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**Innovations Deserving  
Exploratory Analysis Programs**

***Transit IDEA Program***

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## **SmartSander Enhancement for Commuter Rail**

Final Report for  
Transit IDEA Project 49

Prepared by:  
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United Kingdom

***February 2008***

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**TRANSPORTATION RESEARCH BOARD**  
*OF THE NATIONAL ACADEMIES*

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National Research Council

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John Kesich	Deputy Chief Mechanical Officer – Metro-North Railroad
Russel Kology	Deputy Director of Equipment Engineering - Metro-North Railroad
Timothy Marriott	Master Mechanic, Fleet Engineering - Long Island Rail Road

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## EXECUTIVE SUMMARY

SmartSander is an automated improved train sanding system developed by DeltaRail to ameliorate fall adhesion performance issues faced by commuter rail operators. SmartSander was originally designed to work with UK stepped electro-pneumatic brake controllers and typical European Wheel-slide Protection Systems. In operation, SmartSander uses a combination of driver's brake demand, train speed and wheel-slide activity to deliver a variable quantity of sand to the railhead appropriate to efficient stopping of the train and protecting track circuits from the insulating effects of sand.

This project dealt with the use of intelligent sanding systems to improve wheel-rail adhesion as a means to improve commuter rail safety and performance in the fall. The test done in this Transit IDEA project involved development of a SmartSander prototype optimized for US commuter rail operating conditions and installation on a Metro-North Shoreliner commuter rail cab car, originally manufactured by Bombardier.

Low wheel-rail adhesion continues to be a major issue for the commuter rail industry, particularly during the fall when there are leaves on the track. The inability to brake effectively in low adhesion conditions has both important safety implications and carries performance/cost inefficiencies for commuter rail operations.

Although large strides have been made in the development of better Wheel-slide Protection Systems, these systems can only optimize the prevailing wheel rail adhesion. Wheel-slide Protection Systems protect the wheels on the train during a stop, but do not necessarily improve stopping performance.

Consequently, some commuter rail operators have occasionally disabled Wheel-slide Systems during emergency stop situations, allowing stops to be made with all wheels locked. This helps make stopping distances more consistent but leads to the costly creation of flats on the train wheels as they slide to a stop.

In the absence of SmartSander, there would be two options available to commuter rail operators, and both have significant down sides. The first would be to tolerate wheel flats. However, flats cause noise and present a risk to the commuter rail operation.

The second would be to re-true the wheels on a wheel lathe, which is costly, as material must be removed from an expensive component. In addition, there is no guarantee that the wheels will not be subject to further flats in a short period if the root cause is not addressed.

SmartSander is an improved sanding system originally developed by DeltaRail in the UK to ameliorate fall adhesion performance issues faced by commuter rail operators. Funding of this project from the Transportation Research Board's Transit IDEA Program enabled a field test in service of the effectiveness of a SmartSander system, which has been optimized for the US commuter rail environment.

It was decided with DeltaRail's partner, Metro-North Railroad, that this project would use a Shoreliner commuter rail cab-car to demonstrate the SmartSander. Metro-North Railroad kindly agreed to provide a cab car and the assistance of their engineers and technicians to give this demonstration a practical grounding. Following design reviews and discussions, a kit of parts was delivered by DeltaRail to Metro-North's Croton Harmon maintenance facility, with some modified parts and adapters to fit the SmartSander variable rate valves to the existing Metro-North sand hoppers. The designs were based around the existing vehicle wiring schematics provided by Metro-North and clearance diagrams for the third rail.



Fig. 1 - Fall Leaf Conditions Leading To Adhesion Problems

Cab car 6305 was fitted in October 2006 at Croton-Harmon by Metro-North Staff and tested in service during the fall of 2006. The installation went smoothly and Metro-North made modifications to the train in order to interface the SmartSander to the WSP dump valves and to the existing sand delivery hoses. The original sand boxes contained damp sand so these were cleaned and replenished with fresh dry sand and the sand box lids were fitted with new clips to secure them tightly.

One session of attended testing was carried out on 4 November 2006 on the Wassaic branch of Metro-North Railroad. The Engineer was asked to brake heavily on contaminated rail and the SmartSander was allowed to automatically sand the rails as he braked. The train came to a stop without excessive slip, although the dump valves were operating in succession on the cab car. No wheel damage was generated during the testing.

Following service running where SmartSander operation was monitored using the vehicle's event recorder, modifications were made to the mapping of the brake interface coding and to the SmartSander logic to eliminate unwanted sanding during cab signal testing by inhibiting automatic sanding below 3 mph.

The demonstration of SmartSander with Metro-North has generated interest within Metro-North and other companies in the direct management of low-adhesion using on-train sanding. There will be further demonstrations and validation of the SmartSander concept in the United States as railroads become attuned to the benefits which can be had. Two other transit agencies have shown an interest in either fitting or trialling SmartSander on their fleets and Metro-North Railroad has written the specification for their new M-8 fleet with sanding systems in mind. Bombardier, manufacturers of Long Island Rail Road's M-7 Electric Multiple Unit trains, purchased ten sets of SmartSander equipment the fall of 2007 and achieved major improvements in stopping performance during controlled tests. The benefits delivered from seven year's operation in the UK appear to hold true in the USA.

The cost-benefit of SmartSander has been proved in the UK where the separation of track from trains into different operating companies has focussed commercial minds on the attribution of delay costs. In the USA the downside of delays leading to reduced customer satisfaction is very real. Intelligent sanding systems can actually restore adhesion conditions during low adhesion thereby complementing wheel slide protection systems which can only make the best use of existing adhesion conditions. The avoidance of delays and the spin-off wheel maintenance reduction can produce a strong benefit in commuter and other transit operations.

In terms of deceleration performance, the observed tests and event recorder data from service operation show that SmartSander can allow engineers to brake confidently during periods of low-adhesion and achieve deceleration rates up to 2 mph/s which represents a significant improvement over typical poor adhesion brake rates which can be as low as 0.4 mph/s. Because sand rate is related to the level of braking demanded, some education may be necessary to give engineers the confidence to use higher brakes rates in poor conditions.

## INTRODUCTION

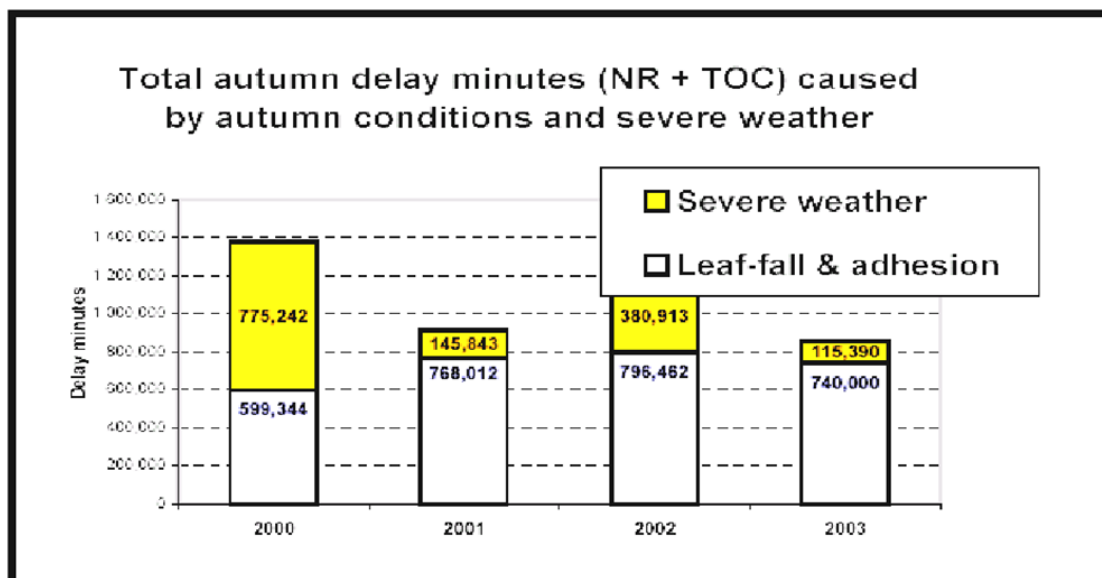
Low wheel-rail adhesion continues to be a major issue for the commuter rail industry particularly during the fall when there are leaves on the track.

