

Traction Control and Validation Test



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16. Abstract <p>This report provides a review of automatic traction control systems (ATC) used on heavy commercial vehicles and shows how they are integrated with antilock brake systems and electronic engine controls in such a way as to prevent loss of stability and control caused by excessive drive-axle wheel slip. It discusses the development of a vehicle test procedure for evaluating ATC performance and describes full-scale vehicle testing that was performed on low friction road surfaces to evaluate the test procedure. Research described in this report was performed in response to recommendations made to the National Highway Traffic Safety Administration (NHTSA) by the National Transportation Safety Board (NTSB) in their accident investigation report number PB98-916203.</p>			
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TRACTION CONTROL AND VALIDATION TEST

1.0 INTRODUCTION

In July 1998, the National Transportation Safety Board (NTSB) published a report entitled "Multiple Vehicle Crossover Accident, Slinger Wisconsin February 12, 1997 " (report number PB98-916203 NTSB HAR-98/01) which detailed the results of an accident investigation it had conducted.

This accident occurred on a roadway with patches of ice and involved a tractor-double trailer combination ("doubles") losing control, crossing the median and striking a flatbed tractor trailer traveling in the opposite direction. The flatbed tractor-trailer then crossed the median and struck a van traveling in the opposite direction. In the report the NTSB concluded, among other things, that:

- The initial loss of stability was the result of wheel spin-up on the doubles combination's single drive axle.
- At the speed and under the conditions in which the accident took place, antilock brake and traction control technology would have given the doubles truck driver more time to respond to the loss of stability.

In effect, NTSB felt that if the doubles vehicle had been equipped with a traction control system, the accident might not have occurred.

At the end of their report, NTSB made a number of recommendations to various organizations in government and industry. One of the recommendations to the National Highway Traffic Safety Administration (NHTSA) was to "Work together with the Federal Highway Administration, the American Trucking Associations, the International Brotherhood of Teamsters and the Motor Freight Carrier Association to conduct laboratory and truck fleet testing to assess the safety benefits of adding traction control devices to antilock brake systems (ABS) and report your findings to the National Transportation Safety Board (H-98-15)" [recommendation number].

The report that follows describes the project that was initiated by the NHTSA to address the NTSB recommendation relative to traction control systems and testing.

2.0 OBJECTIVE AND SPECIFIC TASKS

To address NTSB recommendation H-98-15, NHTSA established a project to develop written, standardized, and repeatable test and data collection procedures that could be used by industry to evaluate heavy vehicle traction control system performance at highway speeds. This work was performed by Radlinski & Associates, Inc. (RAI). The specific tasks NHTSA specified for this project were as follows:

1. Write test and data collection procedure for traction control devices at speeds above 40 mph on surfaces of low coefficient of friction such as ice or melting snow and ice.
2. Validate the test and data collection procedure for traction control devices at speeds above 40 mph on surfaces of low coefficient of friction, using one or two devices presently manufactured in the US.
3. Conduct a briefing for NTSB, NHTSA and Federal Motor Carrier Safety Administration (FMCSA) personnel at the Department of Transportation headquarters in Washington, DC.
4. Prepare a final report containing the test and evaluation plan and the data developed in evaluating the plan.

3.0 TRACTION CONTROL SYSTEMS

Automatic traction control (ATC) systems (also called ASR for automatic slip regulation) are currently available as regular production options on most heavy commercial vehicles (power units). These systems are integrated with ABS which is now mandatory for all air-braked vehicles and vehicles with hydraulic brakes having a GVWR in excess of 10,000 lbs. These systems utilize components of the ABS as well as additional components specific to the ATC.

The ABS wheel speed sensors are used to determine drive axle(s) slip by comparing the speed of the drive axle(s) wheels to the speed of the wheels on the steering axle. When the speed of the drive axle(s) exceeds that of the steering wheels by some predetermined amount, the traction control software in the ABS electronic control unit (ECU) can command either of two different events: 1) a reduction of engine speed (RPM) and 2) application of the drive axle brakes on one side of the drive axle(s).

