NOTES ON MODIFICATIONS TO
DRAUGHTING ON NO 6

Introduction

Talyllyn Railway No 6 is an 0-4-0 well tank locomotive with 6.875" bore cylinders. In its original state the blast nozzle was mounted, as an inverted Y piece, very high in the smokebox and exhausted directly into a tapered chimney with no petticoat. It had run for an unknown number of years with a 3mm wall sleeve fitted to the blastpipe nozzle giving an effective diameter of 39mm. Before the 2002 season this sleeve was removed as it had deteriorated. The effect that was then noted was that the engine was much freer running but its steaming ability had reduced from excellent to average. We decided that our first experiment in re-draughting would be to try to preserve the excellent running quality of the engine whilst returning its previous steaming abilities.

The Theory

There is quite a lot of information on the internet concerning locomotive draughting. Some of this is devoted to Porta's theories and his design of the Lempor multiple jet blastpipe. Others, notably Koopmans and more historically Ell, have taken a similar path but have concentrated on the more conventional route of replacing the single nozzle blastpipe with a multijet design. There are strong arguments for the idea that a multijet will always outperform a single jet by giving more vacuum for a given backpressure. We decided to use Koopmans theory for the proportions of our front end design. A Mathcad worksheet was produced to calculate the dimensions and we used a three nozzle design where the three nozzles' total surface area was equivalent to a single nozzle of 45 mm diameter. This is shown below;

$D := 45mm$ $\quad n := 3$ $\quad L := 2.1 \cdot D \cdot \sqrt{8}$ $\quad x := \dfrac{L}{\left(\sqrt{8} - 1\right)}$ $\quad x = 146.184mm$

$T := D \cdot \sqrt{8}$ $\quad D_m := \dfrac{D}{\sqrt{n}}$ $\quad L_m := 2.1 \cdot D_m \cdot \sqrt{8}$

$$P_{cd} := D \cdot \frac{\left(L - L_m + x\right)}{x} - D_m$$ Pitch circle on which orifices lie

$P_{encl} := P_{cd} + D_m$ $\quad L = 267.286mm$ distance of single nozzle from throat

$D = 45mm$ single nozzle diameter

$n = 3$ number of nozzles for multijet

$P_{cd} = 53.795mm$ Pitch Circle on which orifices lie

$P_{encl} = 79.775mm$ Circle enclosing all orifices

$D_m = 25.981mm$ diameter of multijet nozzle

$L_m = 154.318mm$ distance from throat to multijet nozzle

$T = 127.279mm$ throat diameter

The reason for choosing a 3 jet nozzle was a practical one since it was difficult to make a 4 jet that would line up with the current exhaust pipes as the enclosing circle of the jets was larger than for a 3 jet. In addition we planned to fit a cast iron petticoat and a stainless steel tapered liner. The calculated distance for the throat from the nozzle turned out to be almost the same as the actual distance from the current single nozzle to the base of the chimney. Interestingly this was much too short by around 140 mm for a properly designed single nozzle. Andrew Barclay (and Orenstein and Koppel) clearly designed the blast arrangements for convenience of tube cleaning and simplicity rather than optimum blast performance.
The original change in diameter from 39mm to 45mm is an increase in area of 33% and should have lowered the back pressure by around 0.8 bar. The change in vacuum is not possible to calculate since the draughting was far from optimum and we do not know whether sonic conditions existed with the original and/or final nozzle size. In practice we actually fitted a three nozzle arrangement that was equivalent to a 46.8 mm single nozzle thus making the nozzle area approximately the same size as the exhaust pipe cross-section. This should improve the back pressure by about another 0.2 bar, in theory, and reduce the vacuum compared to the 45mm equivalent multijet by about 3% (assuming sonic conditions, more if not sonic). It is unlikely to be worth going further in area increase than this. We had some difficulty fitting the chimney liner because the centre line of the nozzles did not coincide with the chimney centreline. However, since the chimney taper was very close to the liner taper we decided to leave the liner out and fit the petticoat in a compromise position with a small gap between it and the chimney. This will be corrected at some future time but will involve new exhaust pipes.

