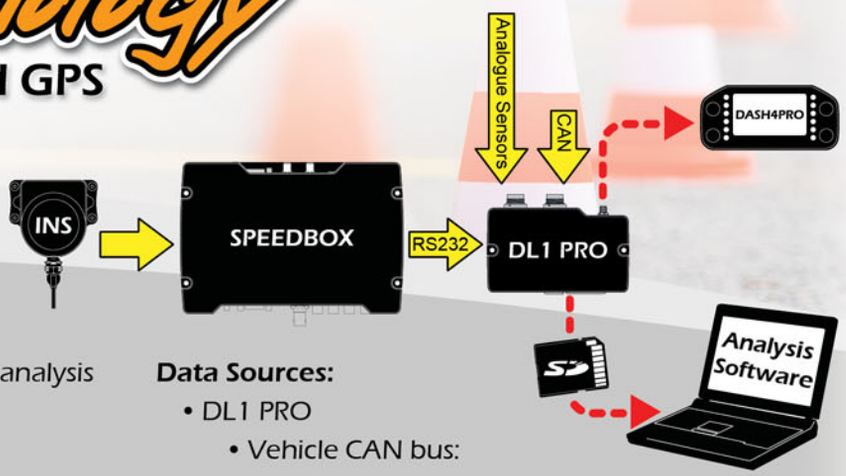
# Race Technology

**Experts in data logging and GPS**




## Brake Testing Application

This application note describes a brake test and analysis of the brake testing results.


**Equipment Used:**

**Logging and Sensing Equipment:**

- SPEEDBOX-INS single antenna system
- DL1 PRO data logger + RAW CAN licence
- DASH4PRO display
- GoPro video camera with interface cable


**Sensors:**

- 150mm linear sensor for brake pedal travel
- Brake pedal force sensor
- Rubbing thermocouple on offside front and offside rear brake discs
- -100°C to 1100°C thermocouple amplifiers
- 250bar pressure sensors on offside front and offside rear brake lines after ABS pump

Above, rubbing thermocouple installation

**Data Sources:**

- DL1 PRO
  - Vehicle CAN bus:
    - 4 wheel speeds
    - Engine speed
    - Throttle position
    - Steering angle
    - Engine load
    - Intake air temperature
    - Coolant temperature
  - Analogue inputs:
    - Brake pedal force
    - Brake pedal position
    - Front and rear offside brake disc temperatures
    - Front and rear offside brake line pressures
- SPEEDBOX-INS
  - Roll / pitch / yaw angles
  - Roll / pitch / yaw rates
  - Three axis acceleration
  - Vehicle position
  - Speed / heading / gradient
  - Braking distances and times from 60mph to halt

**Data Outputs:**

All data was logged on to the SD card in the DL1 PRO, during the test certain data channels were also displayed on the DASH4PRO to ensure that the test was running correctly.

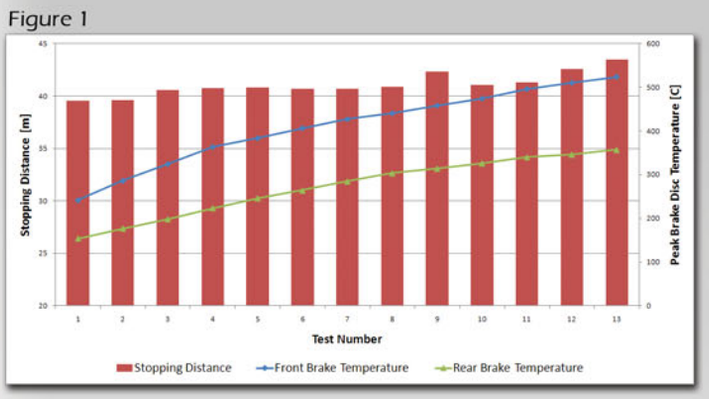

**Test Method:**

Accelerate from a standing start to over 60mph, brake to a halt whilst providing enough pressure to activate the ABS. When the vehicle comes to a halt repeat the acceleration.

This was repeated 14 times to see the effect of change on the braking due to temperature changes in the brakes. This is very similar to the AMS test.