Engine speed reduction is accomplished by the ABS ECU sending a signal to the engine ECU over the electronic data link between the two ECUs. This data link is provided if the traction control option is ordered or in some cases if the vehicle has an engine retarder. The communication protocol can either follow SAE J1922 or J1939. While all current ABS ECUs can support either protocol, J1939 is becoming more common and is considered to be the system of the future since it allows faster communication

Due to the fact that ATC is highly integrated with the engine, ABS and pneumatic systems, retrofitting ATC to older vehicles is generally not practical.

Automatic application of the drive axle brakes occurs only if the speed difference between the left and right wheels exceeds a predetermined level. In that case the brakes on the faster wheel are applied until speed is reduced to match the other wheel. Brake application is made via a special traction control valve that is installed in the rear-axle relay valve control port. During normal service braking, this valve passes air from the foot control valve directly to the relay valve, but in the case of a traction control event this valve, which is also connected to the drive-axle brake system air reservoir, applies

full reservoir pressure to the rear-axle relay valve control port. The delivery air from the relay valve is then directed to the appropriate brake by controlling the ABS valves. The ABS valve on the rear brake that needs pressure is left open and the valve on the opposite side is closed. The ASBS valve also modulates (controls) the pressure level at the brake to control wheel slip. The ABS ECU performs this control function via its traction control algorithm in the ABS ECU.

Brake application during traction control only occurs at speeds below 25 to 30 mph. Above that speed the brake control function in the ATC algorithm is turned off since there is the possibility of loss of control of the vehicle due to only one brake suddenly automatically applying when the vehicle is on a very slippery surface. Brake overheating during a prolonged traction control event is also a possibility at the higher speeds.

Figure 1 is a basic ATC functional schematic:

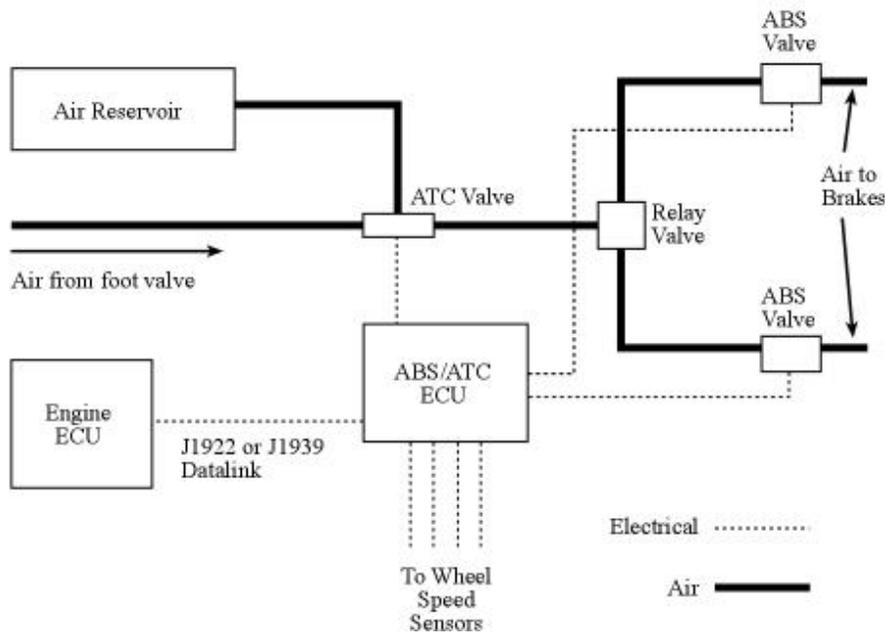


Figure 1 Automatic Traction Control System Schematic

ATC serves two primary operational functions:

1. Improves mobility on low friction surfaces allowing the vehicle to start from a stop when the vehicle is on a grade.
2. Prevents skidding while driving at highway speeds caused by over-speeding and spinning the drive wheels.