The inability to brake effectively in low adhesion conditions has both important safety implications and carries performance/cost penalties. Although large strides have been made in the development of better Wheelslide Protection Systems, these systems can only optimize the prevailing wheel rail adhesion. Wheelslide protection systems protect the wheels on the train during a stop, but do not necessarily improve stopping performance.

The result is that US commuter rail operators sometimes disable Wheelslide Protection Systems during emergency stop situations, allowing stops to be made with all wheels locked. This helps make stopping distances more consistent but leads to the costly creation of flats on the train wheels as they slide to a stop. There are two options available to commuter rail operators, and both have significant down sides. The first is to tolerate wheel flats. However flats cause noise and present a risk to the railroad. The second is to re-true the wheels on a wheel lathe, which is costly, as material must be removed from an expensive component. In addition, there is no guarantee that the wheels will not be subject to flatting again in a short period.

Traditional sanding systems have been used to improve adhesion by placing sand between the wheel and rail. These either use purely manual control or operate automatically under emergency conditions. There is little optimization available to ensure reliable performance or protection of track circuits.

SmartSander is an improved sanding system developed by DeltaRail in the UK to ameliorate fall performance issues suffered by commuter rail operators. Funding from the Transportation Research Board's Transit IDEA program has enabled a demonstration of the effectiveness of a SmartSander, which has been optimised for the US Commuter rail environment. DeltaRail has worked with Metro-North Railroad (MNR) to demonstrate SmartSander on one of their Shoreliner commuter rail cab cars.



Key NR = Network Rail  
TOC = Train operating Company

Fig 2 - Autumn (Fall) delay minutes costed previously in the UK

In the UK, the inability to apply traction under low adhesion conditions, combined with the need to drive defensively during the fall (i.e. brake early and gently on the approach to stations and signals etc.), results in considerable delays to passenger services throughout late autumn and early winter. Figure 2 shows the delay minutes accumulated across the UK network during the falls of 2000, 2001, 2002 and 2003. As the graph shows, around  $\frac{3}{4}$  million delay minutes are typically lost during fall.

Damage to wheel and rail is widespread, but is often hidden in departmental maintenance budgets. However, the direct cost of remedial and treatment programs in the UK is estimated conservatively at approximately \$75million per year. In addition, the impact of delay and adverse media coverage on riders' perceptions is difficult to calculate, but significant.

With low adhesion making this level of impact on the cost and operation, it is the biggest single cause of disruption in the railway calendar. It deserves to be taken seriously.

## THE PROJECT

Metro-North Railroad Shoreliner cab-car 6305 was selected to demonstrate the SmartSander. This vehicle already has a manually operated sander fitted where the engineer can select sanding when he feels that the conditions warrant it.

Metro-North Railroad has kindly agreed to provide a cab car and the assistance of their engineers and technicians to give this demonstration a practical grounding. The cab car was fitted at the Croton-Harmon maintenance facility by Metro-North staff and tested in-service during the fall of 2006.



Fig 3 Metro-North Shoreliner Cab Car



Fig 4 - Cab car engineer's desk



Fig 5 - Cab sand button (lower left) and loco sand button (right)

### 3.1 WORK PROGRAM

This project was performed in two stages as outlined below;

Stage I - Design and manufacture pilot installation kit

Task 1 - Preliminary design

Task 2 - Installation design

Task 3 - Installation kit

Stage II - Installation and test

Task 4 - Pilot installation

Task 5 - Installation and maintenance manual

Task 6 - Installation optimization

Task 7 - Evaluation and final report

## SMARTSANDER TECHNOLOGY

SmartSander is an improved sanding system developed by DeltaRail in the UK to ameliorate fall performance issues suffered by commuter rail operators. SmartSander is currently designed to work with UK stepped electro-pneumatic brake controllers and typical European Wheelslide Protection systems. In operation, SmartSander uses a combination of driver's brake demand, train speed and wheelslide activity to deliver a variable quantity of sand to the railhead appropriate to efficient stopping of the train whilst protecting track circuits from the insulating effects of sand.

## POTENTIAL PAYOFF

DeltaRail's experience in managing low-adhesion and its consequences has highlighted the following benefits from SmartSander.

### 5.1 IMPROVED SAFETY:

- A reduced risk of red light violations and Station run-bys
- Improved stopping performance during low adhesion rail conditions.
- Improved stopping reliability (sand is available in all brake demands).
- Reduction in air consumption during train stops.
- Reduced risk to track circuits, through optimal (not excessive) sanding.

### 5.2 IMPROVED OPERATIONAL COSTS:

- Reduced wheel defects due to slide events (typically 80%).
- Reduced delays through improved punctuality.
- Reduced sand consumption (SmartSander<sup>®</sup> sands early and optimally reducing overall sand use).
- Less downtime and improved availability (less wheel-flats = more availability).
- Longer component life (wheels, bearings and suspension).

### 5.3 IMPROVED CUSTOMER SATISFACTION:

- Improved passenger environment due to minimising noise caused by defective wheels.

#### 5.4 RAPID AND RELIABLE DEPLOYMENT:

- A low risk and proven solution (over 1000 cabs successfully fitted).
- Implementation and delivery within your required timescales.

SmartSander has a proven track record in improving operational safety and performance and has been installed on over 1000 vehicles in the UK and continental Europe. The UK South Eastern Fleet comprising Class 465 and 466 trains has historically suffered consistently poor performance in low adhesion conditions. DeltaRail fitted the SmartSander system to the 190-train fleet in the fall of 2000.

These trains were monitored over the following three years, while operating on the Kent Link suburban services. The results showed that the fleet benefited from **an average of a 30% reduction in delay minutes**, which resulted in a saving in excess of \$750,000 in delay penalties each fall (at \$110/minute of delay).

By comparison, the delay minutes experienced on the remainder of the fleet, not fitted with sanders, remained at the same high level as before, over those three years.

The increased adhesion provided by SmartSander, operating at all levels of brake demand, meant that the train operator also benefited from a significant reduction in wheel damage on the Class 465 and 466 fleets. A total of 446 wheels were turned in 1999, prior to SmartSander fleet fitment. This reduced to 23 in 2000 and 156 in 2001.

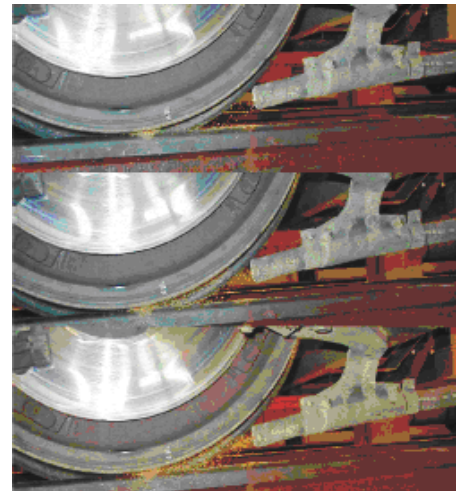


Fig 6 - Variable sand delivery rate, depending on speed, slide and brake step.

#### 5.5 SAFETY BENEFITS

SmartSander offers increased operational safety in low adhesion conditions, a prime concern for all train operators. The example to the right deals with a problematic UK fleet. The Class 465 and 466 fleets had historically suffered consistently poor performance in low adhesion conditions.

Before fitting the SmartSander system, Class 465 and 466 Electric Multiple Units had a 30% probability of an incident each autumn. DeltaRail installed the SmartSander system to the 190-train fleet to deliver a consistent and guaranteed adhesion improvement. Fitting began in August 2000 and was completed by Christmas of that year, with 115 units fitted by mid-autumn.

At the mid point of the 2000/2001 period when low adhesion incidents occurred, low adhesion incidents for the SmartSander fitted EMU's dropped dramatically to 0.08 incidents per EMU, a 73% reduction.

