Electronic Locomotive Indicating trials by ASTS Ltd

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Instrumentation targets

Devise a plan to define and measure various parameters on steam locomotives to enable us to analyse the current performance

Identify areas where improvements could be made (or not !!)

Further measurements post modification to check the results and provide a pre and post comparison for the first time to clearly see the effects of changes on performance

Create instrumentation system that can be used on any size locomotive without risk of damage to the locomotive

Eventually instrument the KWVR S160 with our Lempor exhaust fitted

Measurements that need to be taken

- Piston position
  - – enhanced method of determining this using Hall Effect sensors
- Steam pipe pressure and temperature
  - – monitor feed to cylinders to measure energy going in
- Cylinder pressure front and rear
  - – monitor pressure fluctuations with valve movement and generate indicator diagrams
- Blast pipe pressure and temperature
  - – measure steam outlet pressure from cylinders to determine difference
- Smokebox vacuum
  - – monitor vacuum that creates gas flow and monitor exhaust performance
- Firebox vacuum
  - – monitor firebox vacuum to determine flow
- Arch vacuum
  - – measure pressure drop over the arch
- Event marker
  - – mark events during the test run

Instrumentation chosen to take measurements

Pico 16 channel data logger 1216 with interface board

4 off Omega 0-20 bar pressure transducers

3 off Omega 0 to -1 bar vacuum transducers

2 off Hall effect position sensors with magnet trigger mounted on the cross head

K Type Thermocouples

Various loco owner manufactured pipe connections to transducers

Sample rate of whole system is 1 KHz

Locomotive of Choice
KLR owned ‘Badger’

Badger Instrumentation
Reasons for the choice

The Operations Manager at the Kirklees Light Railway is keen to investigate the way Porta inspired modifications work on his locomotives

The railway has excellent workshop facilities to manufacture the required pipework and connections to the locomotive

It is relatively easy to work on the locomotive and it can be fitted out quickly for testing although limited space creates some problems

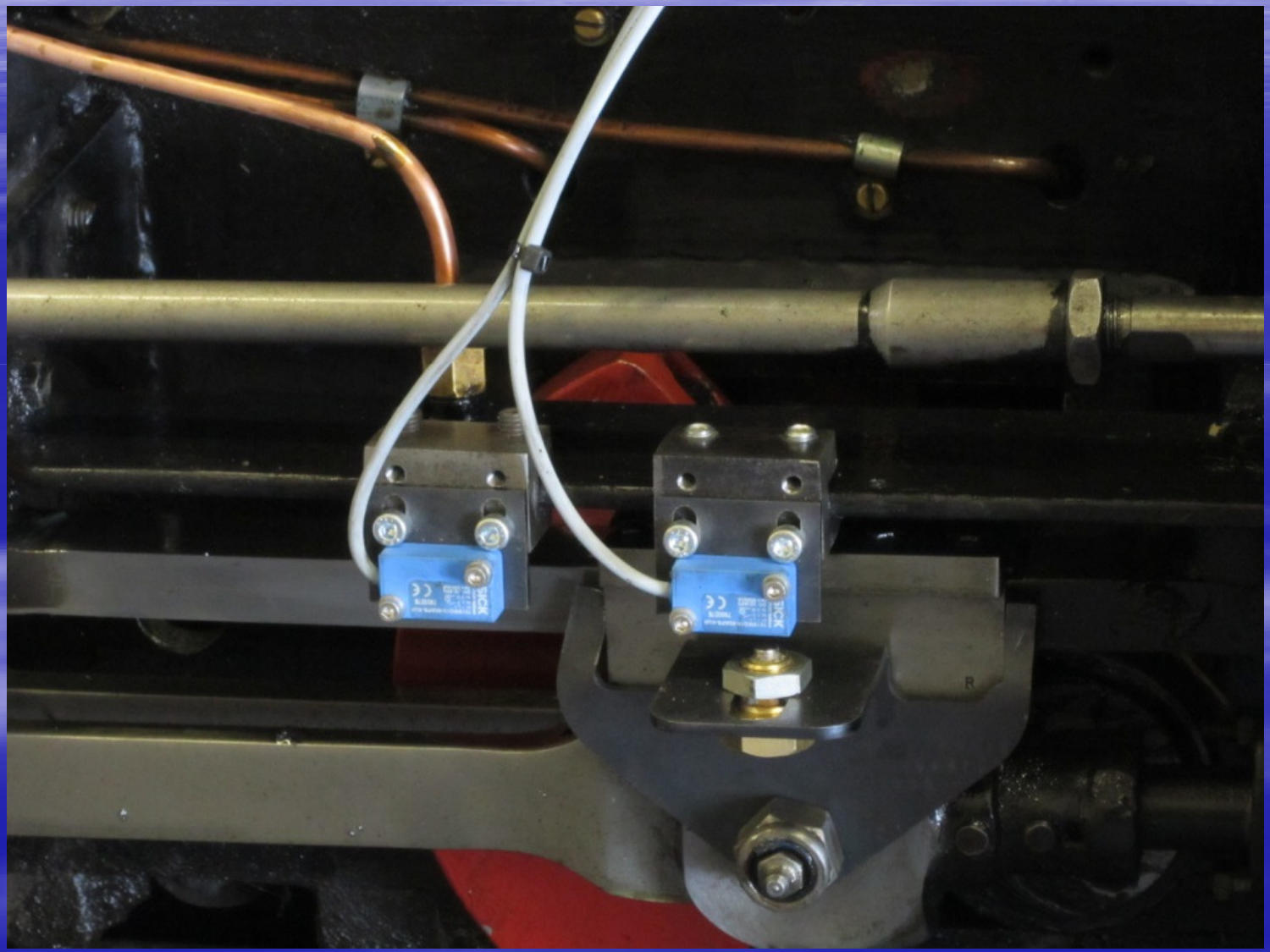
On non-operational days we can have access to the whole railway for testing but this does put testing on hold during the summer running season

Relatively close to main players with reasonably good road access

Locomotive is quick to steam and consumes relatively little coal, keeping testing costs to a minimum

