the range of tests conducted on the WSPER® has subsequently been extended. As a result, a recent WSPER® investigation of a Faiveley WSP has revealed a potential for wheel damage on a UK train which has actually suffered wheel damage in-service. This indicates that, although the Faiveley tests discussed in this report show that the potential for wheel damage will be significantly reduced compared with the Oerlikon WSP, there may still be some residual risk that is not demonstrated by the Faiveley test bench.

Overall, the Faiveley WSP does seem to offer significant benefits in reducing stopping distance, air consumption and wheel damage compared with the older Oerlikon WSP design.

4 Review of UK Reports on Scrubber Brakes

4.1 Class 158 Scrubber Block Brake Tests[5]

During the Autumn of 1991 a rise in the number of Class 158 units failing to operate track circuits was noticed. It was reported that the disc braked 158 units were prone to leaf debris building up on the wheels while block braked 155 units were much less susceptible to this effect.

A single Class 158 vehicle was fitted with scrubber block brakes to explore the practicability of using this technique to improve track circuit actuation under heavy leaf contamination conditions. The block brake was set up to generate approximately 10% additional brake effort under normal train braking.

The report describes tests on the BR Research Test Track to help evaluate the new block brake's performance in respect of contamination removal from the tread.

4.1.1 Simulated Leaf Film Technique

To simulate the hard, thin and very tenacious film that leaves rolled onto the tread of a disc braked wheel produces, adhesive paper tape was applied to the wheel tread. The paper has some of the base constituents of leaves and while it may not have the same resinous content it has been shown to exhibit many of the characteristics of rolled leaf film when applied to the railhead. Once the paper is rolled onto the rail, or in this case the wheel, it looks like black leaf film, displays the same low adhesion values when dampened and is both hard wearing and tenacious. Paper tape had not previously been applied to the wheel tread.

All four wheels of the motor bogie fitted with the block brake were jacked clear of the railhead and a single layer of the adhesive tape was wetted and applied to the wheel tread. The wheels were lowered and the vehicle rolled approximately 600 metres to roll in the paper. The paper application process was repeated to give two layers in total on wheels 4 and 5 and four layers on wheels 3 and 6. The 158 was then driven approximately 2km at low speed to roll in the paper tape prior to the first block brake application.

4.1.2 Scrubber Brake Test Method.

Prior to the tests the blocks had been fully bedded in. Destroying the film by operation of the block brake was a one off operation and as much information as possible had to be gained from the tests. It was assumed that the higher speeds and brake powers would be most destructive. For this reason, the first test was at a low brake demand and at low speed. The train was run up to the test speed, the train brake and block brake applied simultaneously at the required brake demand and the train was allowed to brake to a stand. If the contaminant was not removed, both brake demand and speed were then increased and the test was repeated.

4.1.3 Test Results.

- A brake application of two thirds the maximum from 40 mph to a stand left a continuous band of rolled in artificial leaf film round the circumference of the tread.
- A similar application from 60 mph removed much of the rolled in film but left some in the centre of the tread.
- A maximum brake application from 40 mph was required to remove all the visible black film from the centre of the tread.

Hence it was concluded that a higher brake demand and/or speed was required to optimise the removal of contaminant and improve the available adhesion.

4.2 Comparison of Block and Disc Braked Wheelset Adhesion[6]

These tests were designed to determine if the adhesion available to a block braked wheelset is greater than that available to a disc braked wheelset. The level of any improvement was measured on naturally occurring low adhesion and the statistical significance of that result was established. The tests were carried out during the autumn of 1989 using the British Rail Research Tribometer Train to measure the adhesion level under the various test conditions.

4.2.1 Test Equipment and Procedure

The Tribometer Train test vehicle consisted of a 2-axle wagon with brakes that could be applied in a controlled way, independently of the train brakes. As normally configured, the test vehicle was fitted with servo-hydraulically operated disc brakes but for these tests one axle was fitted with similarly operated high phosphorous cast iron block brakes. Both axles were modified to allow the accurate measurement of wheel/rail adhesion and axle speed, which could be compared with the true vehicle speed.

Alternating event measurements were made on each axle on naturally occurring low adhesion so that a minimum database of 30 results on each brake type was accumulated. Each event was a single wheel slip event and was recorded as an adhesion /slip curve.

4.2.2 Test Results

Thirty six adhesion/slip curves with a peak adhesion (rising slip) less than 0.1 were measured using the disc braked axle, together with thirty seven corresponding block brake axle curves. The mean measured improvement in adhesion was 20% over most of this longitudinal slip range (see Fig.1 below). A statistical analysis of these results shows a 99% confidence of an improvement in the effective adhesion available to a block braked wheelset at any level of longitudinal slip less than 37% of train speed.