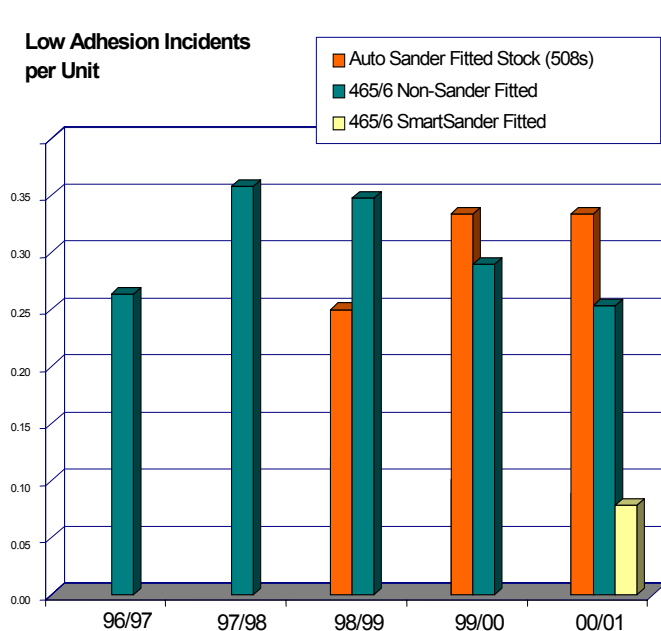


Fig 7 – Reduction in adhesion incidents

## 5.6 PERFORMANCE BENEFITS

Performance figures for these trains monitored for the autumn of 2000/1 operating on the Kent Link suburban services show that the fleet has benefited from **an average of a 30% reduction in delay minutes**, with a saving in excess of \$1000,000 each fall (at \$100 per minute of delay). By comparison, the delay minutes experienced on the remainder of the fleet, not fitted with sanders, remained at the same high level over those three seasons.

## 5.7 OPERATIONAL COST BENEFITS

The increased adhesion provided by SmartSander operating at all levels of brake demand, meant that the train operator also benefited from a significant reduction in wheel damage on the Class 465 and 466 fleets. A total of 446 wheels were turned in 1999 prior to SmartSander fleet fitment. This figure was reduced to 23 in 2000 and again by 156 in 2001.

*The reduction in station overruns since the fitting of DeltaRail's SmartSander to the 465 / 466 fleet averaged 70%*



Fig 8 Class 465 Network fleet operating in Kent UK

*An average 80% reduction in wheel turning during the leaf fall season is one of the typical benefits of SmartSander fitment*



Fig 9 Wheel Damage

- Improved safety and stopping during low adhesion rail conditions
- Reduced wheel truing cost overall by reducing wheel defects due to slide events with a target of allowing four re-turns being made over a wheel's life rather than three
- Reduced sand consumption
- Improved commuter rail passenger environment due to minimizing noise caused by defective wheels.

## TASK 1 PRELIMINARY DESIGN

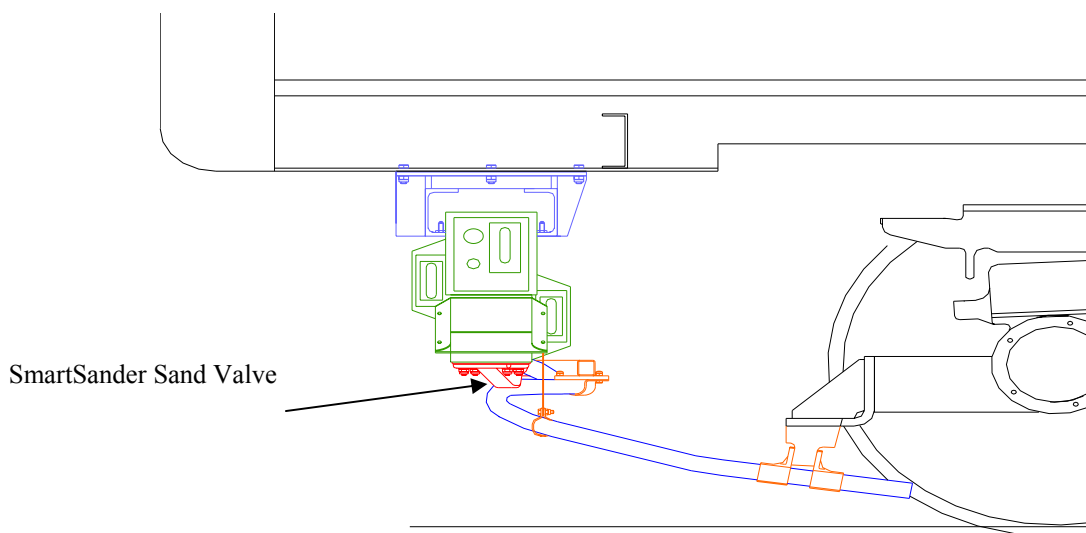
### 6.1 VEHICLE SPECIFICATION

There are several aspects of the MNR Shoreliner fleet that were of relevance to the SmartSander installation. These were as follows;

1. Consist: locomotive with 2 –10 coaches (including the cab car)
2. 100mph maximum speed
3. Wabco 26-C trainline brake control (proportional) set to 110psi (~7.5bar) in release
4. Wabco E5 and E7 Wheel Slide Protection System (E-7 on the trial car)
5. 3mph.ps (13%g) best deceleration rate, typically 2mph.ps (9%g)
6. Train air supply 130 – 140psi (8.96 – 9.65bar)
7. Sanders presently fitted to cab cars deliver to Axle #1, sand hoppers 5 cu ft (225kg) per side
8. 74V DC discrete train lines with “train sand” line
9. Sand size 180 – 850 microns ~ the same as UK locomotive sand
10. No known maximum sand delivery rate
11. Sander to be used for wheel slide only.

### 6.2 DESIGN CONSIDERATIONS

Figure 10 shows a sketch, based upon existing UK designs, and shows how the SmartSander equipment would interface to Metro North’s Commuter Rail Cab Cars.



**Fig 10** Typical leading axle SmartSander Installation

Technically the Shoreliner Cab Car presented few problems. As these vehicles were already fitted with regular sanders, it was decided to re-use several parts of the existing sander. This was to ensure that the SmartSander installation was completed efficiently and on time. Therefore the equipment supplied by DeltaRail was restricted to the components listed below:

- Design Configuration
- Installation manual
- Installation kit procurement
- SmartSander Hardware including (per cab car):
- 2 off Variable rate sand valve
- 2 off sand delivery hose (length to be determined)
- 1 off Control unit
- 1 off train pipe interface unit
- 1 off EP Valve Unit
- 1 off Circuit Breaker
- 1 off Interface Modules for Wheel Slide Protection System
- Cable and connectors between controller and train
- Cable and connectors between controller and air valve units
- 1 off Interface module for Train speed

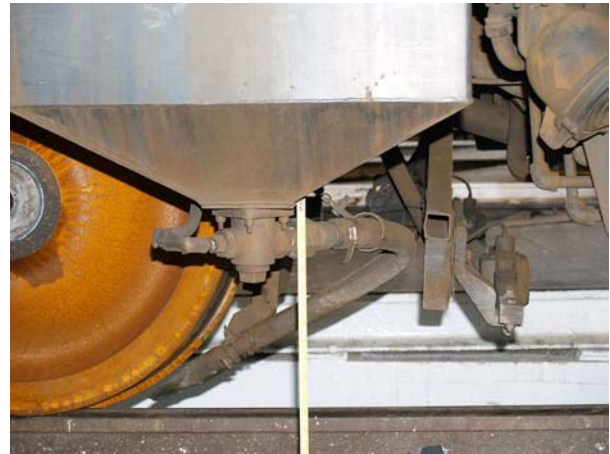


Fig 11 Shoreliner sanding valve attached to hopper at leading end of cab car.

It was agreed to fit two sanders (one at each rail) situated prior to the first axle of the leading vehicle (cab occupied). It is anticipated that this will initially give a sand rate of:

- 1 kg/min per rail when Wheelslide activity is experienced at all speeds up to 30% brake demand;
- 2kg/min per rail when Wheelslide activity is experienced at all speeds up to 60% brake demand OR when the driver depresses the manual sanding button;
- 3kg/min per rail when Emergency braking is selected;

All the above configurations are based upon the requirements of the UK Railway Group Standard GM/RT 2461 'Sanding Equipment Fitted to Multiple Units and On-Track Machines'. These configurations offer significant benefits compared with standard fixed rate sanders that do not automatically output sand at all brake rates.

The benefits include;

- Sand consumption is generally reduced by the early treatment of poor conditions with low sand outputs.
- Higher sand rates are available when maximum brake rates are required.