To improve mobility (Item 1), both the engine speed reduction and brake apply functions are utilized. Skidding and loss of stability at higher speeds (Item 2) is controlled via engine speed reduction only since brake application at higher speeds could result in brake overheating. The report which follows deals only with the engine speed reduction function of ATC.

4.0 TEST PROCEDURE DEVELOPMENT

In developing a test procedure that would evaluate the ability of an automatic traction control system to control skidding the following parameters were considered:

- Test surface friction
- Type of maneuver
- Speed
- Throttle activation
- Test vehicle loading and configuration
- Road grade

To evaluate each of these parameters, developmental tests were run using a short wheel-base, single-drive axle tractor (Figure 2), both with and without a trailer connected, on test surfaces at the Transportation Research Center (TRC) in East Liberty, Ohio. The following is a detailed discussion of each of the parameters with conclusions based on the testing that was performed.



Figure 2 Vehicle used for test procedure developmental testing

Test Surface Friction – Since skidding is most likely to occur on slippery surfaces, only low friction surfaces were considered for this procedure. Ice or snow are the most common low friction surfaces encountered by drivers on the road, but their availability for testing is limited and the actual friction level varies considerably with ambient temperature and other weather and grooming factors. While it is used by ABS/ATC suppliers for “Winter” testing and was used in this program for validating the test procedure and two different traction control systems, it was not considered as the most desirable test surface.

Another surface evaluated was Jennite, a brand of driveway sealer commonly used in the U.S. for ABS testing. When this surface is wet, the peak coefficient of friction (PFC) is usually in the 0.30 to 0.40 range when measured using the American Society for Testing and Materials (ASTM) standard E-1337 pavement friction measurement procedure specified in Federal Motor Vehicle Safety Standard (FMVSS) No. 105 and FMVSS No. 121. Unfortunately, this surface was found to not be slippery enough. Test vehicles could not “break” traction on this surface, even when empty.

The surface that appeared to offer the best features was a wetted, epoxy coated surface. The PFC of this surface was in the 0.20 to 0.30 range, making it closer to ice (which varies from less than 0.10 to about 0.20 PFC). Vehicles could break traction on this surface, bringing the traction control system into operation. A number of proving grounds have this surface or one with an equivalent friction level available for year-round testing.

Maneuvers – One of the maneuvers considered and evaluated was a straight line run where the vehicle transitioned from a relatively high friction surface (dry asphalt) to a low friction surface (wet epoxy) while under a pulling load at a constant throttle position. The pulling load was simulated by lightly applying the trailer brakes (to about 10 psi). Without ATC the vehicle would begin to lose control once the drive axles entered the low friction area and began to slip. With ATC functioning, handling was improved.

Driving around a low friction (wet epoxy) curve and suddenly increasing engine power was also evaluated as an ATC test maneuver. The curve used had a 500-foot radius, which represents a “tight” exit ramp. It is also the radius specified in FMVSS 121 for the Stability and Control test. While driving around the curve without ATC operational, the rapid application of engine power caused an immediate yawing and loss of control. With ATC operational, control was improved. The curve was more demanding because it placed a side force on the vehicle, accelerating the loss of control.

Speeds – The statement of work for this project stated that the test procedure should be developed for speeds over 40 mph. Initial testing indicated that speeds over 40 mph are hazardous from a testing safety standpoint, requiring very large low friction test areas and are not really necessary in order to evaluate the performance of ATC. If the vehicle slides off of the low friction test area, it could “trip” and rollover when it reaches the higher friction surface. Since ATC changes operating modes from brake-apply and engine-control to engine-control-only at about 25 to 30 mph, testing at 30 mph is

sufficient to evaluate the ability of the ATC to control skidding at higher speeds. In fact, if the ATC valve used to control the brakes is disabled, even lower speeds could be used.