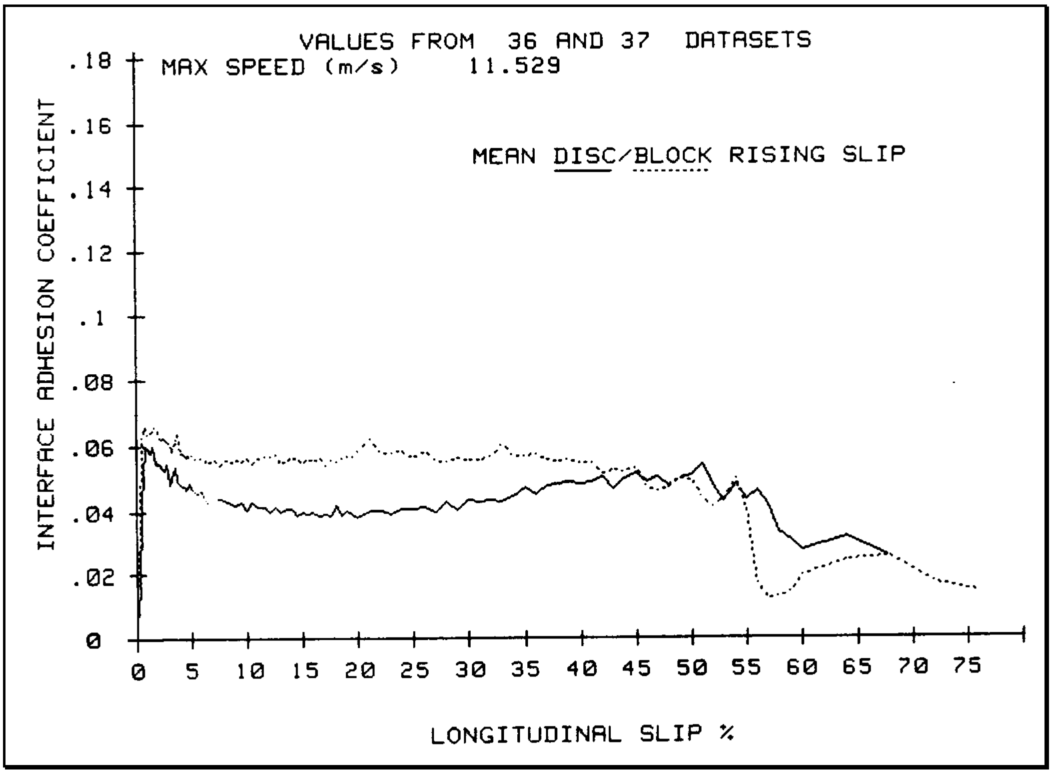

Fig. 1 ~ All results with peak adhesion less than 0.1

The number of results where the peak adhesion was less than 0.06 were reduced to 10 and 5 respectively for disc and block braked axles. The percentage improvement increased to 40% (see Fig.2 below) with a confidence level of 95% for slips less than 34%.

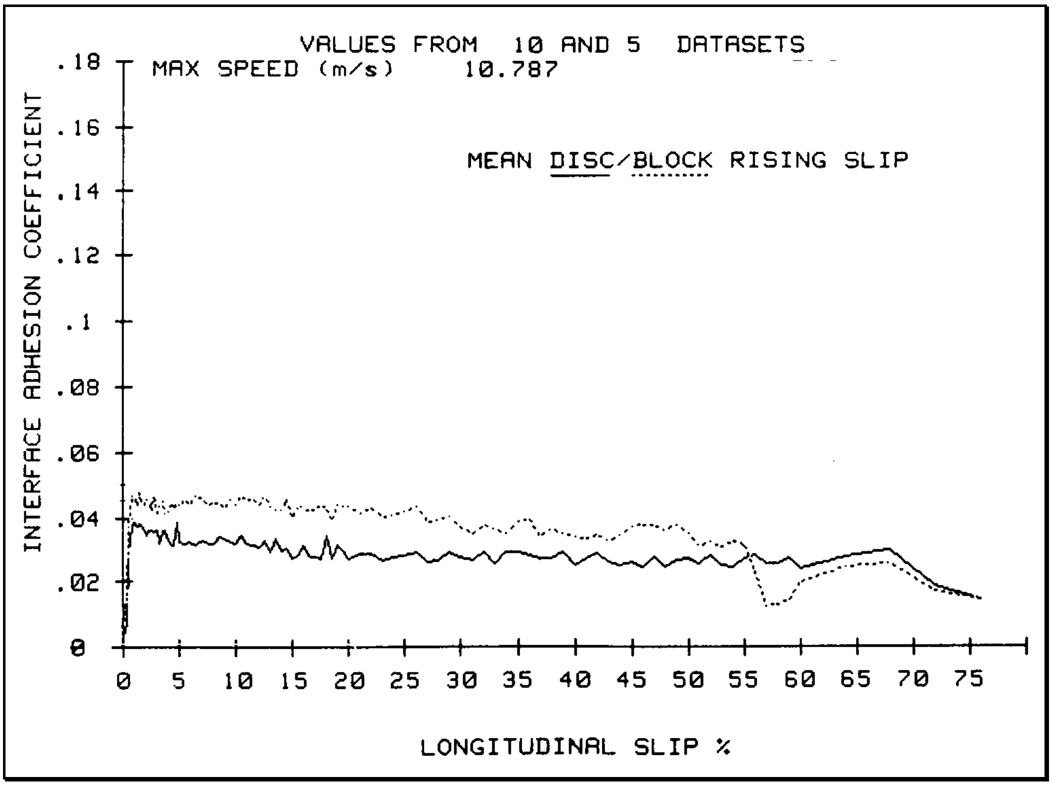

Fig. 2 ~ All results with peak adhesion less than 0.06

The above mean adhesion/slip curves are made up from individual curves that terminate at various slip levels. Hence, the mean results of Figs. 1 & 2 above around 50% slip should be discarded.