## TASK 2 INSTALLATION DESIGN

### 7.1 SAND DELIVERY SYSTEM

As mentioned above, it was decided to re-use the existing sand hoppers and sand hoses. Due to different mounting arrangements, an adapter bracket (see Figure 8) was designed to allow the fitment of the SmartSander sand valve to the existing hopper. The sand hoses will then be attached to these sand valves. The sand hoses lead down to deliver sand immediately before the leading axle of the car.

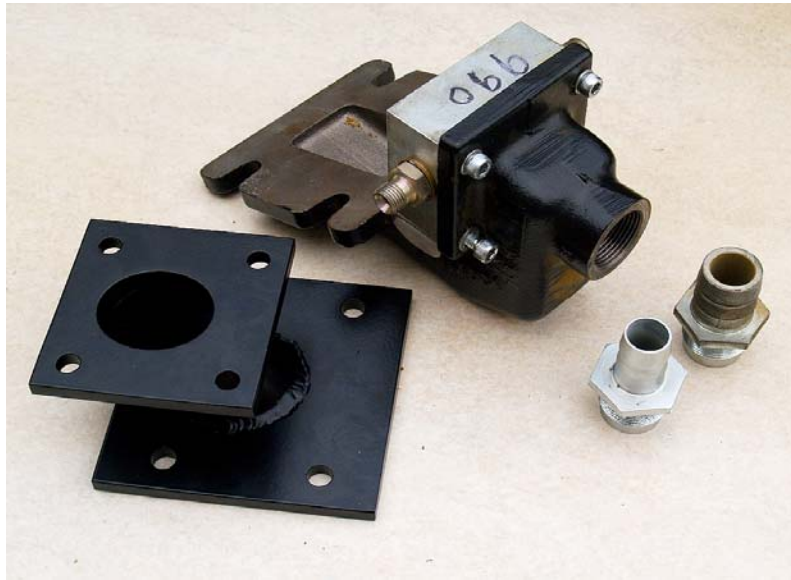


Fig 12 - Sand valve with adapter and hose nozzles

## 7.2 BRAKE CONTROL

The type of brake controller fitted on the Shoreliner had not previously been encountered on trains fitted with SmartSander in the UK. Therefore an interface unit was designed that converted brake pipe pressure into electrical signals in a form suitable for the SmartSander control unit. This interface unit was connected to the brake pipe on the Shoreliner Cab Car.



Fig 13 SmartSander Brake Pipe Interface Unit which converts brake pressure to a 3-wire 'westcode' brake interface typical of UK braking systems



Fig 14 Brake pipe on Shoreliner Cab Car. This interface is fed into the event recorder so SmartSander could be connected here.

### 7.3 AIR SUPPLY

The train air supply was found to be sufficient for the needs of SmartSander, that being 7 bar (100psi). The design of SmartSander minimizes the length of time the sander is actuated for, and as such, minimizes the air consumption. Experiments in the UK have shown that the reduction of WSP blowdown caused by SmartSander more than compensates for the air used in ejecting the sand. Therefore, the air consumption of the sander was not considered to impact on the air capacity of the train.

### 7.4 DECELERATION RATES

The deceleration rates required by Metro North were consistent with those in the UK so minimal changes in the control system were needed.

UK brake Step	UK Decel Rate	US Decel Rate	Brake Press <sup>1</sup> (psi)	Brake Cyl Press	Notes
EMG	12%g	3 mph/s	< 85	45-50	Emergency
3	9%g	2 mph/s	85-95	45-50	Full service
2	6%g	1.3 mph/s	95-100	30	2/3 brake
1	3%g	0.7 mph/s	100- 108	15	1/3 Brake
0	0%	0%	>110	0	Release

DeltaRail worked during the project with Metro-North and others to determine typical sand rates and how those compare with optimal rates. The 74V DC trainlines and other controls were hardwired between the SmartSander controller unit and the EP valve unit.

### 7.5 DESIGN PARAMETERS

When designing the installation of each SmartSander component, the following issues had to be considered;

- The appropriate point in the train's systems to connect to (e.g. connection to brake pipe at entry to data recorder)
- The physical restrictions of the connection point (e.g. space available, presence or lack of suitable mounting brackets)
- The limitations of the space envelope available (e.g. clearance from the electrical 3rd rail (see Appendix 1) and clearance from line-side structures)

Overall, these restrictions had to be balanced with the requirement to position components for optimal performance of the SmartSander (for example, ensuring that hose runs to each side of the vehicle were the same length as each other)

### 7.6 OTHER TRAIN INTERFACES

The SmartSander system requires a number of interfaces to various electrical and pneumatic systems on the train. These include:

- Manual sanding signal (driver's button)
- Cab Makeup Relay (determines that this cab is active)
- Power supply

Additionally, Metro-North was able to provide extra inputs to the Shoreliner event recorder so that the operation of the SmartSander could be monitored in service.

- SmartSander 'operational' (voltage free contact)
- F and B end dump valves fro Decelostat WSP system.

<sup>1</sup> These values measured from cab-car 6306 based upon cab gage and Metro-North expert engineer operation of brakes.

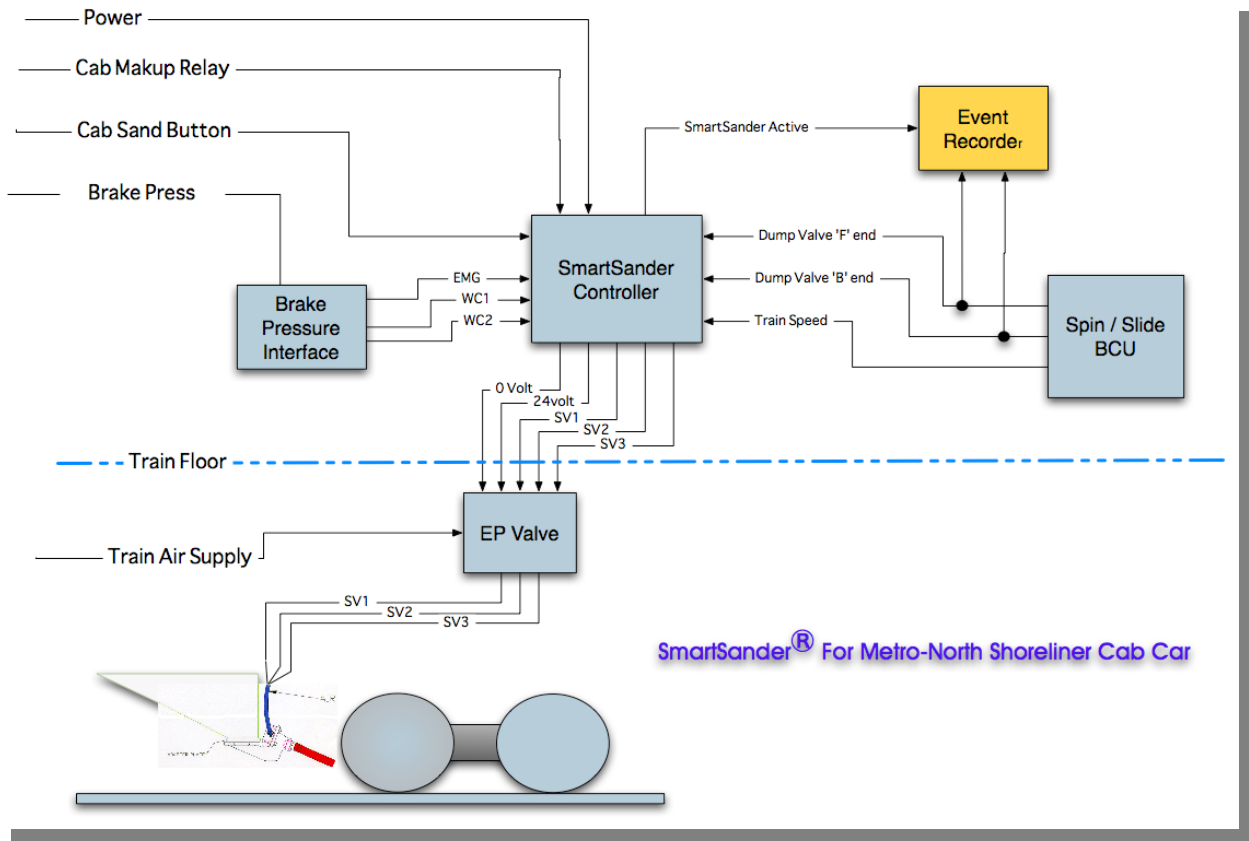


Fig 15 Sander Schematic

## 7.7 FUNCTIONAL SPECIFICATION - PRELIMINARY

The sander was designed to operate continuously whenever slip is detected. Slip is defined when the Wheel Slip Light is active (Train line 10 on sheet B01 of P-521-0037). Sanding will cease 1.5 seconds after the Wheel Slip Light goes out. The sand rate (provisional at this stage) is variable with respect to brake demand and train speed and suggested rates are as shown in the table below.