Experimental Results

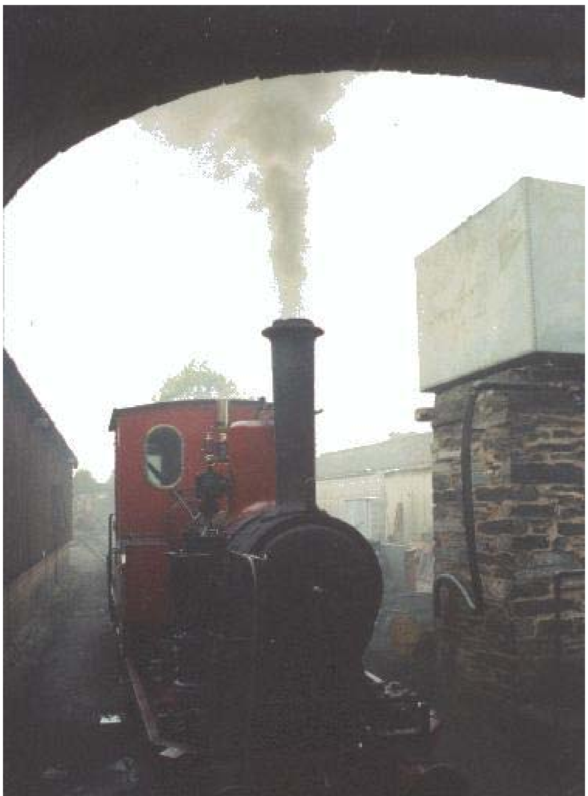
Before making any changes to the draughting we decided to measure the smokebox vacuum and cylinder pressure plotted against time for the engine when climbing a gradient with a substantial trailing load. As we were not interested at this stage in the details of the cylinder events we did not need to measure the piston position and so we plotted rather unconventional pressure v time indicator diagrams. This still gave us the back pressure measurements and also proved to be an illuminating way to look at the cylinder events. Measurements were taken using a Honeywell vacuum transducer connected to the smokebox and a GEMS pressure transducer connected to the front of the left hand cylinder. These were then fed to a two channel digital oscilloscope connected to a laptop computer. The results are shown on the attached representative AC plots. These show that the vacuum has improved by about 20%. Thus on a size for size basis the improvement is about 23%. There is some evidence for a backpressure fall of about the predicted 0.2 bar. Although apparently small this is very significant for the cycle efficiency and for the locomotive operation as it represents about 15% of the normal backpressure. The normal running backpressure is now about 1.3 bar with full regulator and fully notched up. Two other features of note on the plots are a 400-500Hz oscillation in the vacuum when the damper is shut. This is similar to an orchestral A! Also there appears to be a blip in the vacuum reading just

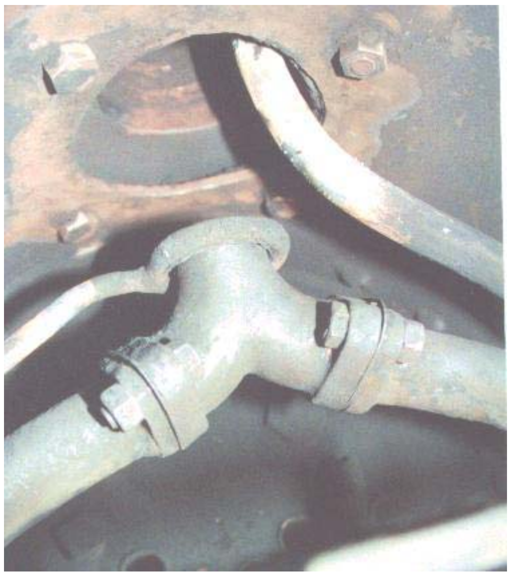
before the main chuff. This could be leakage under the slide valve from the cylinder to exhaust just after the valve opens to live steam.
Although one should be wary of subjective judgements the general feeling from footplate crews is that the steaming is as good or even better than it was before the nozzle liner was removed and it also seems to be more free running. This is as good as we could have hoped for. It will be interesting to see if we notice any change in economy for the engine.