4.2.3 Test Conclusions

Cast iron brake blocks are known to form a transfer coating on the tyre surface during braking. Such a coating has a rough and non-continuous surface that may be able to break through films on the railhead. Disc braked wheelsets, however, have tyre surfaces that are smooth. Hence the difference between the adhesion seen by disc braked and block braked wheelsets in these tests may be due to two factors:

1. The above surface roughness effect.
2. The contribution of the block brake in removing any contamination that may have formed on the wheel tread (the scrubber block effect).

The mean adhesion seen by the block braked wheelset from the above factors was 20% above that for a disc braked wheelset for adhesion measurements with a peak value of less than 0.1. This result is valid up to a slip level of 37%.

Similarly, the mean adhesion seen by the block braked wheelset was 40% above that for a disc braked wheelset for adhesion measurements with a peak value of less than 0.06. This result is valid up to a slip level of 34%.

5 Overall Comparison

5.1 Adhesion Below 0.1

The Faiveley WSP tests (Ref. 1) indicate that the Faiveley WSP will give a 14% to 30% reduction in overall stopping distance over a range of artificial low adhesion conditions (0.08, 0.06, and 0.02) when compared with the Oerlikon WSP currently fitted to the SGM III stock. The lower figure only applies if the results of one test series are discarded, as discussed in Section 2.2.

The BR Research tests to compare block and disc braked wheelsets (Ref. 6) indicate a 20% higher adhesion, equivalent to a 20% reduction in stopping distance, can be achieved by a cast iron block braked wheelset compared with a disc braked wheelset over a range of naturally occurring low adhesion conditions (below 0.1). The cast iron block brake friction is likely to be higher than will be achieved with scrubber blocks because of the cast iron transfer coating effect that roughens the tread surface.

The effectiveness of scrubber blocks may be further limited, as follows:

1. The scrubber brake only applies when the vehicle brake is applied. In normal running, significant contamination may be picked up on the wheels such that wheel slip will occur as soon as the brake is applied.
2. The scrubber brake force is designed to be low and will be further reduced by the reduction in brake pressure caused by WSP activity in low adhesion conditions. Contrary to this, the BR Research Class 158 scrubber block brake tests of April 1992 (Ref. 5) indicate that an effective scrubbing action in very low adhesion is best achieved at high brake forces and high speeds. Thus the wheel cleaning effect is likely to be quite limited when braking in low adhesion conditions.

Hence, when scrubber brakes are necessary in low adhesion conditions, their efficiency is limited by the presence of those same conditions.

It is concluded that, within the confines of the available data, the Faiveley WSP will contribute a similar or better level of adhesion improvement to that offered by the combined effect of the Oerlikon WSP and scrubber blocks currently fitted to the ICM III stock.

5.2 Adhesion Below 0.06

The Faiveley WSP tests (Ref. 1) indicate that the Faiveley WSP will give a 15% to 37% reduction in overall stopping distance in artificial very low adhesion conditions (mean 0.06 and 0.02) when compared with the Oerlikon WSP currently fitted to the SGM III stock. The lower improvement figure only applies if the results of one test series are discarded, as discussed in Section 2.2.

The BR Research tests to compare block and disc braked wheelsets (Ref. 6) indicate a 40% higher adhesion can be achieved by a cast iron block braked wheelset compared with a disc braked wheelset over a range of naturally occurring low adhesion conditions (below 0.06). The same limitations to these results apply here as those discussed in the previous section (4.1).

Again, it can be concluded that within the confines of the available data, in very low adhesion conditions the Faiveley WSP will contribute a similar or better level of adhesion improvement as that offered by the combined effect of the Oerlikon WSP and scrubber blocks currently fitted to the ICM III stock.

5.3 Adhesion Below 0.02

There is no numerical data for the comparison of scrubber brake performance and modern WSP under extremely low adhesion conditions. However, the following should be noted:

1. Such low levels of adhesion usually occur on leaf film, which may be difficult to remove with scrubber blocks when the brake pressure, modified under WSP control, is low.
2. It is stated in Ref. 4 that 'even a modern WSP, providing sustained slide, could do little to improve adhesion on fallen leaves'.
3. Contrary to the other WSP test bench results (Ref. 1), the Oerlikon WSP actually stopped slightly quicker than the Faiveley WSP at low speed on very low adhesion (0.02).

Hence, it is not possible to make a critical judgement between block brakes and WSP under extremely low adhesion conditions. However, it is generally accepted that, under such conditions, neither improved WSP nor scrubber blocks alone will improve adhesion or the utilisation of adhesion to a safe operating level. Other measures to improve adhesion, such as sanders, are required.

6 References

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