Badger Instrumentation

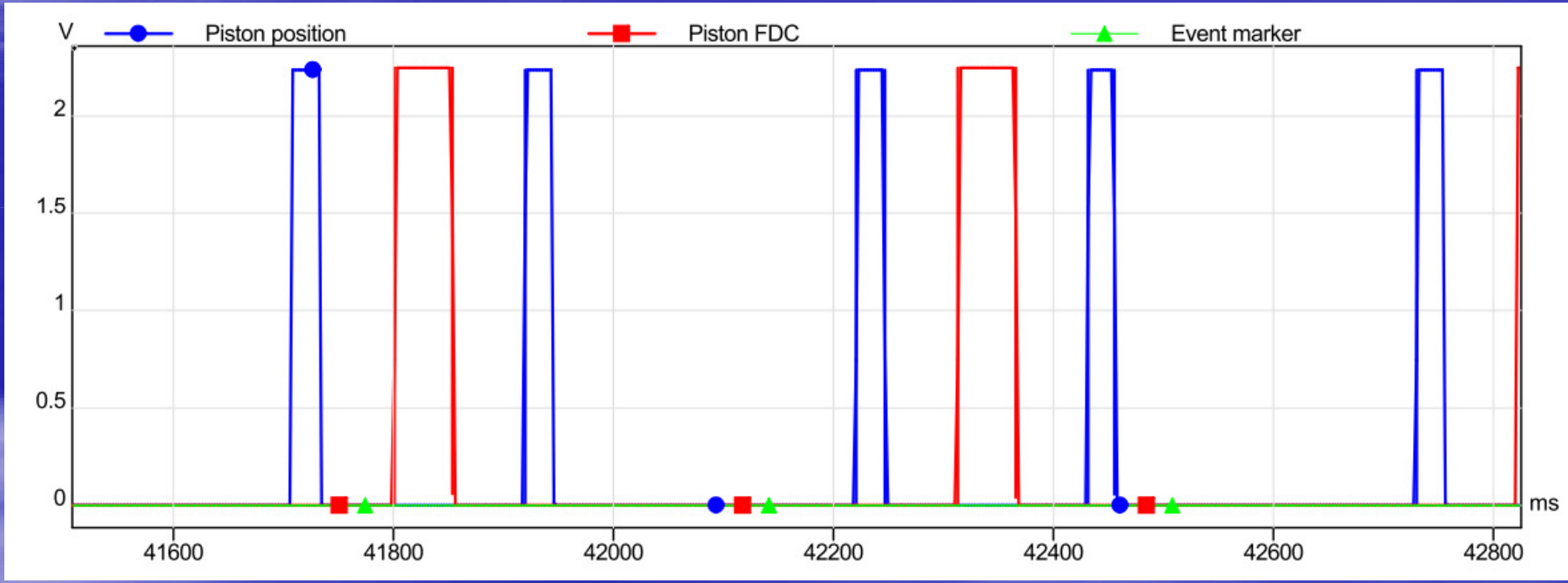
Original fit



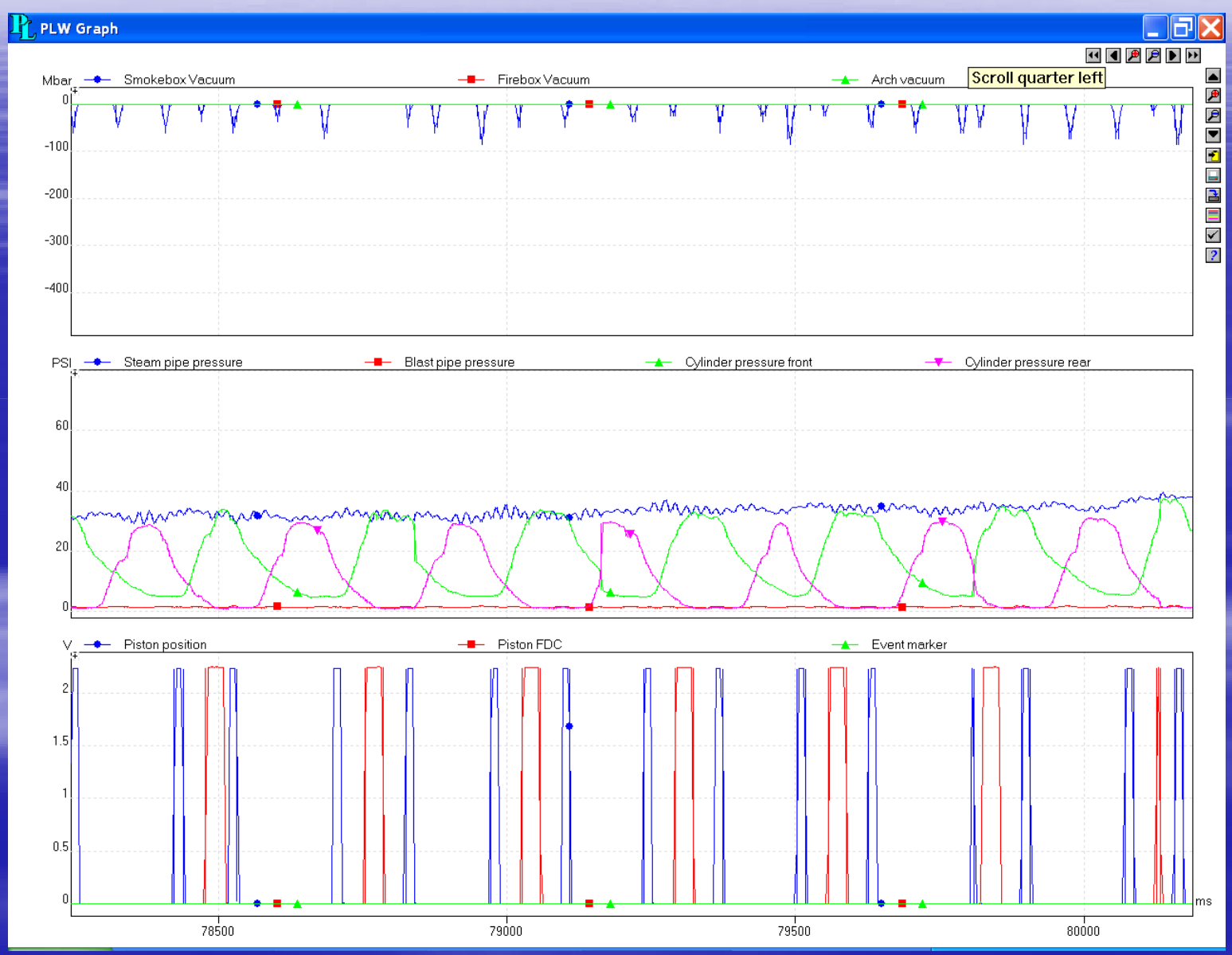
Badger Instrumentation
Original fit

Badger Instrumentation
Original fit

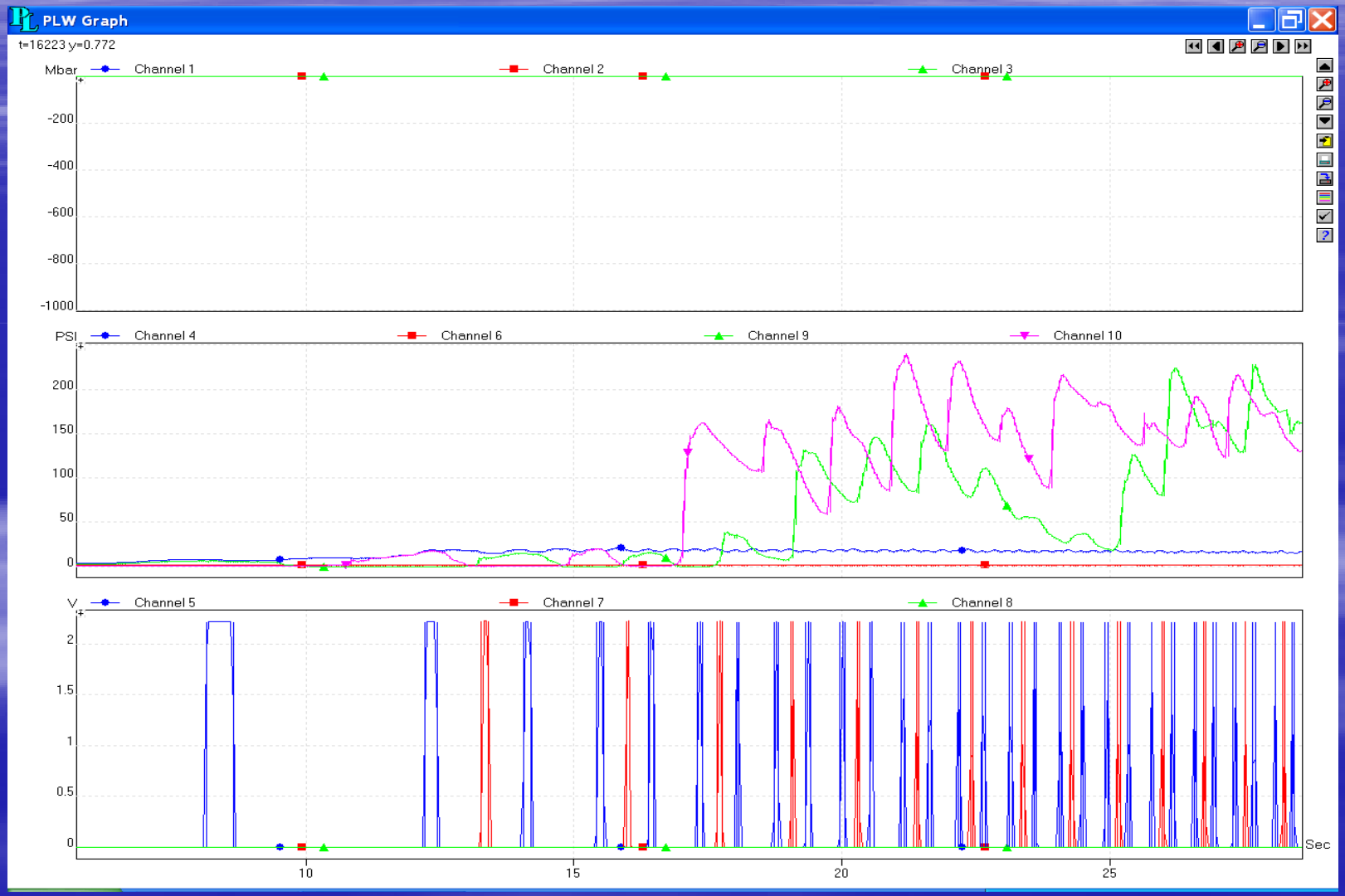
Position Sensor Output



Example Data explanation



Badger Instrumentation
The first problem



Badger Instrumentation

Cylinder pressure investigation

Various theories came up about the cause of the over-pressure readings

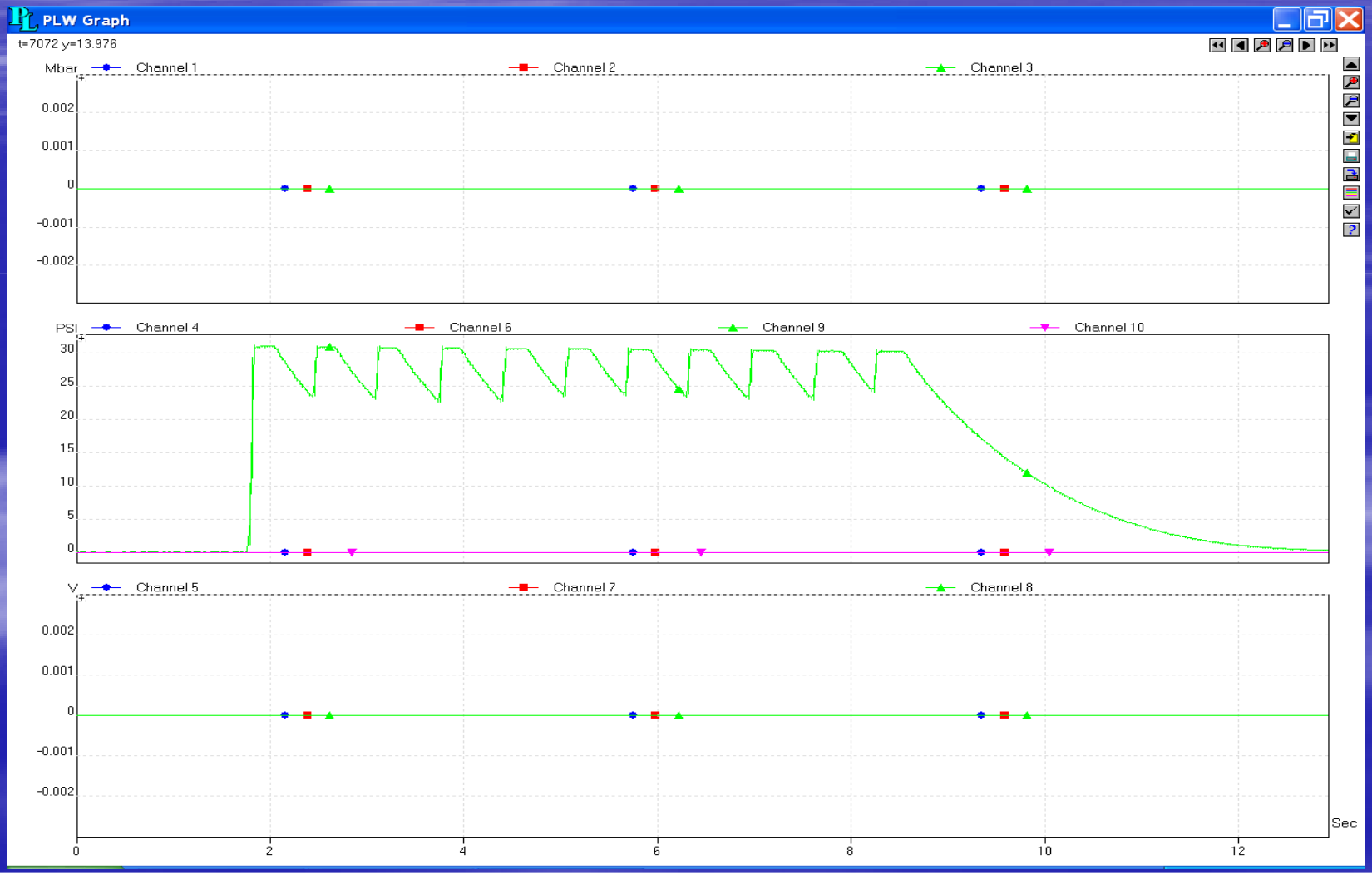
Track vibration was considered but tests found that although there was an effect it was very small, not enough to explain the problem