Traveling around a 500 ft radius curve on a wet, epoxy-coated surface at speeds above about 20 mph was not possible due to the fact that there was not enough lateral traction available to keep the vehicle under control. Use of a larger radius curve would be required if an epoxy or lower friction surface such as ice is utilized.

Throttle Activation – In the discussion of Maneuvers above it was mentioned that a rapid throttle application in a slippery curve produced a condition that could be used to evaluate ATC performance. While it could be argued that this would be an unrealistic action by a driver in “normal” operations, it is a very repeatable control input that suddenly increases wheel slip initiating the ATC operation. Because of its simplicity and repeatability, it is the recommended approach for an ATC test procedure.

Vehicle Loading and Configuration – An empty vehicle loses traction most easily and is the recommended test vehicle loading condition. In addition, there is no particular reason to perform the test with a trailer attached (unless it is to simulate a pulling load). Testing with a bobtail tractor is the least complex, safest and most demanding condition for ATC. Use of a vehicle with a single drive-axle and a relatively short wheelbase also places the greatest demand on the ATC and is recommended.

Road Grade – While going up a hill with a vehicle is more likely to result in a wheel slip due to the increase in driving force required, a test on a flat track with a sudden throttle increase can produce the same result. As was discussed above, use of a trailer with its brakes applied can also be utilized to simulate a grade.

5.0 INSTRUMENTATION

In order to determine how ATC responds to different conditions during testing, the following basic measurements should be made:

- Speed of at least one front wheel - this gives a good indication of vehicle speed.
- Speed of each driven wheel – indicates whether the drive wheels are slipping
- Vehicle yaw rate – indicates how the vehicle is responding and the workload imposed on the driver
- Vehicle position with respect to lane boundaries – indicates if the vehicle is able to maintain the intended path. Does the vehicle stay within the lane boundaries is a simple but effective measure.

Other measurements such as lateral acceleration of the vehicle, steering wheel angle, indication of when an engine RPM reduction command is sent by the ATC and the corresponding engine RPM are also desirable measurements from the standpoint of understanding how the ATC is functioning but they are not absolutely necessary to determining the extent to which ATC can help improve vehicle control.

6.0 ATC TEST PROCEDURE RECOMMENDED

Based on the preliminary testing that was conducted, the following test conditions, instrumentation and maneuvers are recommended for evaluating the performance of ATC at highway speeds:

Test Surface – Utilize a low friction test surface with a PFC of 0.25 or less. PFC can be determined by an ASTM traction trailer using the ASTM Procedure E-1337 as specified in FMVSS 105 and FMVSS 121. Actual measurement of PFC is not necessary but is useful to quantify the friction level of the surface being used. Ice, snow or wet epoxy coated surfaces are suitable. The surface must be slippery enough so that the vehicle drive axle(s) will break traction when the ATC is turned off and a rapid throttle application is made.

When comparing different ATC system configurations, care should be taken to design the test so that surface friction variation does not influence the results. For example, if testing on ice or snow, which tend to vary as a function of temperature and grooming, alternate the different ATC configurations from run to run or “back to back”. Test surface should be of sufficient size to allow the driver to safely recover from a loss of control event during the test maneuver.

Maneuver – Any or all of the following maneuvers are useful for evaluating the ATC engine control function.

- Rapid throttle apply in a curve
- Rapid throttle apply in a straight line on a surface with a one or two percent cross slope
- Transition from high to low friction while towing a trailer with the brakes lightly applied to simulate a load. Trailer must be loaded above the trailer axle so that the trailer wheels do not lock when the trailer transitions to the low friction surface.

Vehicle speed in the maneuvers must be above the speed at which ATC induced braking occurs or the traction control braking function must be disabled.