Conclusions

A multijet nozzle clearly is a significant improvement over a single jet in both vacuum and backpressure. We do not know how well a properly designed single jet nozzle in this application would work but within the confines of the present exhaust pipes this would not be possible to do. I suspect the improvement would be small since the original arrangement had the blast hitting the tapered chimney walls at a point well inside the chimney, which would seem to be fairly satisfactory since there was no danger of the blast hitting the edge of the chimney entrance. The range from maximum to minimum vacuum is higher on No 6 than any of the other TR locomotives even in its unmodified form which suggests a relatively efficient system. It is therefore pleasing to see that it can be improved.

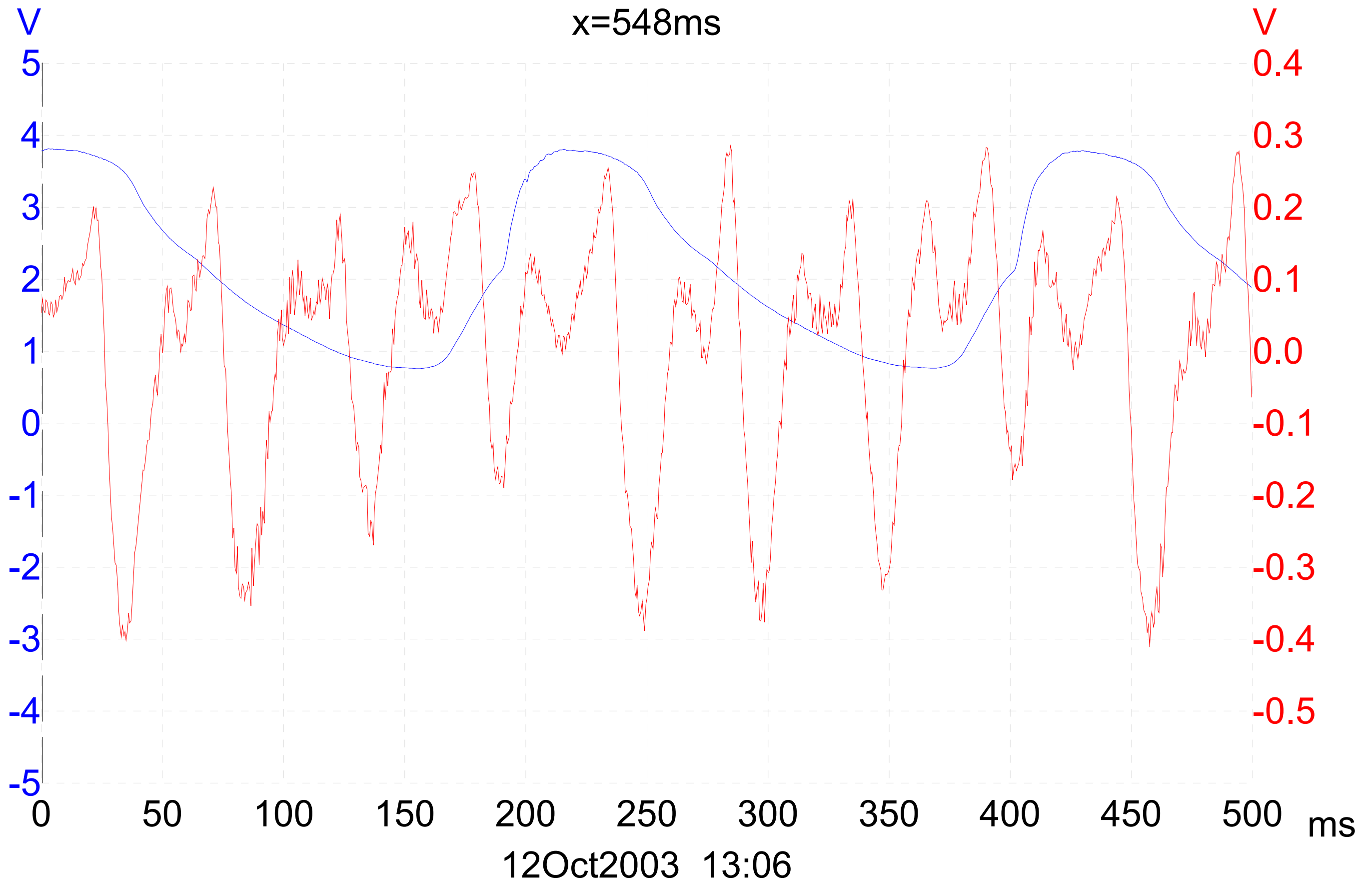
John Scott Nov 12th 2003



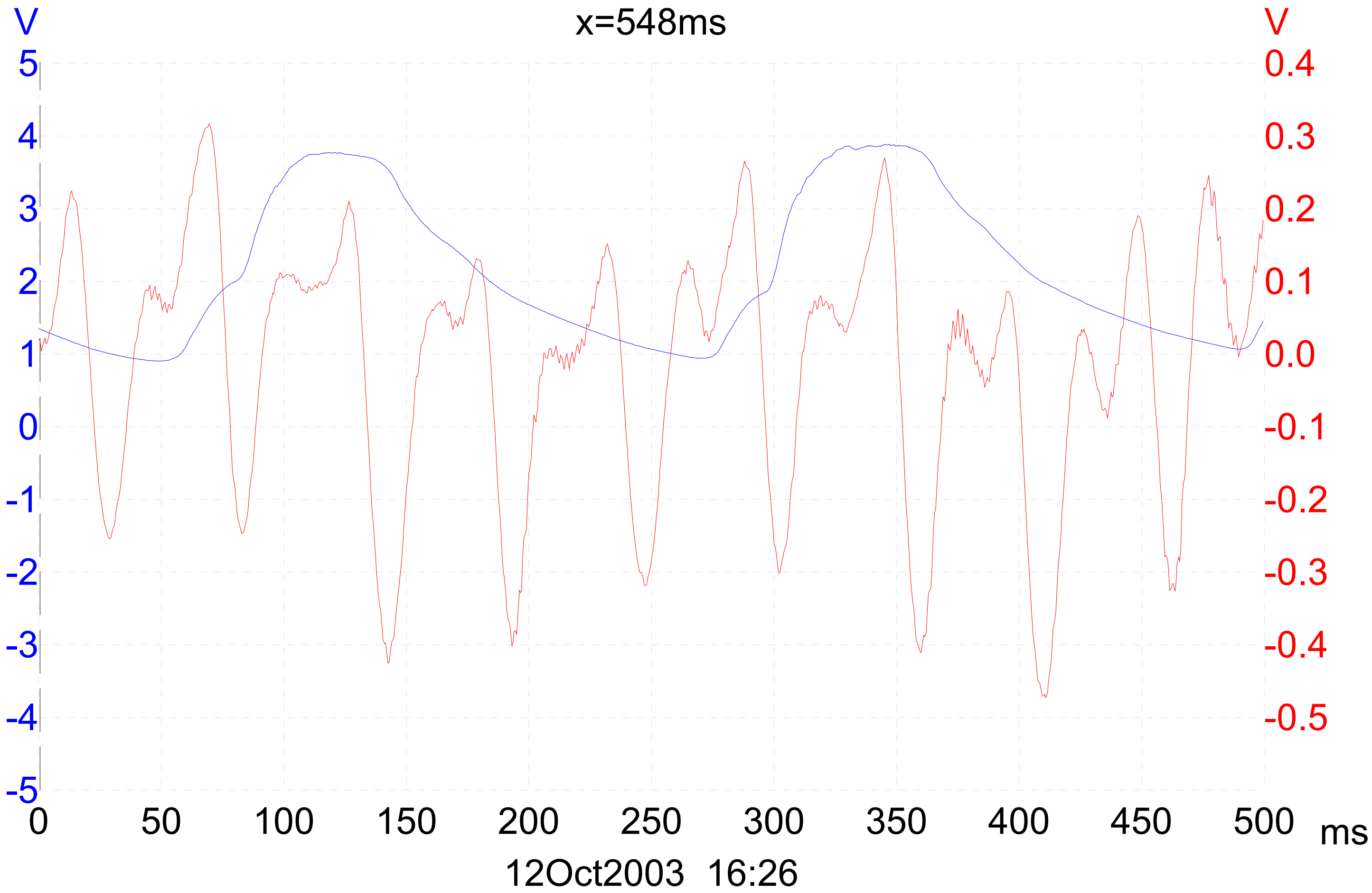


Left: Barclay 0-4-0 well tank loco of 1918, now TR No 6 raises steam outside the Loco shed before testing. The loco is fitted with Walschaerts valve gear and the cylinder steam supply is saturated.