The valve arrangement on the loco will not allow the over-pressure to actually happen as it would blow the valve plate off the seat so this too went

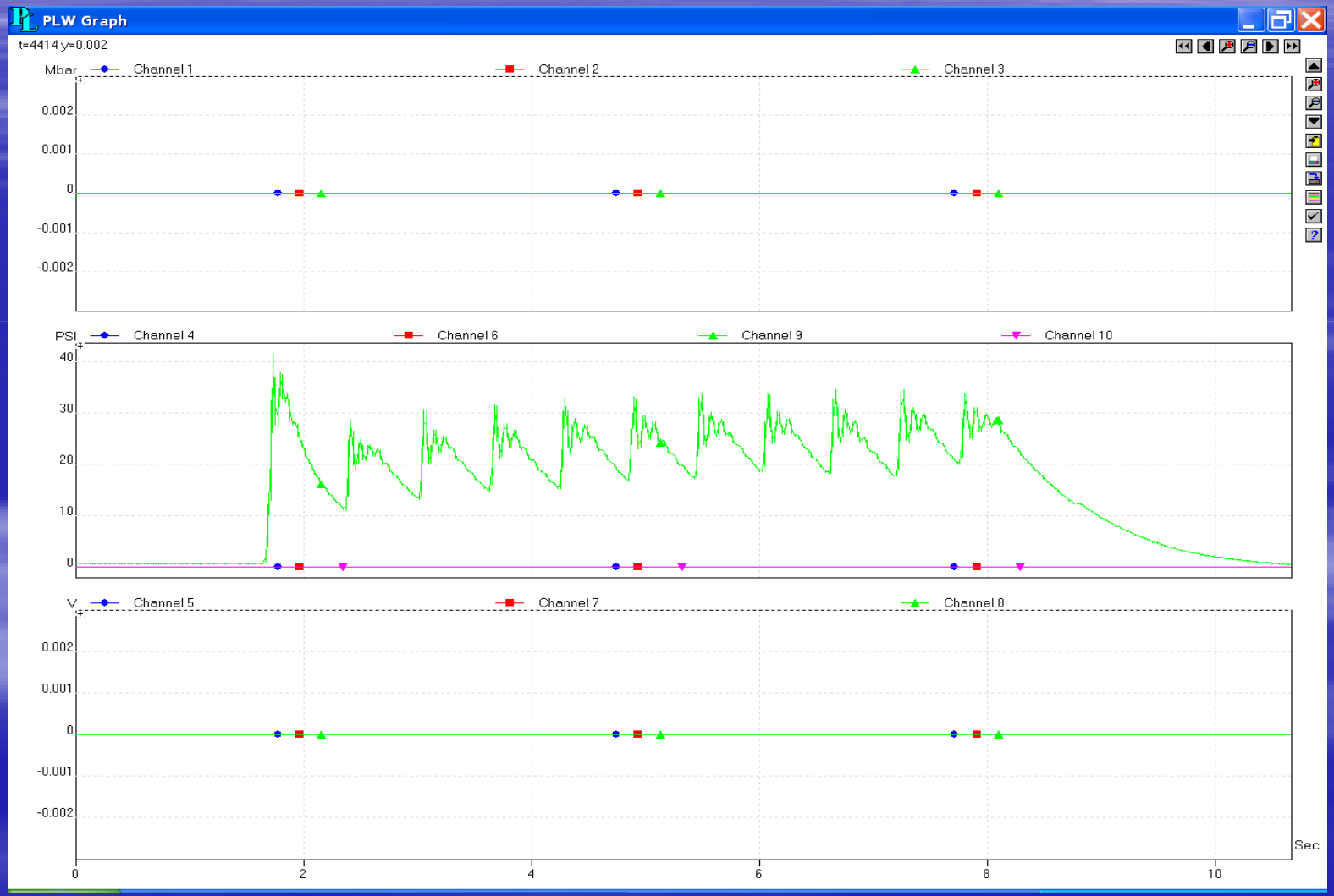
The connection under the drain cocks could easily allow condensate to get into the transducer pipe

After much investigation it was found that when condensate gets into the pipe to the transducer with air above the water then the water ‘plug’ gains momentum with the steam pressure pulse behind it. The effect of this is that the air above the water slug compresses until it overcomes the water slug inertia, thus producing the over-pressure in the transducer pipe