In all functions, the sander continues to operate for a further 1.5 seconds after the end of the WSP activation. All the above configurations are within the requirements of the UK Railway Group Standard GM/RT 2461 'Sanding Equipment Fitted to Multiple Units and On-Track Machines', but offer significant benefits compared with a standard fixed rate sander which will only output sand at the higher brake rates.

Nominal Brake Step and Pressure	Cab Occupied	Cab Sanding Button	WSP Activity	Traction	Speed > 10mile/h	Sand Rate Kg /min
0 ** >110 psi	Yes	Yes	Yes	Yes	~	2.0 2.0
1 100 – 108 psi	Yes	~	Yes	No	No Yes	0.5 1.0
2 95 - 100 psi	Yes	~	Yes	No	No Yes	1.0 2.0
3 85 - 95 psi	Yes	~	Yes	No	No Yes	2.0 3.0
EMG <85 psi	Yes	~	Yes	~	No Yes	2.5 3.0
EMG **	Yes	Yes	~	~	No Yes	2.5 3.0

**\*\* Note** - Manual control using cab button

## EQUIPMENT SUPPLY

DeltaRail provided a complete installation kit for the Metro-North Railroad Shoreliner cab car 6305 based upon the findings of the Stage 1 investigation.

The pilot design was installed on the sample vehicle, by Metro-North Railroad staff with due note being taken of any changes required to the design or installation procedure. The principle investigator was resident for this phase, to ensure the installation was fitted according to agreed specification.

Following a successful trial with Metro-North Railroad, the results are included in this final report for the project and the results will be reported in papers presented to the Commuter Rail Industry by the Principal Investigator. A generic design will be created for use on other commuter railroads.

### 8.1 INSTALLATION PICTURES

The following series of pictures shows how the SmartSander prototype was installed on the cab car at Croton-Harmon.

Fig 16

Cab Car 6305 ready for swapping existing sanding equipment for modified SmartSander parts.



Fig 18

Modified Dump valve interface. Metro-North brake specialists designed an interface for connecting to the dump-valve signals.

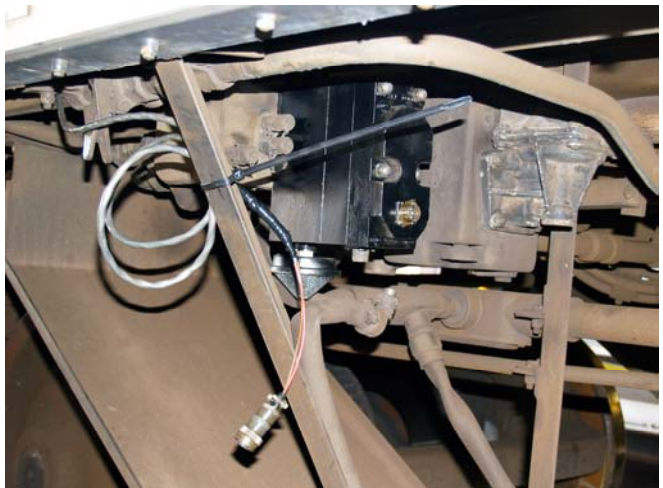


Fig 17

Wiring had to be routed through the vehicle flow from EP box and Dump valves. Fortunately this junction box allowed easy routing of the cables through existing glands.



Fig 19

Location for controller is in equipment locker behind engineer's desk. Lights on SmartSander controller provide easy visualization of sander functions.



Fig 20

Sand Valve attached to existing sand hopper and connected to EP box via additional pipework and existing sand delivery hoses.



## TESTING AND ANALYSIS

### 9.1 OBSERVED TESTING

A special test was organised by Metro-North on the Wassaic branch on Metro North on 4<sup>th</sup> November early in the morning. There were areas of leaf contamination but the morning was cold and there was frost on the rails. Event Recorder Data was downloaded and analysed.

In the UK Sanders are applied to the third axle only for several reasons: -

- Avoidance of hysteresis
- Provision of unsanded axle for track circuit shunting
- UK trains have other equipment located at the front axle

The test involved the use of ‘full service’ brake on known slippery sections of the track. In view of the considerations above it was satisfying to note that the use of both WSP dump valves combined with a 1.5 second minimum sanding period had avoided the perceived problem of hysteresis.

While each dump valve operated in turn during the stop, the sander maintained sand output, resulting in a smooth, jerk-free stop. Figure 23 and Figure 24 are results from the Wassaic branch test.

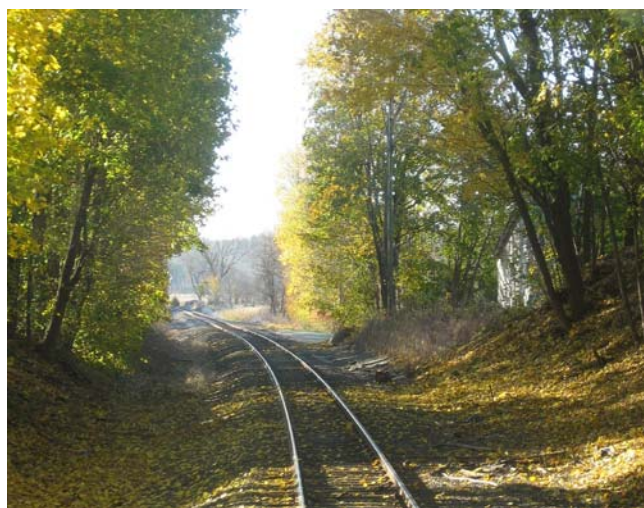
Fig 21

Cab car 6305 operating on the Wassaic branch of Metro-North.



Fig 22

The Wassaic branch is a lesser-used line and passes through areas of tree-lined countryside.



## 9.2 EVENT RECORDER RESULTS

It was decided that the existing Event Recorder fitted to 6305 should be used to monitor sanding activity and performance. In all of the traces below additional signals are shown as: -

- Spare 2 – Front Dump Valve
- Spare 1 – Rear Dump Valve
- Throttle DB – Sander Activity

Figure 23

Stop under test conditions on the Wassaic branch with full service brake (Cylinder press  $\geq 45$ psi).

Note the dump valve activity (spare 2 and spare 1) which is discontinuous but the continuous sander output and smooth deceleration once sand has been applied in quantity.

Deceleration rate is an average 1.8 mph per second over the entire deceleration but improves to 2.0 mph per second over the period that the sander was fully operational.