Instrumentation – Equip the vehicle with instrumentation to measure and record the following parameters versus time:

- One front wheel speed
- Speed of each driven wheel
- Vehicle yaw rate

Optional:

- Steering wheel angle
- Engine RPM
- SAE J1587, J1922 or J1939 data link (to determine when the reduce throttle command is given by the ABS ECU to the engine ECU)
- Drive axle brake pressure on each rear wheel (to determine if ATC applies the brakes)

Test Vehicle Loading – Vehicle should be empty or lightly loaded

7.0 TESTING TO EVALUATE THE PROCEDURE

In order to evaluate the procedure, the 4x2 tractor shown in Figure 2 was tested to the recommended procedure in three different configurations:

- ATC turned off
- With Bendix AL-7 ATC
- With Meritor WABCO Version D

All three of the maneuvers (see section 6.0 Maneuvers) listed above were used and all utilized a wet epoxy surface.

Figure 3 is a recording made without ATC where the vehicle was coupled to a trailer with the brakes lightly applied (10 psi control line pressure) to simulate a grade and then driven at 35 mph across a transition from dry asphalt to the wet epoxy. Note that after the transition that the yaw rate is very cyclic indicating that the vehicle is yawing left and right as the driver fights to control it. On this graph and on all graphs that follow, the yaw rate zero-level is half way up on the y-axis. Also note how the wheel speeds increase (this occurs at the transition). The right-side wheel speed continues to increase but the left side drops back to match vehicle speed.

Figure 4 shows the same maneuver with ATC operational. Note here that the yaw rate remains low and the wheel speeds do not increase very much above vehicle speed.

Figure 5 shows a straight-line run with a bobtail tractor starting at 25 mph on wet epoxy where the throttle is suddenly fully applied. The vehicle yaws out of control even with the ATC operational. This occurred with both brands of ATC tested. Both ATC systems appeared to not be able to gain control of the wheel speeds quickly enough and the one percent cross slope on the surface was enough to “pull” the vehicle out of control as soon as spinning occurred and lateral traction was lost.