Badger Instrumentation
Clean pipe



Badger Instrumentation
Water in pipe



Badger Instrumentation

Cylinder pressure solutions

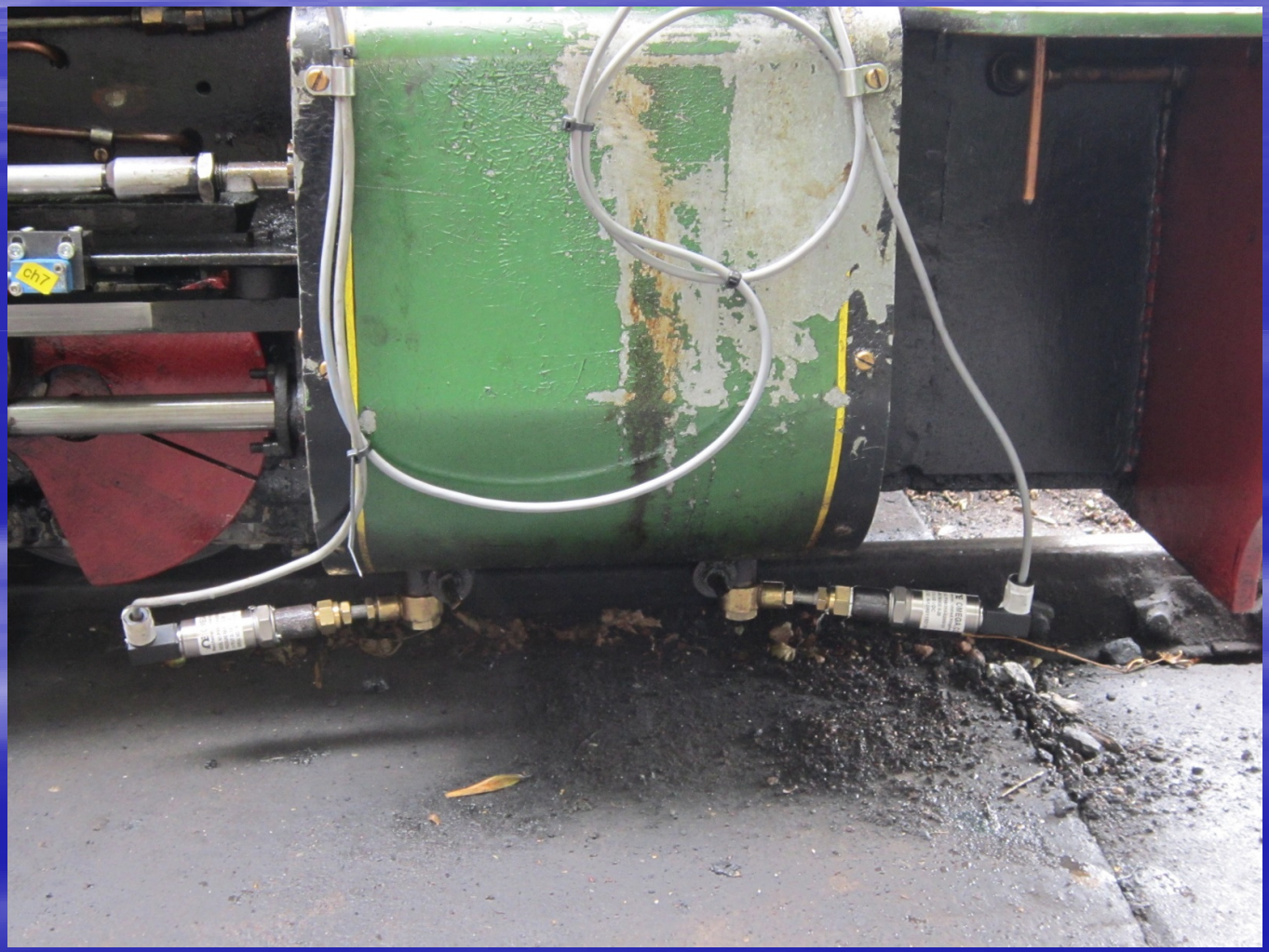
Further testing showed that if the transducer pipe is full of water then, as this is incompressible, it merely transfers the steam pulse to the transducer

Solution one is to fit the transducer pipes above the drain cocks and see if this keeps the condensate out but this does not solve any vibration issues and turned out to be impossible to fit

Solution two is to shorten the transducer pipes to 4” and fit them below the drain cocks to deliberately fill them with condensate. This also means that the transducers are now almost horizontal which solves any vibration issue

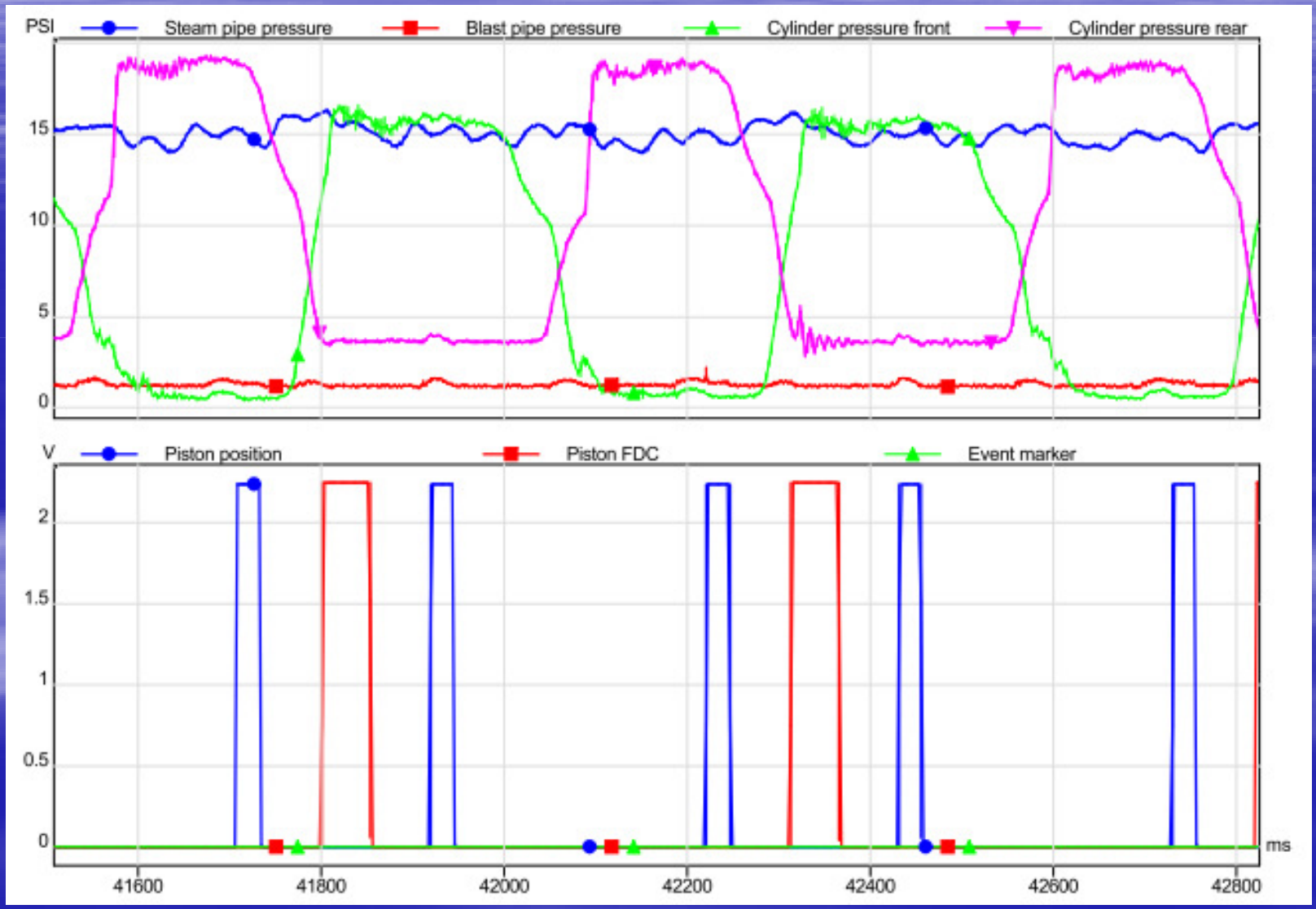
This solution also has the advantage that any further condensate while running will not affect the readings but could cause problems by overheating the transducers