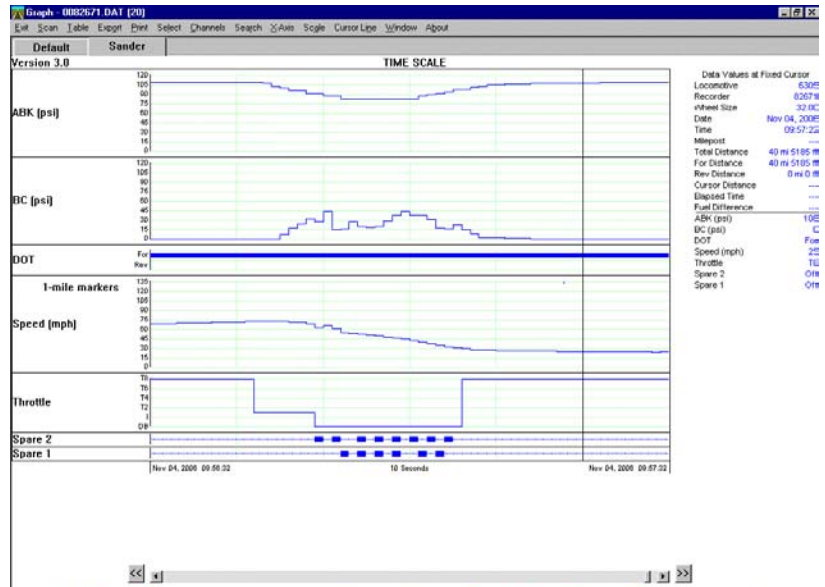


Figure 24

Lower requested deceleration but still with major wheelslide. Brake pipe 90psi

Deceleration 1.5 mph per second

Brake cyl press 15 – 25 psi

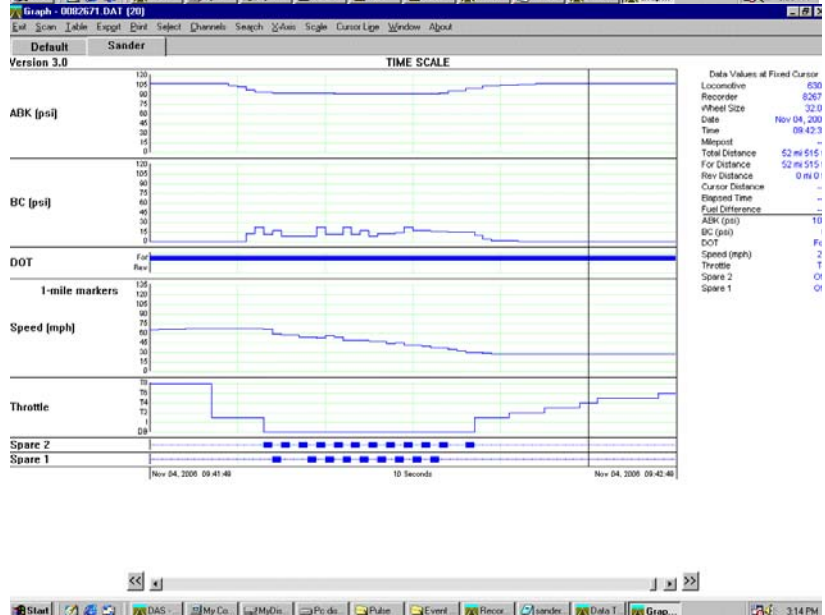


Fig 25

Duty cycle showing two hard stops (last two on this screen) following a series of more gentle stops. Wheel slide occurs.

Brake cylinder pressure is higher as shown in these traces.

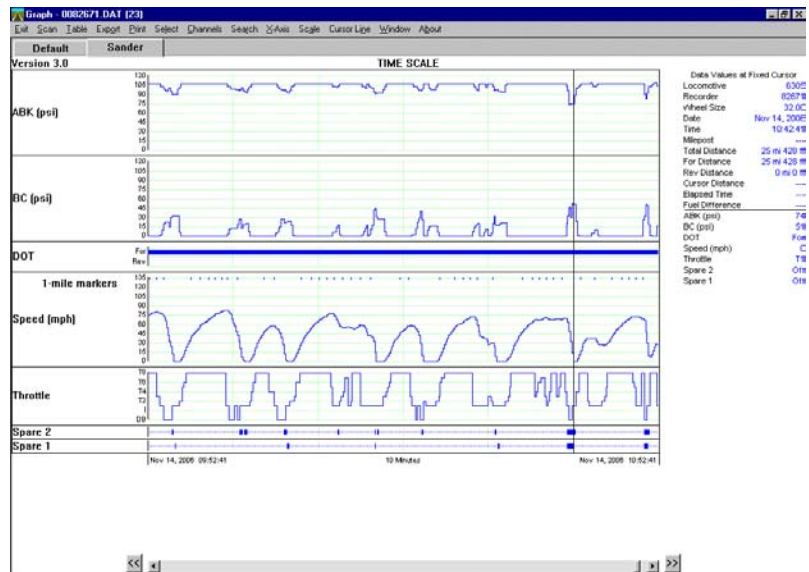


Fig 26

Hard deceleration with sander active. Note amount of dump valve activity. The sander stays on almost continuously.

Deceleration rate achieved is approximately 1.9 mph per second.

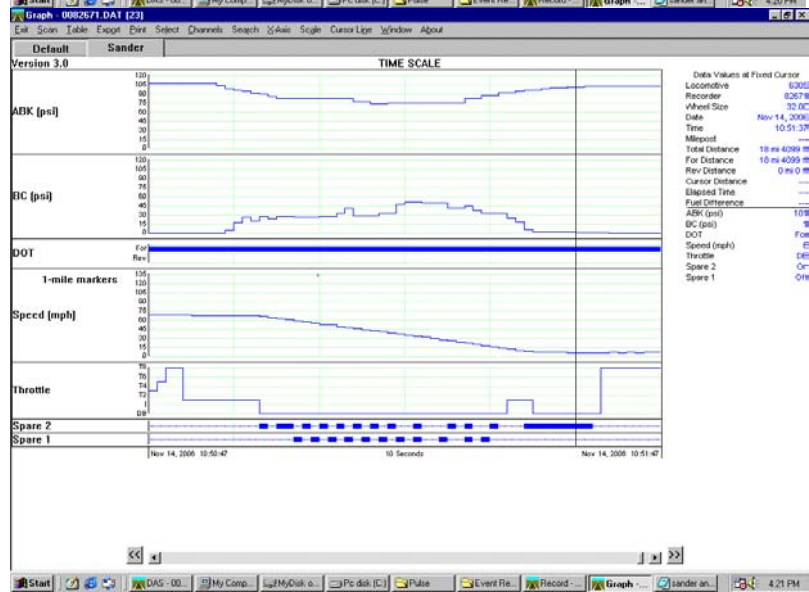


Fig 27 - Two areas of spurious sanding activity were determined with 6305. One was due to a badly set up speed probe which gave a high-speed output as the train was decelerating to a stand. The second one was triggered as the WSP unit performed a self-test at zero speed.

Both of these caused the sander to operate briefly and deposit sand. These incidents were eliminated by incorporating a low-speed cut-off into the sander logic to inhibit sanding at low speed (less than 3mph)

Both causes are shown on the plot to the right as activity on the 'Spare 2' (Front Dump valve) event recorder line accompanied by activity on the Throttle DB setting (sander)



## SYSTEM OPTIMIZATION

### 10.1 SAND VALVE

Although consideration was given to the differences between UK and US practice during design, it became apparent both during installation and testing that some modifications were needed. The sand valves as delivered did not have a suitable hose adapter for the larger size hose used on this particular cab car. Modified hose adapters were fabricated on site by the machine shop at Croton Harmon.



- Fig 28 (Top Left) Two variants of SmartSander hose nozzle
- Fig 29 (Top Right) SmartSander valve as delivered
- Fig 30 (Bottom Right) SmartSander Valve with modified nozzle

Some modifications were made to the wiring and to the coding for the brake pressure interface. The first attempt at translating brake pressures into UK-style brake steps did not work well at the first attempt and the lookup table was rectified by careful measurements of brake pressure and inputs to the SmartSander on the actual cab car. These new values provide a better mapping between the air brake pressures and typical UK westcode steps.