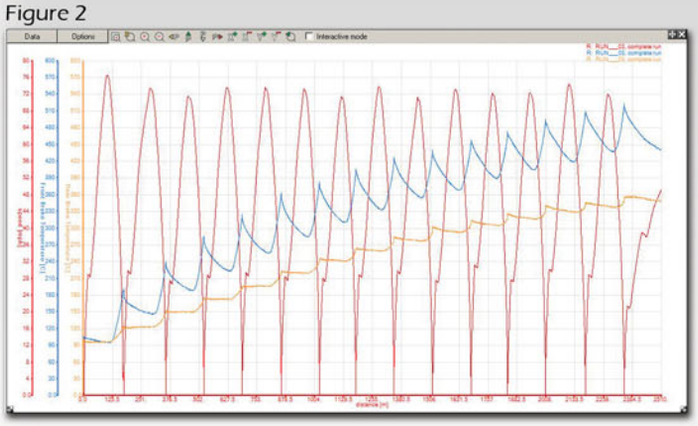
**Results:**
Logged data from the SD card was loaded into the Analysis software. This included the braking distance results from the SPEEDBOX-INS which are typically accurate to within 2 cm. The following results contain screenshots from the Analysis software.

Figure 1




Front and rear brake disc temperatures during the test:

Figure 2



Speed - Front Brake Temperature - Rear Brake Temperature

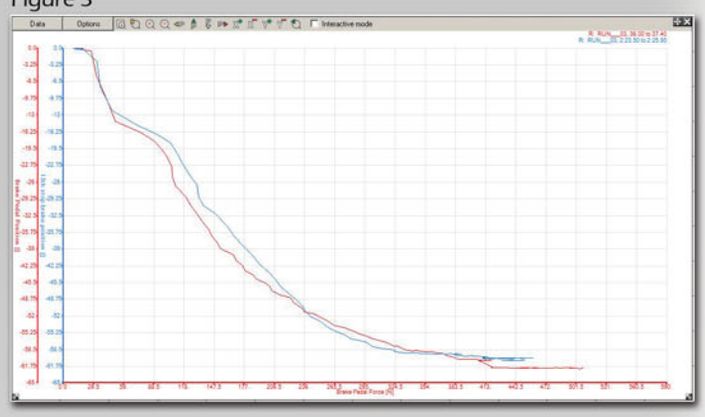
From Figure 1 we can see that during the last few tests the braking distances were getting longer. This can be caused by either the front or rear brakes losing effectiveness, which could be due to a reduction in braking force as the pads get hot or by fluid starting to boil.

**Pedal force vs. position**

To investigate whether the fluid was overheating or not the brake force in relation to the pedal position is investigated.

From Figure 3 it can be seen that the pedal is coming to a stop at a similar position on the 13th test as it was on the first test:

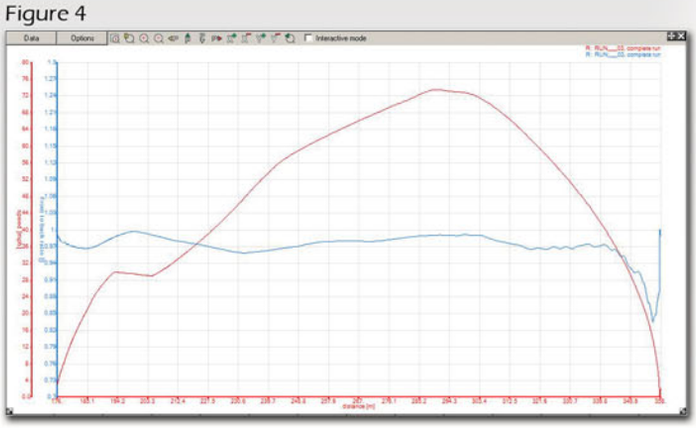
Figure 3



Brake Pedal Position Test 1 - Brake Pedal Position Test 13

To look at the effectiveness of the front brakes compared to the rear brakes we can use the Analysis software to compare the average front wheel speeds with average rear wheel speeds. During heavy braking, if a wheel is close to locking up and is having the ABS act upon it it will go slightly slower than other wheels. By setting up a user defined variable to look at the average front wheel speed and average rear speeds and plotting the ratio between them during acceleration and braking we can see which end of the vehicle is providing the most braking effort:

Figure 4



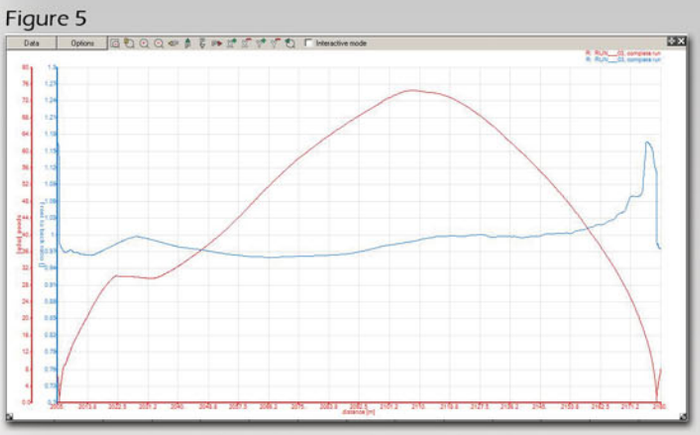
Speed - Brake Pressure Front to Back Ratio