Badger Instrumentation
Next idea

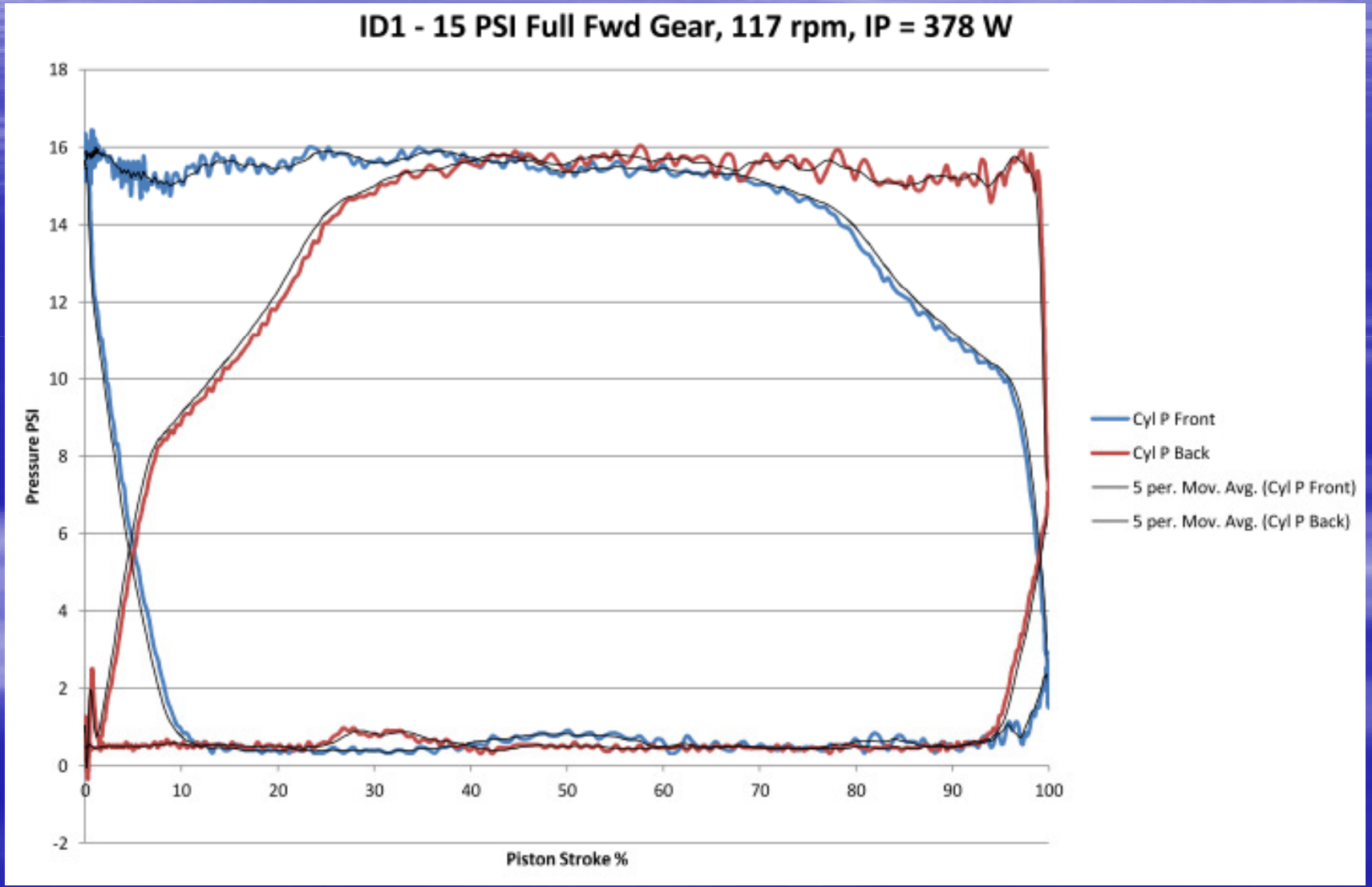


Badger Instrumentation
Full second fit

Analysis 1


PSI
Steam pipe pressure
Blast pipe pressure
Cylinder pressure front
Cylinder pressure rear
15
10
5
0
V
Piston position
Piston FDC
Event marker
2
1.5
1
0.5
0
ms
41600
41800
42000
42200
42400
42600
42800

Indicator Diagram 1



Badger Instrumentation

Problems were not fully understood at first as it needs the complete system to be together to run correctly

The complete instrumentation assembly was brought back to enable investigation into issues

Test compressor, vacuum pump, reservoir, digital pressure gauge and water manometer brought together to enable investigation off the locomotive

Various adaptors, connectors and pipe work acquired for the testing

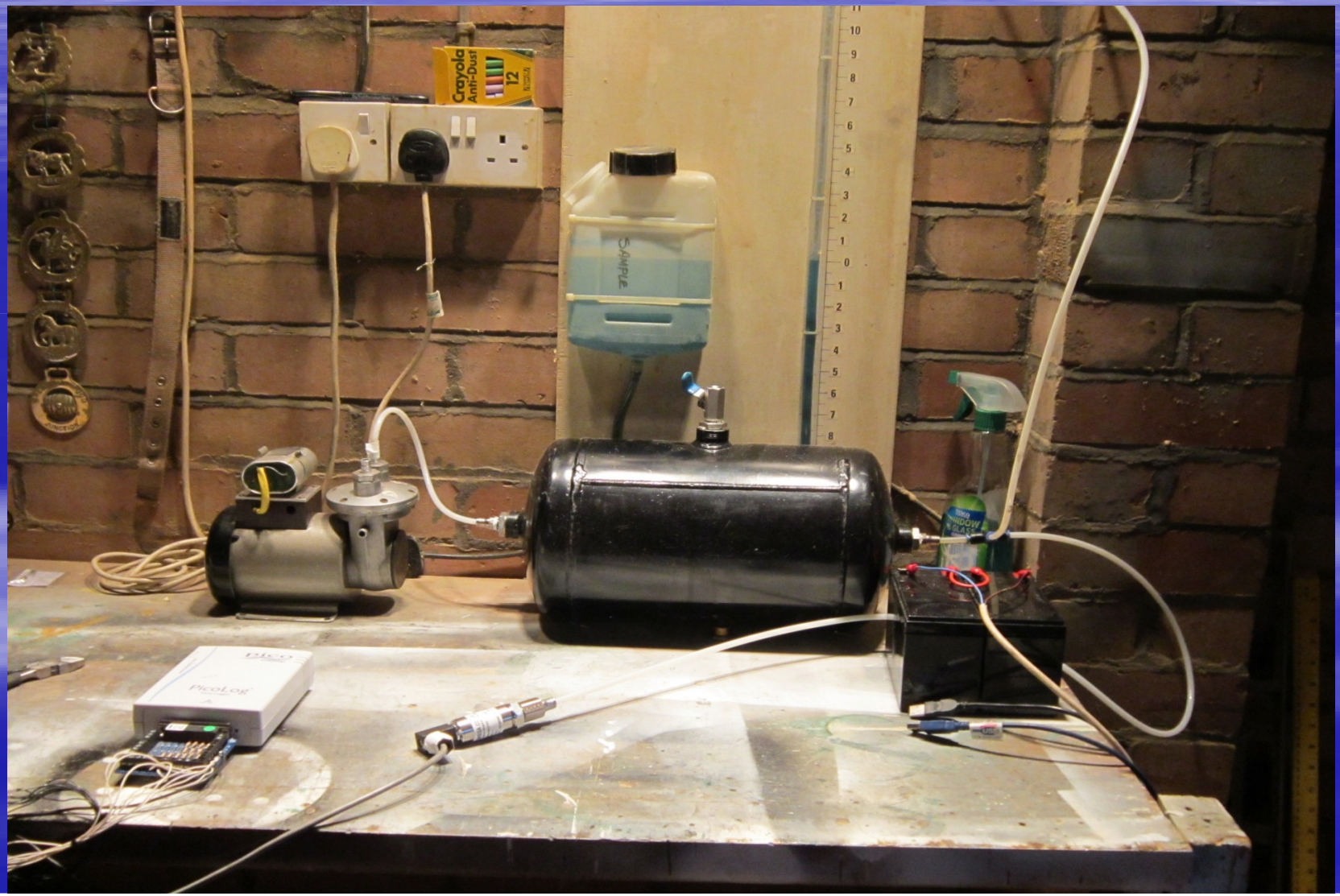
Instrumentation investigations

Two setups are required, one for the pressure transducers and one for the vacuum transducers.

The vacuum transducers were checked against a water manometer

The pressure transducers were checked against a pressure gauge with known calibration of +/- 1 % which is accurate enough for our purposes.

Badger Instrumentation
Vacuum testing



Badger Instrumentation
Pressure testing

Further testing

There still remained the mystery of why pressures do not go to zero and why there are offsets in the readings so further investigation was required

A jig was devised to allow direct comparison after a test run between the three pressure transducers to confirm test run results

That Eureka moment !