10.2 WIRING SCHEMATIC

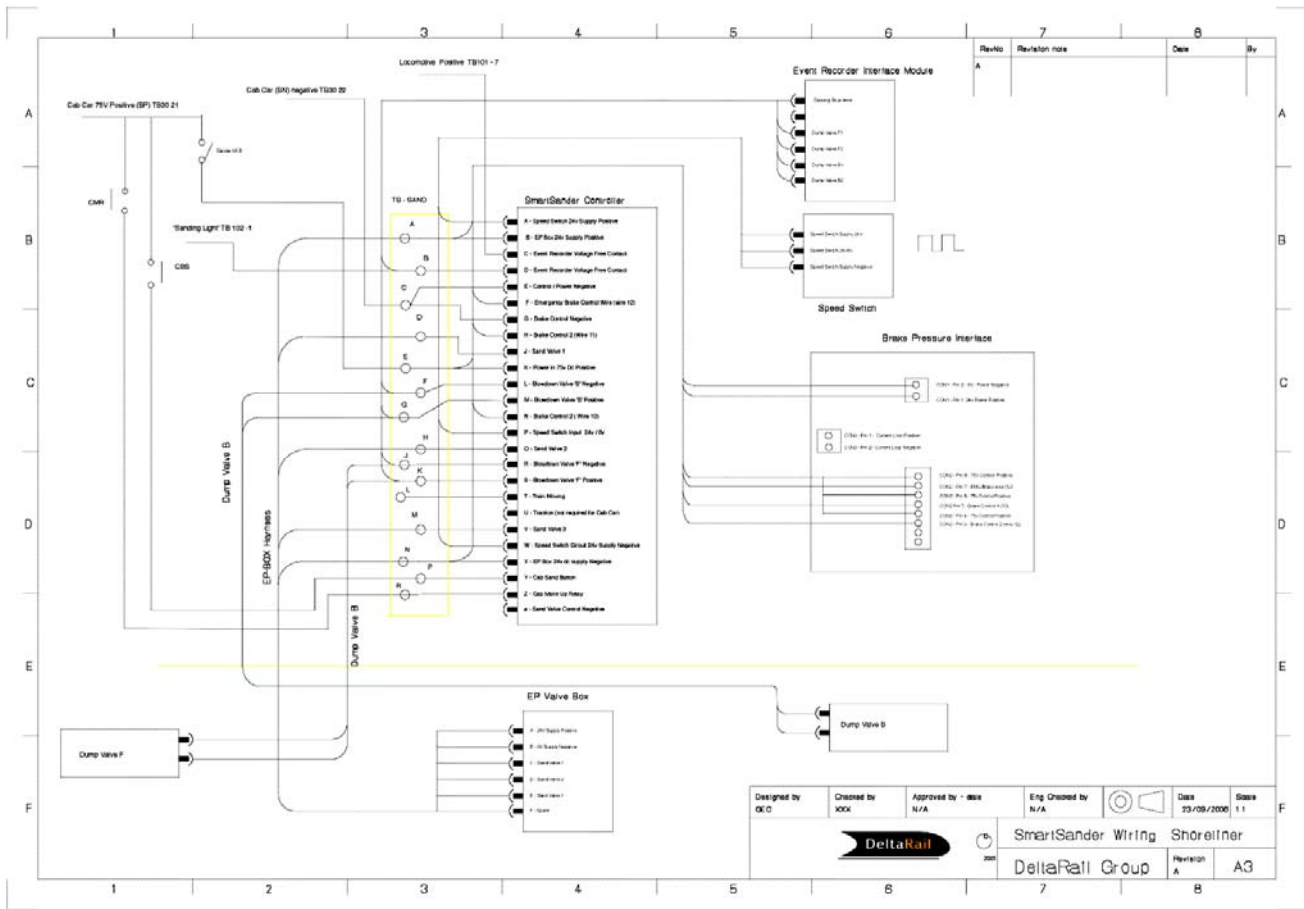


Fig 31 Final wiring schematic for SmartSander installation

10.3 REVISED LOGIC SPECIFICATION

In addition to the changes to the brake pressure translation (column 1 below) the ‘no-motion’ relay was added to the SmartSander logic to inhibit sanding below 3mph. The SmartSander traction input was disabled for this vehicle because it had no traction system.

Nominal Brake Step and Pressure	Cab Occupied	Cab Sanding Button	WSP Activity	Speed > 3 mph	Speed > 10 mph	Sand Rate Kg/min
1 ** >110 psi	Yes	Yes	Yes	Yes	~	2.0 2.0
1 100 – 108 psi	Yes	~	Yes	Yes	No Yes	0.5 1.0
2 95 - 100 psi	Yes	~	Yes	Yes	No Yes	1.0 2.0
3 85 - 95 psi	Yes	~	Yes	Yes	No Yes	2.0 3.0
EMG <85 psi	Yes	~	Yes	Yes	No Yes	2.5 3.0
EMG **	Yes	Yes	~	Yes	No Yes	2.5 3.0

\*\* Note - Manual control using cab button

## **SUGGESTIONS FROM REVIEW PANEL**

A review panel was set up in December 2006 to discuss the trial and suggest improvements. However, during this project, review panel members have freely offered suggestions and advice.

### **11.1 DISABLE SAND OUTPUT AT LOW VEHICLE SPEEDS.**

The Shoreliner Cab Car performs regular tests of its electronic systems resulting in the energizing of WSP dump valves at zero speed. Because the SmartSander is an automatic system based upon wheel slip indication sand is deposited automatically during these tests. Additionally, brake tests performed at start of day by engineers put the brake system into 'penalty' mode which also requires that sand be deposited (in both regular and SmartSander mode). An addition to the SmartSander logic inhibits sanding at less than 3 mph (No motion relay). Both causes of 'nuisance sanding' are therefore eliminated.

### **11.2 MAKE CAB BUTTON INDEPENDENT OF SMARTSANDER ELECTRONICS.**

In converting the sander on cab car 6305 to an automatic system the cab sand button effectively became 'fly by wire' i.e. it was not connected directly to the sand valve as in the previous system. There are, as usual, benefits and disbenefits of this approach. The intended benefit is that the cab button effect can be made more intelligent by combining the engineers intentions with measurements of train speed and slip level to produce an optimized output. The disbenefit is failure of the cab sand button if the sander fails or is disconnected at the circuit breaker. A simple relay circuit will be designed to overcome this.

### **11.3 MAKE SMARTSANDER INDEPENDENT OF WSP INPUTS.**

The original SmartSander Patent was created for a system much less dependent upon the train WSP system for its determination of adhesion level. Experiments have been carried out looking at the possibility of determining whether a train is sliding by comparing the demanded brake rate with actual deceleration. In the real world this is complicated by the fact that railroad gradients produce similar results on typical sensors, as do the regular deceleration rates. A 1 in 50 grade is the equivalent of 2%g deceleration. Filtering techniques aimed at producing a gradient-independent deceleration measure are being investigated for future developments of SmartSander.

## **PLANS FOR IMPLEMENTATION**

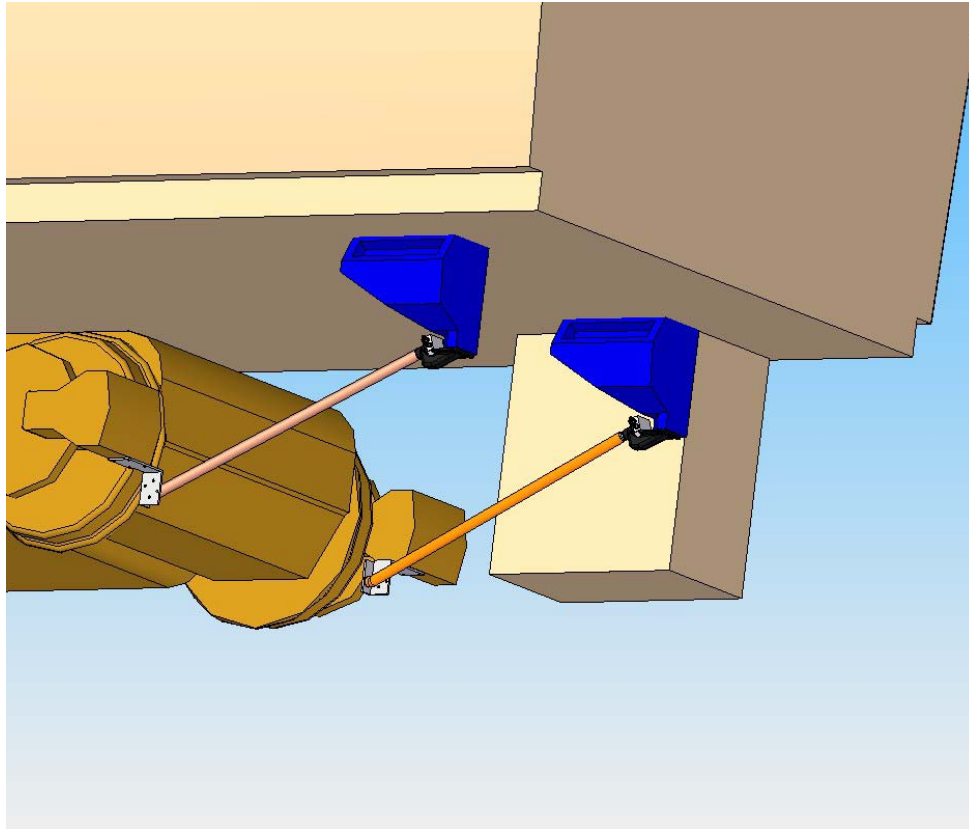
The demonstration of SmartSander with Metro-North has generated interest within this and other companies in the direct management of low-adhesion using on-train sanding. In fall 2007 there were to be further trials with SmartSander on LIRR M-7 cars. Further validation of the SmartSander concept in the United States will occur as railroads become attuned to the benefits which can be had. Two other authorities have shown an interest in either fitting or trialling SmartSander on their fleets and Metro-North Railroad has written the specification for their new M-8 fleet with sanding systems in mind. The benefits delivered from seven year's operation in the UK appear to hold true in the USA despite the limited nature of the trial.