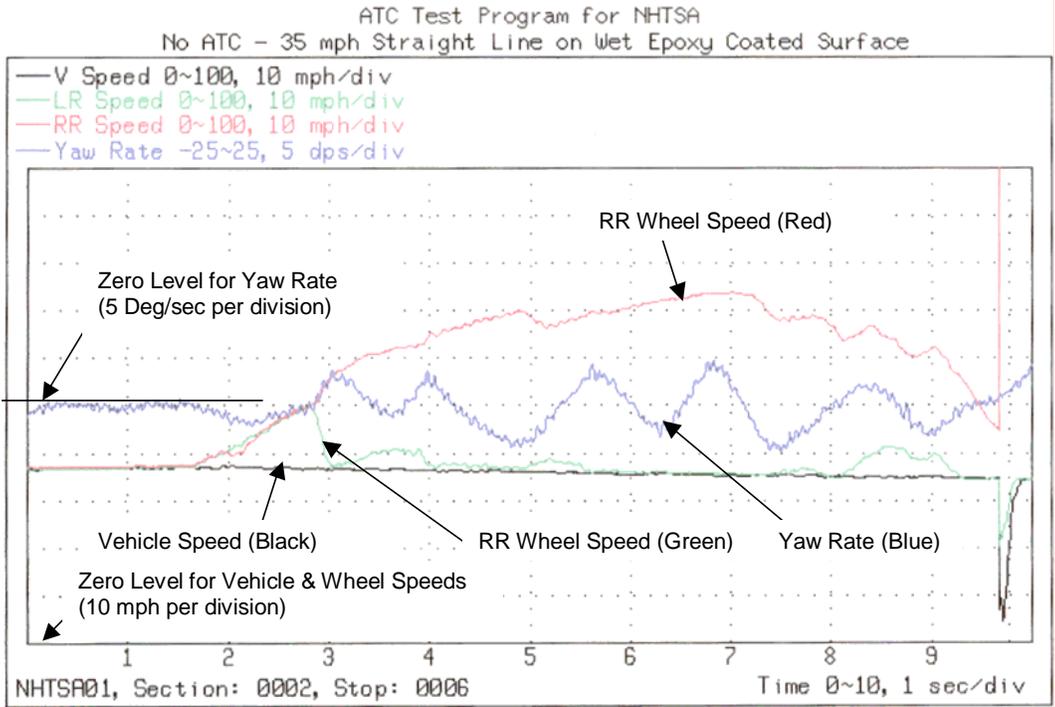


Figure 3 Straight-line, constant-speed transition from high to low friction surface without ATC (engine under load to simulate uphill grade)

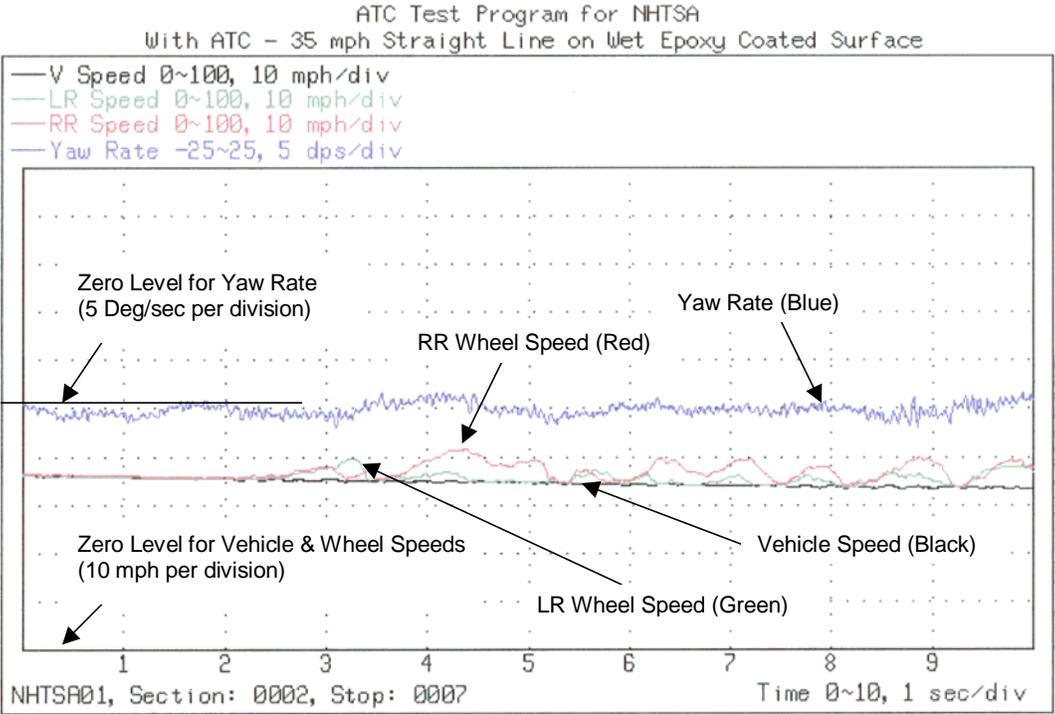


Figure 4 Straight-line, constant-speed transition from high to low friction surface with ATC operational (engine under load to simulate uphill grade)