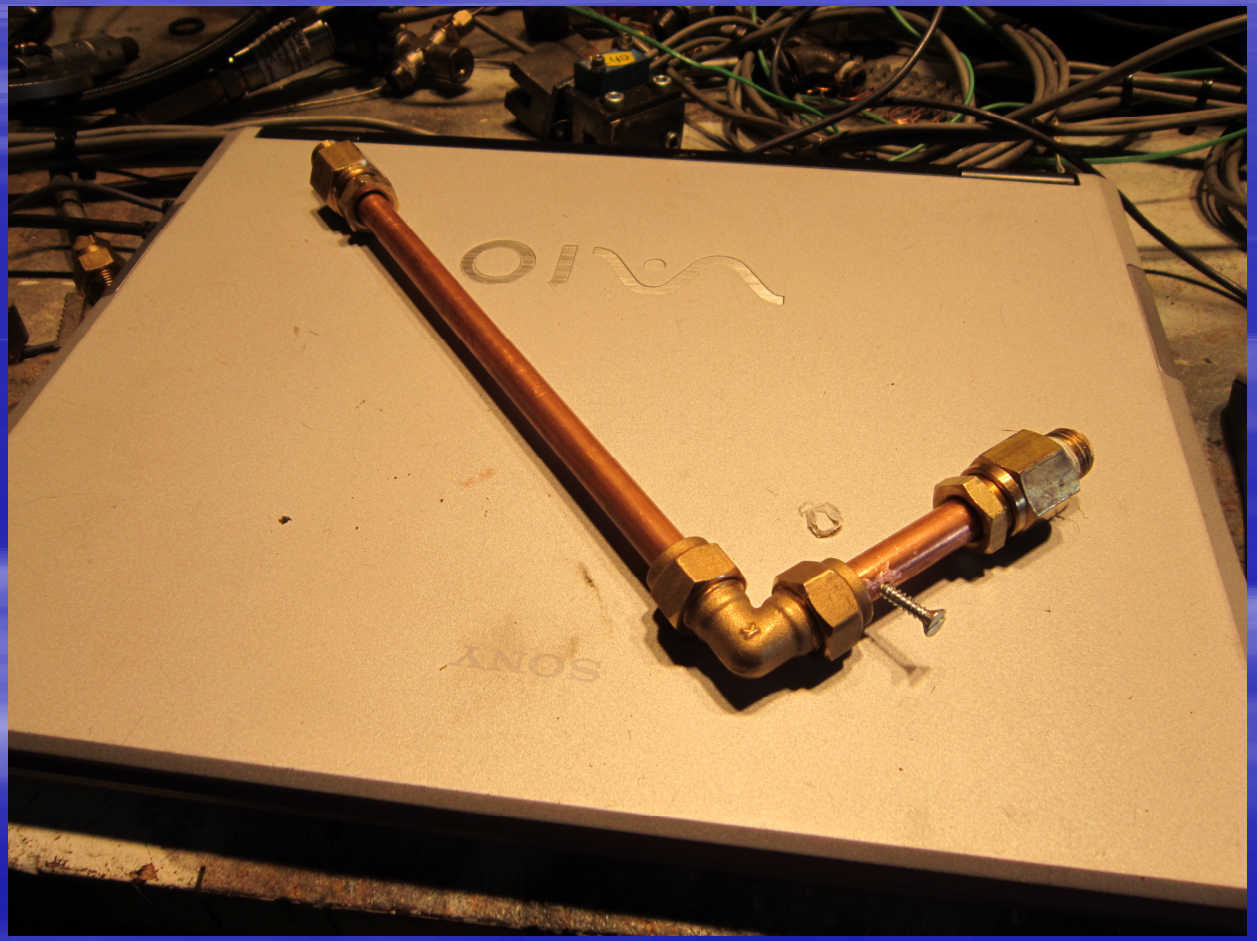
It was discovered almost by accident that if a small leak is allowed in the pipework then water can escape and the problems we had seen previously with water in the system could be eliminated

This does seem counter-intuitive to measuring pressures to some accuracy and at high speed at first sight

After further testing with water in the system it was found that as long as the leak can be calibrated then this has no effect on the peak readings or their timing

First tests with a small hole were excessively leaky but blocking the hole to reduce the hole size seemed to work, but not in a way that would be practical on the track, a solution to this might just work

The first attempt bodge



How to achieve this ??

Further experimentation provided the answer and ultimately the results we were looking for

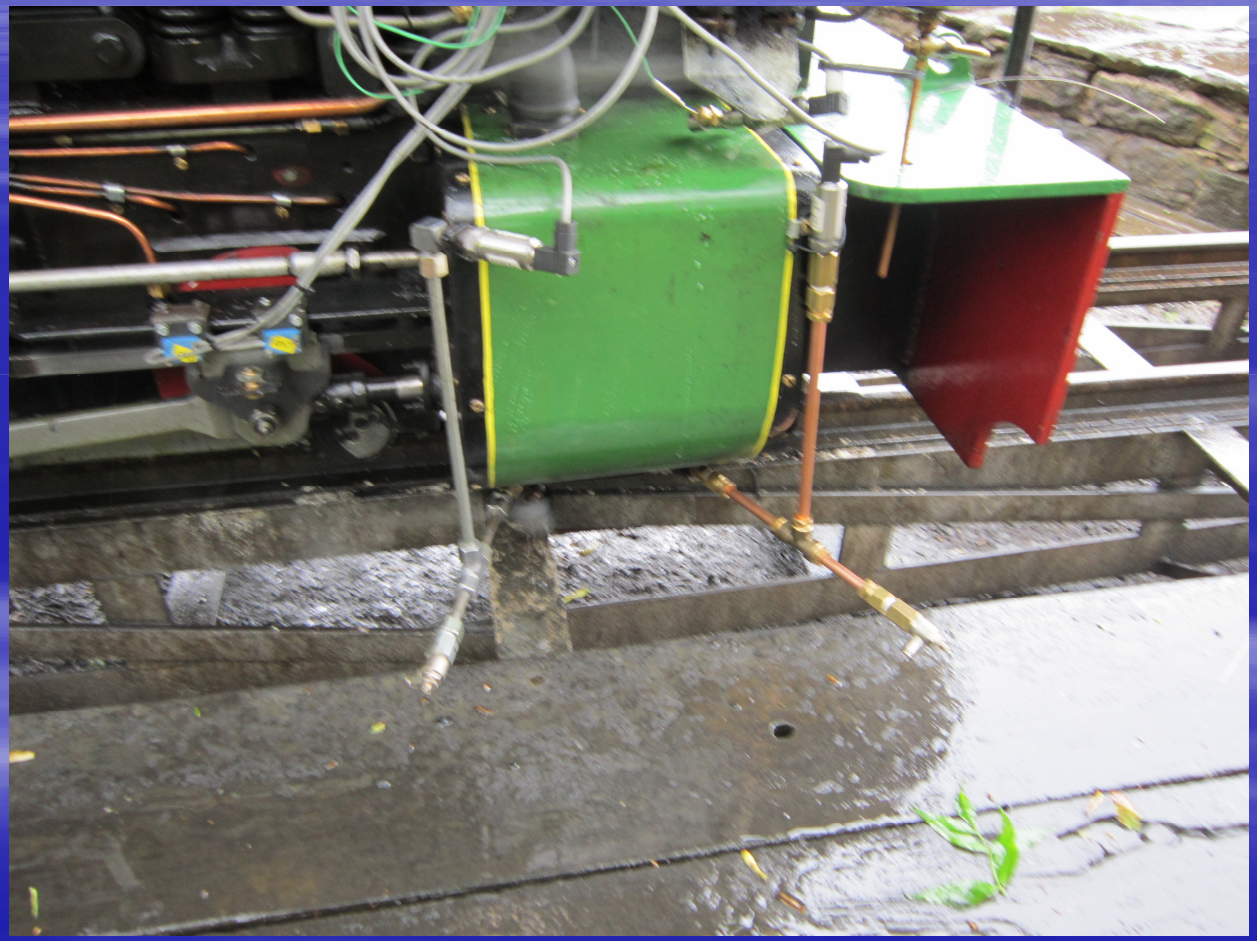
A small adjustable and lockable bleed valve was found which, together with modified pipework to ensure that water went to the bleed valve and not to the transducer provided the answer