The cost-benefit of SmartSander has been proved in the UK where the separation of track from trains into different operating companies has focussed commercial minds on the attribution of delay costs. The avoidance of these delays and the spin-off wheel maintenance reduction has produced a strong benefit in commuter and transit situations.

In the USA the integration of the railroads makes the delay benefits less of an obvious issue, but the downside of delays leading to customer satisfaction is very real everywhere.

## 12.1 SEPTA

The specification for SEPTA's new Silverliner V procurement requires that sanding systems should be fitted to both the single car and married pair variants of the new vehicles. The SmartSander could easily be fitted to these trains in order to improve their low-adhesion performance and wheel life.



### 12.1.1 Excerpt from SEPTA's specification for Silverliner V cars

*Present Silverliner-type electric multiple unit cars have historically operated without the use of sanders for increase of available adhesion. Operating conditions seasonally arise, however, on the SEPTA Railroad Division which reduce the available rail adhesion to unusually low levels, such as dew, frost, and leaf oil accumulation during the Autumn season. Presently SEPTA uses off-vehicle means to mitigate low adhesion conditions.*

*The Contractor shall undertake an analysis during the initial Concept Design Phase of the suitability of the application of sanding apparatus to the "F" end of all cars and the "A" end of single cars. Sanders need not be applied to the "A" end of the married pair. It is envisioned that this apparatus would be adjusted to only provide a minimal rate of sand application, be directional and zero speed interlocked, and have manual control only at standstill to verify functionality. Either truck frame mounted or carbody mounted sand storage reservoirs may be used. In particular, this analysis shall address safety aspects of signal shunting and carbody voltage return degradation effects, and any conflicts with Federal Railroad Administration requirements. This analysis shall be completed 120 days following the Notice to Proceed. If testing concludes that the use of sanders is not warranted, SEPTA will issue a Change Order to deduct their application from the cars.*

## 12.2 LONG ISLAND RAILROAD

Long-Island Railroad is Metro-North's sister company within the Metropolitan Transportation Authority (MTA) and operate many married-pair EMU's with braking control supplied by the traction system manufacturer rather than a standalone Wheel Slide Protection unit. This set up is similar to that operated by Metro-North but with a greater deceleration rate required by the signalling system. Discussions have been held with Long Island Railroad and Bombardier with a view to fitting SmartSander to the leading vehicle of each married pair.

Space is at a premium on these vehicles so that the equipment must reside on only one corner of the vehicle but must lay sand under both wheels of the leading wheelset. A design is currently being prepared for a trial installation for fall 2007 using SmartSander.

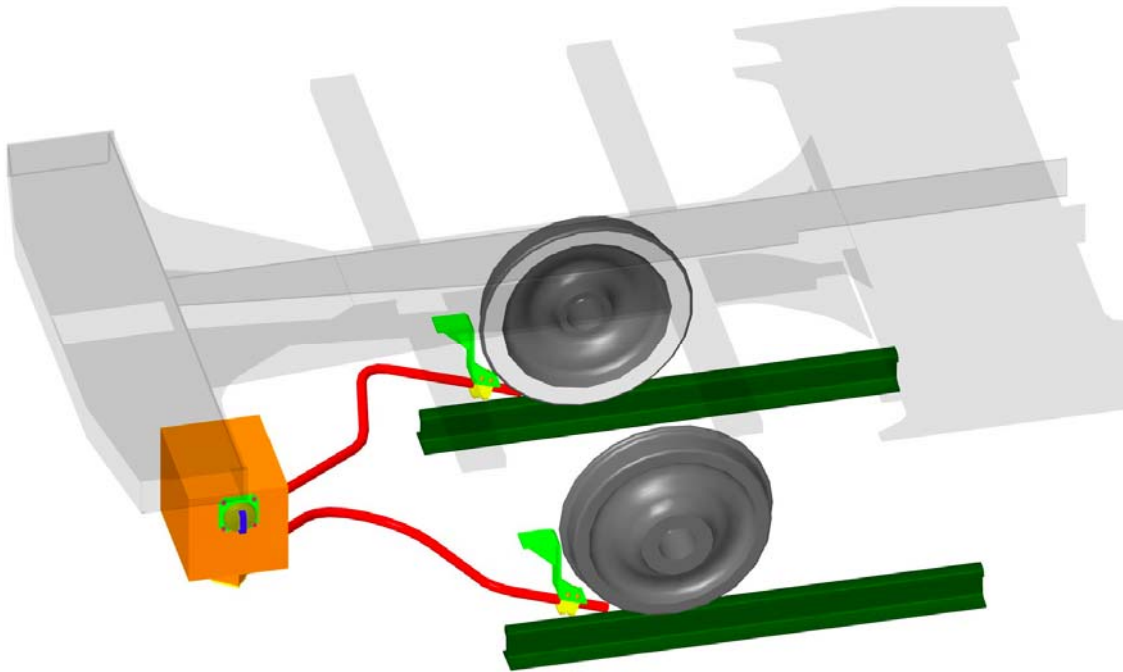


Fig 33 Suggested design for LIRR M-7

## 12.3 METRO-NORTH M8 FLEET

Metro-North Railroad has issued a specification for adhesion management on the new M8 fleet to be built by Kawasaki Railcar for the New Haven line. Metro-North is keen to avoid the wheel damage problems incurred with recent train builds. The cars will be married pair dual-voltage EMUs

## 12.4 SOUND TRANSIT

Sound Transit operates in the Seattle area and has concerns about low adhesion issues affecting their new transit fleet. Discussions are at a very early state, but SmartSander may be one of the solutions required to operate an efficient railroad.

## CONCLUSIONS

- The SmartSander trial with Metro-North progressed without any technical or operational difficulties. The adhesion improving properties of sand were successfully demonstrated in a commuter rail operation in the US, but the perceived downsides of sand affecting track circuit shunting and the additional maintenance required of the sanding system are a potential obstacle.
- Leading axle sanding appears to be feasible in an automatic context but careful design is required to eliminate the system behaving in an unstable way.
- DeltaRail plans to continue the dialog with interested parties on SmartSander implementation.
- The mechanical design and interfacing to US commuter rail vehicles show more similarities than differences compared with European trains.
- In a US context, without commercial delay attribution, the major benefits from SmartSander come from reduction in wheel truing and the consequent downtime improvements arising from reduced maintenance, from reduction in costs, and improved safety.
- In terms of deceleration performance, the observed tests and event recorder data from service operation show that SmartSander can allow engineers to brake confidently during periods of low-adhesion and achieve deceleration rates up to 2 mph/s
- Because sand rate is related to the level of braking demanded some education may be necessary to give engineers the confidence to use higher brakes rates in poor conditions.
- Intelligent sanding systems can actually restore adhesion during low adhesion thereby complementing wheel slide protection systems which can only make the best use of existing adhesion conditions.
- If required, the output rate of the sander can be increased without jeopardizing track circuit shunting for further improvements in deceleration rate.

## GLOSSARY

- |                  |   |
|------------------|---|
| • WSP(s)         | Wheel slide Protection (system)   |
| • Dump valve     | Air operated valve to reduce pressure in brake cylinder to control slip |
| • Event Recorder | Data recorder for recording safety functions of train (aka Black Box)   |
| • Westcode       | Brake interface using three wires                                       |
| • SPAD           | Signal passed at danger   |
| • EMU            | Electric Multiple Unit  |

## INVESTIGATOR PROFILE

### 15.1 PRINCIPLE INVESTIGATOR

**Graham Curtis B.Tech C.Eng FIMechE** has worked in UK railroad research and development for 27 years. For the last ten years he has managed a team developing innovative monitoring and control products for the UK industry. He has recently been engaged in the development of a Railroad Product R&D centre at Glengarnock in Ayrshire, Scotland.

Graham is a joint patent holder for the SmartSander concept and has recently spent time in the United States looking into transferring UK railroad technology and products to North America.



### 15.2 CONTACT DETAILS

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# Appendix 1

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## CONTENTS

3rd Rail Clearance Diagram