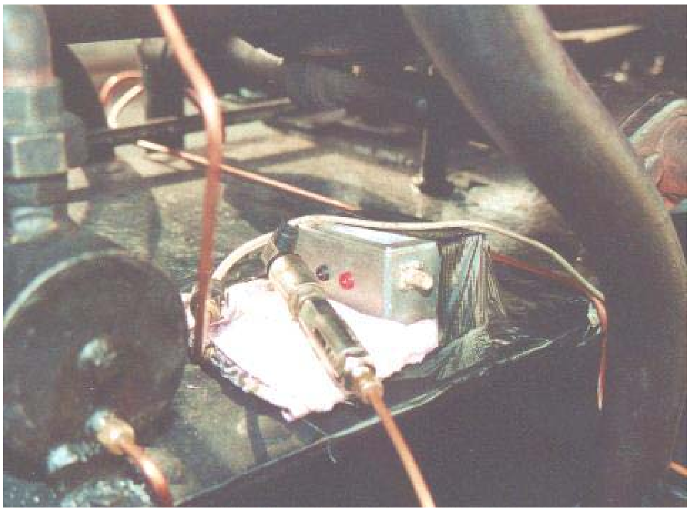
Above: The original blast pipe, blower ring and chimney arrangement. The old sleeve had already been removed from the single nozzle at this time. The pipe to the right side of the chimney is the air pump steam exhaust. Alignment of the exhaust steam pipes is far from ideal.



Loco No6 17.8 mph unmodified damper shut   Max vacuum 20.2 mm Hg, Min 3.2 mm Hg, Av 11.7 mm Hg
Above is AC plot. DC plot was used to calculate above values.



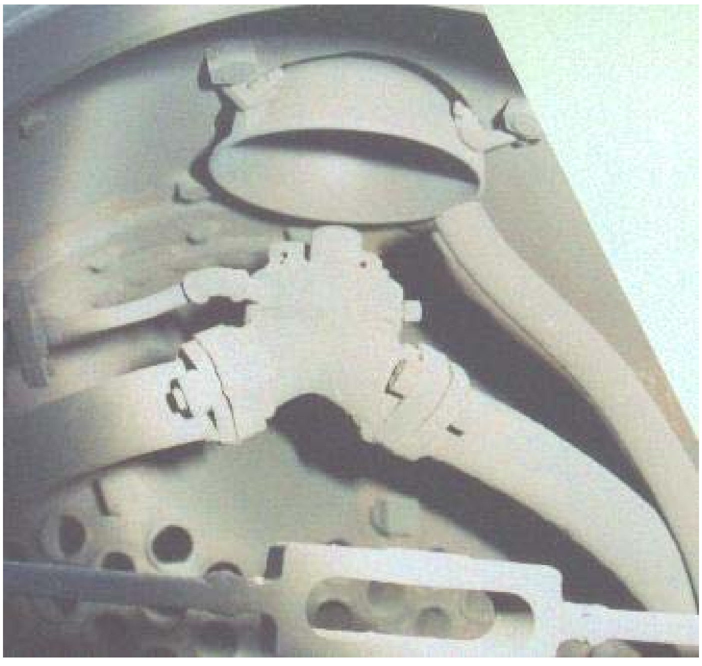
Loco 6 17.8 mph modified damper shut Max vacuum 23.8 mm Hg, Min 3.8 mm Hg, Av 13.8 mm Hg
Plot is of AC signal. DC plot used to calculate above values



Left: GEMS pressure transducer and Honeywell vacuum transducer mounted on the loco's well tank in preparation for testing.

Above and Right: The assembled blast pipe components. The blower is incorporated into the main flange with 3 jets located just outside the retaining screws. Blast nozzles are quickly removed for adjustment or cleaning the assembly.

The whole assembly was internally gas flowed to the maximum extent possible, giving a smooth radiussed entry into each nozzle. This can just be made out on the RH photo.



Right: The final assembly of the new blast pipe and petticoat bellmouth components into the locomotive. It was found to be impossible to align all the components well enough to fit the chimney liner/diffuser without replacing the exhaust steam pipes. It is hoped to undertake this work in the future.
The steam exhaust from the pump has been relocated to reduce smokegas disturbance in the chimney throat.