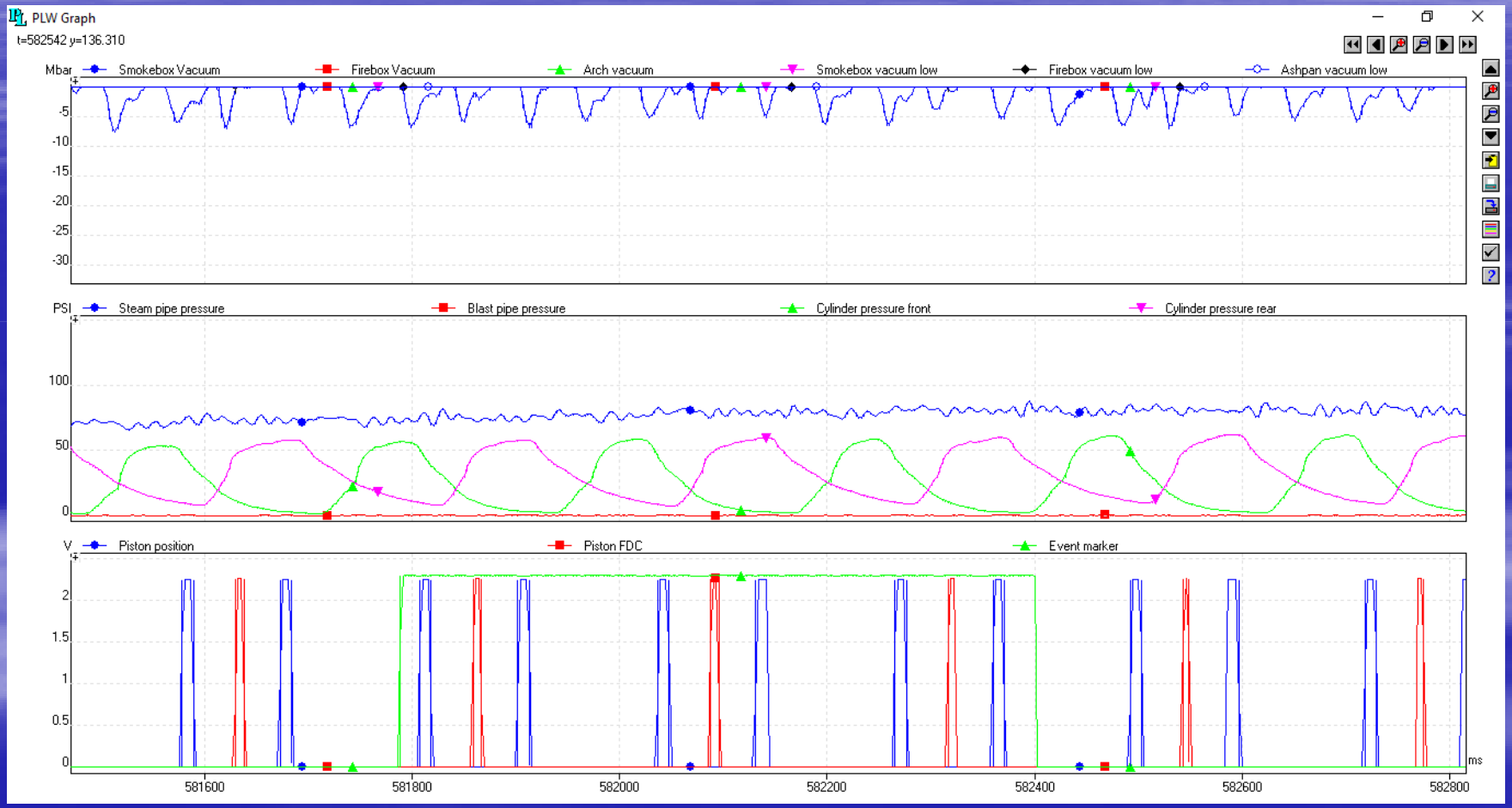
The bleed is adjusted firstly on the test rig and then on the loco to set the bleed so that water comes out and is followed by the tiniest wisp of steam

This ensures that water is continuously bled from the system and that the transducer is also far enough away to keep it cool and away from the water

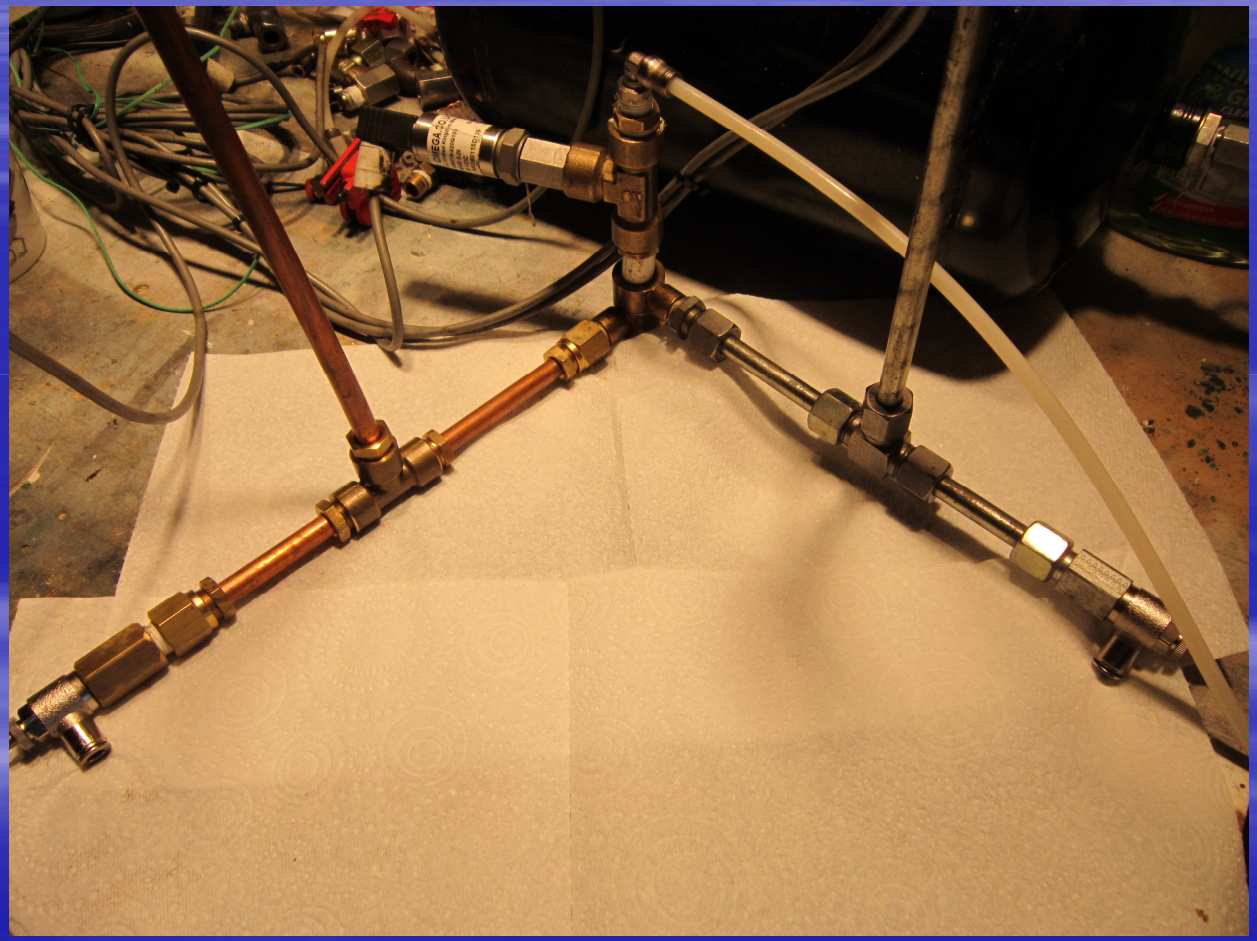
The first attempt at a useable solution

New solution fitted to Badger




PLW Graph
t=582542 y=136.310
Mbar
Smokebox Vacuum
Firebox Vacuum
Arch vacuum
Smokebox vacuum low
Firebox vacuum low
Ashpan vacuum low
-5
-10
-15
-20
-25
-30
PSI
Steam pipe pressure
Blast pipe pressure
Cylinder pressure front
Cylinder pressure rear
100
50
0
V
Piston position
Piston FDC
Event marker
2
1.5
1
0.5
0
ms
581600
581800
582000
582200
582400
582600
582800

Post test run check



The Result

We now having a proven system that works perfectly even at the high RPM of Badger and one we can have confidence in and know how to check it both before and after test runs to validate the data

This is far in excess of any wheel RPM that we will find on standard gauge locomotives where there is also more room to fit the instrumentation

It does raise questions on some areas of the locomotive but at least we are now in a position to go back to the owner and discuss the results with them

Based on this decisions can be made on whether to make changes (or otherwise) and we can then retest the locomotive to measure the improvement when changes are made

Future Instrumentation

We have long wanted to instrument the KWVR S160 locomotive 5820 ever since we design, manufactured and fitted a Lempor exhaust to it 4 years ago.

An opportunity to measure the smokebox vacuum over a full line run arose when they organised a test train ahead of a planned visit by Flying Scotsman this year.

This was done using the S160 on the front of the train in place of Flying Scotsman and the WD on the rear of the train

S160 Instrumentation

Just one transducer was fitted to the S160 to measure the smokebox vacuum to determine the performance of the Lempor exhaust.