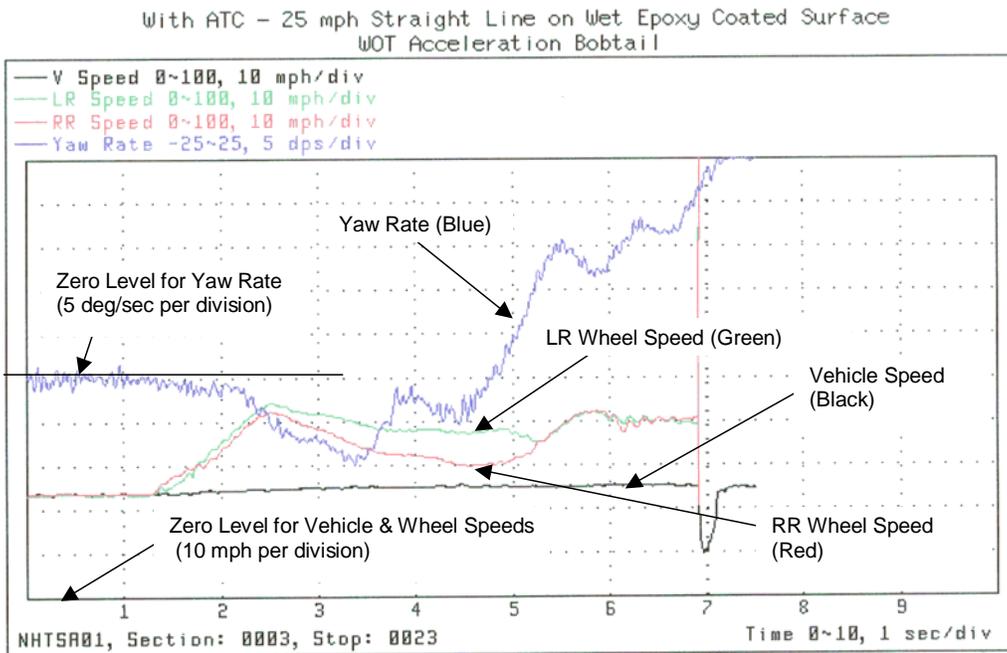


Figure 5 Straight-line rapid acceleration maneuver with bobtail tractor on uniform wet epoxy surface with ATC operational

Loss of control with both brands of ATC in the straight-line rapid acceleration maneuver could have been caused by the slow response of the engine to the ATC commands. The vehicle was a 1995 model with relatively early-generation engine electronics and it utilized a SAE J 1922 datalink between the ABS/ATC and the engine. This is a relatively slow databus compared to the newer SAE J1939 databus .

Another two-axle tractor (see Figure 6) was obtained with newer engine electronics and the capability to communicate with either a J1922 or a J1939 data bus. This vehicle was tested in a bobtail configuration on both snow and ice with both of the databuses (one at a time operational). Results of these tests indicated that the vehicle could be kept under full control at all times with either databus operational. This included the case of full throttle acceleration on glare ice while making a turn. The data recordings for these tests indicated that the drive-axle wheel speeds were kept under much better control (i.e. wheel speeds were not allowed to increase much above the vehicle speed).



Figure 6 Test Vehicle with newer engine electronics and both SAE J1922 and J1939 Datalinks (vehicle was tested bobtail)

8.0 SUMMARY AND CONCLUSIONS

A test procedure was developed for evaluating the ability of heavy truck automatic traction control (ATC) to improve vehicle stability and control on slippery surfaces at highway speeds. ATC is an optional feature of ABS. At speeds above about 30 mph the ATC controls drive-axle wheel slip via engine speed control over a serial datalink (databus) between the ABS/ATC ECU and the engine ECU. At lower speeds the ATC controls engine speed and also applies the rear brakes to control differential wheel speed.

The test procedure developed was evaluated using two different vehicles, two different brands of ATC and two different serial datalinks (SAE J1922 and 1939). The procedure was able to discriminate between different ATC performance levels and did find deficiencies in one of the two vehicles tested. The problem appeared to be due to slow response from the engine on the older vehicle tested (1995 model engine) and occurred with both ATC systems evaluated.

ATC appears to have the potential to significantly improve vehicle stability and control on slippery surfaces at highway speeds. The later model vehicle tested (2000 model engine electronics) was able to negotiate curves on ice surfaces even with full throttle accelerations in a bobtail tractor configuration.

Due to the fact that ATC is highly integrated with the engine, ABS and pneumatic systems, retrofitting ATC to older vehicles is generally not practical.