Figure 4 shows the second brake test, showing vehicle speed and front wheel speed / rear wheel speed ratio. There is some smoothing on the data to show the trends rather than noise on the data. During the first gear and second gear acceleration phases the ratio is dropping down as low as 0.96 as the rear wheels start to go faster than the front wheels, during the transition from acceleration to braking the ratio is back up very close to 1 as expected, then during the braking

phase it is constantly below 1, dipping down as low as 0.85 at very low speeds. This is to be expected as at lower speeds a small differential in speeds will be a larger proportion of the speed. This shows the front wheels are closest to locking up as they are travelling slower than the rear wheels.

Figure 5 shows the same results from the 13th test, where the braking distance was longer:

Figure 5

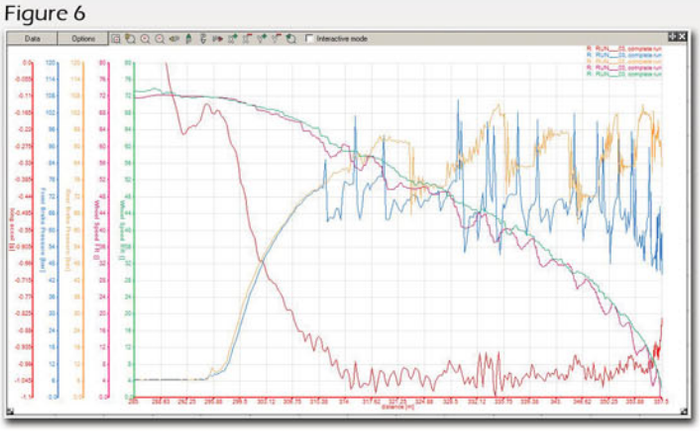


Speed - Brake Pressure Front to Back Ratio

The acceleration phase of the data is exactly the same, but during the braking phase the ratio stays at 1 initially and then starts to increase rather than decrease. This indicates that it is the rear brakes which are now starting to lock up first, the front brakes are no longer working at maximum efficiency.

Brake line pressures during the test, second test:

Figure 6

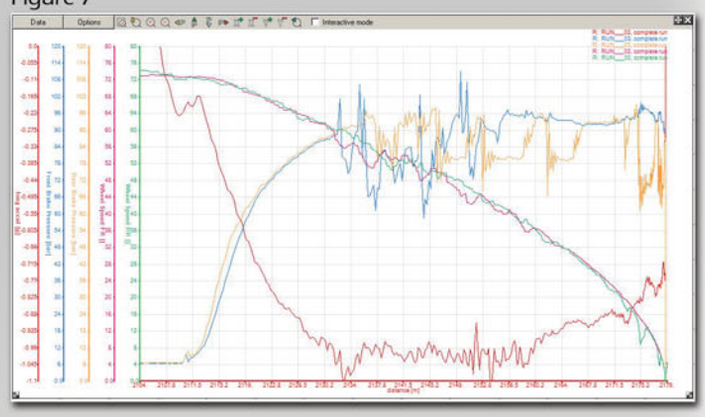


Long Accel [g] - Front Brake Pressure [bar] - Rear Brake Pressure [bar] - Wheel Speed Front Offside - Wheel Speed Rear Offside

Figure 6 shows the front wheel speed dipping as the ABS takes effect throughout the test, the deceleration is reasonably constant throughout the test at around -1g.

Repeated for the 13th braking test:

Figure 7



Long Accel [g] - Front Brake Pressure [bar] - Rear Brake Pressure [bar] - Wheel Speed Front Offside - Wheel Speed Rear Offside

Figure 7: At the beginning of this braking run the front brake pressure is being modulated, but part way through the brakes are losing their effectiveness and from about 50mph the average front brake pressure is now up to close to 100bar and is no longer being modulated. The front wheel speed is no longer showing the dips where it was locking up. The deceleration rate drops from -1g to closer to -0.8g. This demonstrates that as the front brakes become less effective the braking vehicle can't slow down as quickly.

**Conclusion:**

Up until around the 10th test the braking distances are relatively consistent, for the last three tests the distances are starting to increase. This is due to the front brake pads reaching a temperature at which they become less effective, and are only able to generate 80% of the braking force which was generated on the earlier tests.

The data from the test was overlayed on to the video and can be seen on YouTube here:


https://www.youtube.com/watch?v=iSPkbSTx0z4

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