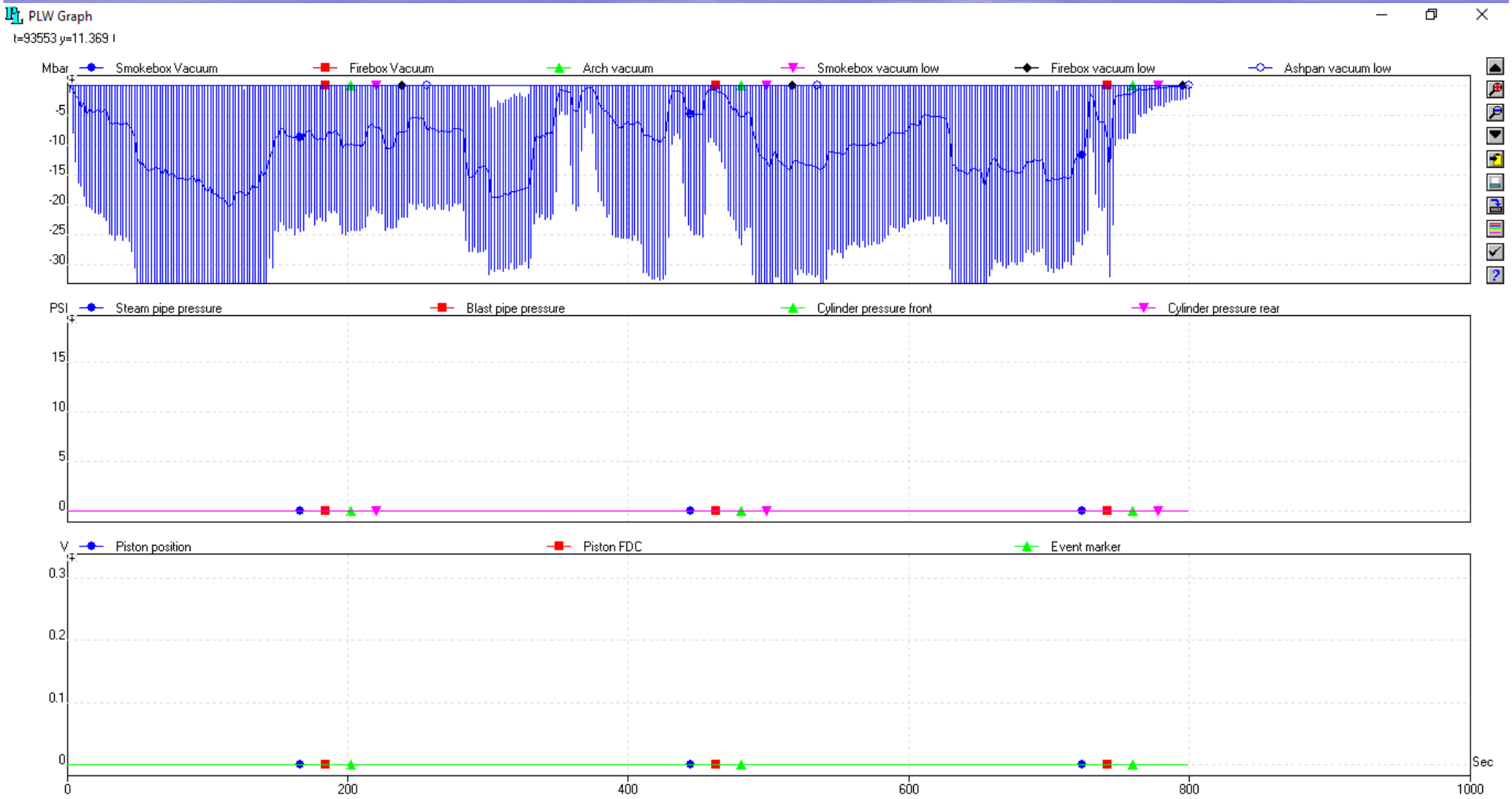
This was to see whether or not the Lempor nozzle dimensions need to be changed

Once again we learnt something about the instrumentation in that we had to run a cable from the transducer the full length of the loco and tender and then into the first carriage, not something we had tried before.

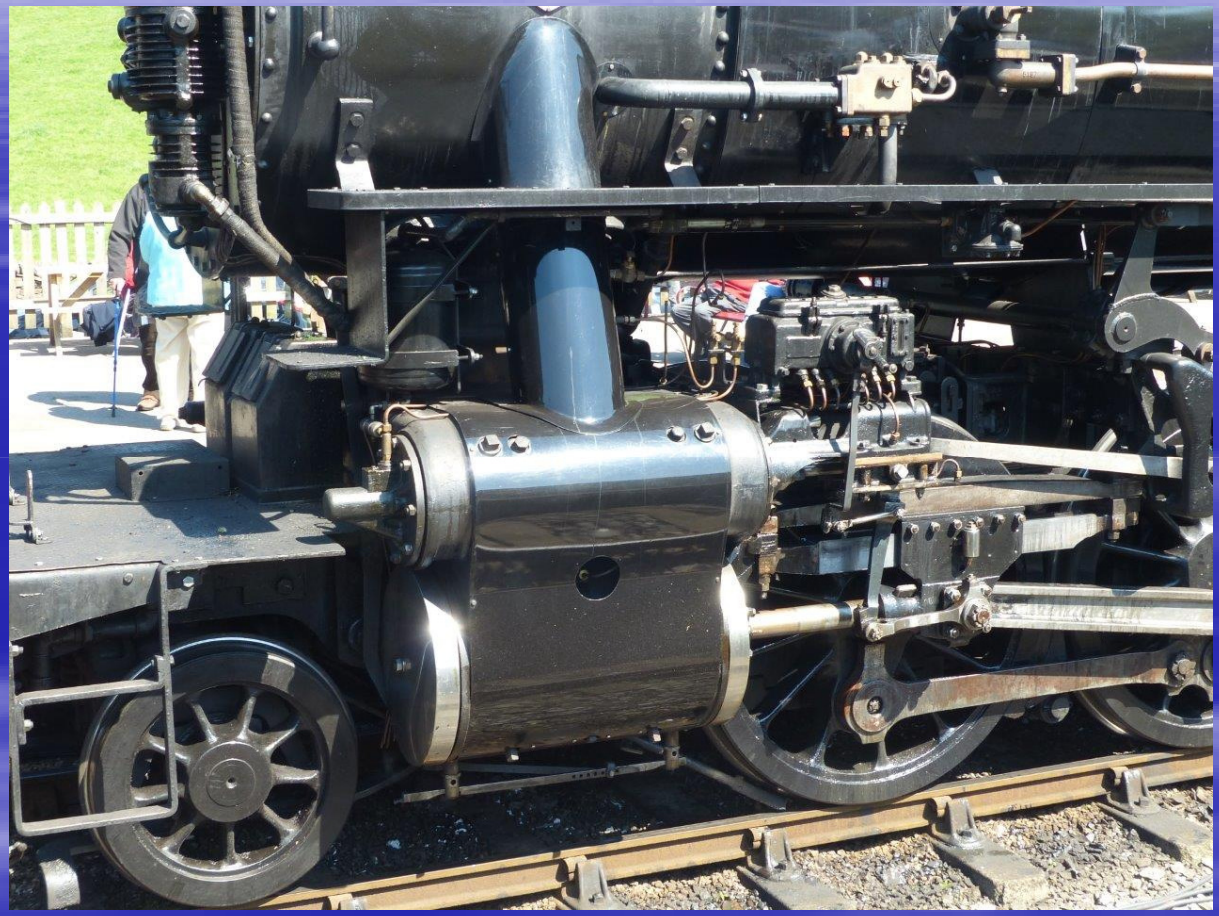
The results we got were much better than expected, the instrumentation worked fine for all three test runs and the data we got was much more than we were expecting


FLYING SCOTSMAN
LIMA
LOCOMOTIVE WORKS
65
J

S160 run 3


PLW Graph
t=93553 y=11.369
Mbar
Smokebox Vacuum
Firebox Vacuum
Arch vacuum
Smokebox vacuum low
Firebox vacuum low
Ashpan vacuum low
-5
-10
-15
-20
-25
-30
PSI
Steam pipe pressure
Blast pipe pressure
Cylinder pressure front
Cylinder pressure rear
15
10
5
0
V
Piston position
Piston FDC
Event marker
0.3
0.2
0.1
0
Sec
0
200
400
600
800
1000

The Next Challenge



And finally….

Does anybody have appropriate skills to help take this forwards ??

If you're interested then further information can be had by contacting myself at the conference or by e-mail at mike.horne2@ntlworld.com

Please note that detailed loco data will not be discussed at this stage as this is the property of the locomotive owner and must remain confidential

ANY QUESTIONS ????