2005 Beltwide Cotton Conferences, New Orleans, Louisiana - January 4 - 7, 2005

THE BETWEEN INSTRUMENT PERFORMANCE OF TWO UPGRADED FMT MACHINES

G. R. S. Naylor, A. M. Abbott, B. Aspros and S. R. Lucas
CSIRO
Belmont, Victoria, Australia

Abstract

A second upgraded FMT instrument incorporating a 10 gram sample has been manufactured. Comparative trials between the two instruments using both cotton lint samples and the physical standards (the HRS) have been undertaken and gave encouraging results for the technology.

Introduction

An accurate measure of the fineness (fiber weight per unit length) and maturity (degree of development of the fiber wall) of a sample of cotton is desired by both cotton classers and the processing industry. Currently no completely satisfactory commercial instruments are available to meet this need.

One technical approach, the Fineness and Maturity Tester (FMT), was originally developed by Shirley Developments Limited (SDL) and their current model the Micromat High Speed Cotton Fineness Maturity Tester is still available. Montalvo, Faught and Buco (2002) identified and overcame some shortcomings of the existing FMT instrument.

At the Beltwide conference last year, Abbott et al (2004) reported work undertaken at CSIRO and sponsored by Cotton Incorporated to design and build a new prototype FMT instrument incorporating (a) the design features identified Montalvo et al (2002) and (b) increased sample size of 10grams. A block diagram of the instrument is shown in Figure 1 and Figure 2 shows the completed instrument. The instrument is computer controlled with a user friendly windows based PC interface.

The original FMT utilizes empirical relationships to extract average fiber fineness, maturity and Micronaire equivalent values from P_L and P_H readings, the measured pressure drops when air flows through the samples under the so called low and high compression conditions in the sample chamber. Abbott et al (2004) specifically designed the shape and size of the enlarged sample chamber (to incorporate the larger 10 gm sample size) such that the numerical values of the P_L and P_H readings of the new instrument would be the same as those obtained with the original instrument. Abbott et al (2004) confirmed this experimentally thus allowing the original empirical equations to be applied to the new instrument. During 2004 a second prototype instrument has been manufactured and this paper reports the results of comparative trials between the two instruments.

Materials

Six well blended cotton samples representing a range of fiber fineness and maturity samples were used for this study. These cottons were also used in the previous study (Abbott et al 2004).

Results

Leak Checks

Montalvo et al (2001) found that leaks in the air system can be a significant source of error with the FMT and that this needs to be carefully managed. This criterion has been incorporated into the current instrument design as described by Abbott et al (2004).

A simple protocol for testing the integrity of the various seals and connections in the plumbing has been developed. Referring to Figure 1, the flow controller acts as a valve in the off position when not operating. Thus, under these conditions, it is possible to pressurize the system simply by manually inserting a plug of suitable size into the top of the test chamber. The plug was designed (a) with an O-ring seal and (b) of sufficient size to reduce the chamber volume giving a pressure value in the range of interest. Recording the pressure over time is then a simple test that takes less than a minute. Figure 3 shows a typical read out over time. With the instrument empty and at the rest position, the test was giving a pressure value in the range of interest. Recording the pressure over time is then a simple test that takes less than a minute. Figure 3 shows a typical read out over time. With the instrument empty and at the rest position, the test was started at approx 11:08:05 with the introduction of the plug. There was an initial rapid rise in pressure with the pressure reading going off the scale of Figure 1. This then rapidly decayed to a steady state value within about 5 seconds i.e. at approx. 11:0810. The drift in the steady state pressure reading was approximately only 1 mm of H_2O over the subsequent minute. The test was ended at 11:09:10 with the removal of the plug and the pressure reading dropped rapidly to zero.

Preliminary Cotton Results

Montalvo at al (2001) developed a detailed daily protocol for instrument calibration and sample preparation etc and obtained good inter-machine agreement. One rational in the present work was to evaluate the potential of the upgraded instrument without the need for such detailed sample preparation and daily calibration etc. Hence comparative trials of the two instruments were undertaken with six test cottons relying on the manufacturer's calibration of the pressure sensors and flow meters. Cotton samples were prepared with one pass through the Shirley analyzer and after weighing (sample mass 10.0g) the sample, in one piece was simply manually 'stuffed' into the measurement chamber. Figures 4 to 8 show the average results from five repeat measurements for each cotton. The agreement between instruments for the P_L and P_H values and the three derived parameters is encouraging.

Further Detailed Calibration and Comparison using the Headspace Resistance Standards

Apart from mechanical leaks, other potential sources of errors arise from the two devices in the FMT, the pressure transducer and the flow meter. The accuracy and consistency of these devices were checked as follows.

The Headspace Resistance Standards (HRS) developed by Montalvo and Faught (1999) were used as a set of physical standards for testing and comparing the two instruments. The set, kindly loaned to CSIRO by Cotton Inc. for this project, is shown in Figure 2 sitting on top of an FMT instrument. It consists of six different lengths of metal tubing that can be separately connected to the instrument by a series of valves to simulate different air flow resistances. Montalvo and Faught (1999) used these to simulate P_L and P_H readings corresponding to low, medium and high micronaire cottons and carefully obtained specific reference values for the different readings i.e. three tubes for P_L readings and three for P_H readings.

(a) Calibration of the pressure transducers

The consistency of the factory calibration of two pressure transducers (to be used in the two instruments) was checked by temporarily connecting both pressure transducers to one instrument and monitoring both transducers during a run of the instrument with the HRS. The computer was set up to sample each transducer every half second and the time data is shown in Figure 9. In this figure at time zero the instrument is in the resting start i.e. before the start of a test and includes switching between several of the HRS tubes. The data from both transducers tracked very well as shown in the regression analysis shown in Figure 10 confirming the suitability of the pressure transducers for this application. It was deemed not necessary to further refine the calibration of the transducers i.e. through software adjustments.

(b) Initial results with the HRS

Figures 11 and 12 compare the results from the two instruments using the HRS unit. (Of the six separate tubes in the HRS, three are used for P_L reading and three fro P_H readings), These results were obtained using the initial calibration of the flow meters as supplied by the manufacturer. The regression between the two machines is very good ($R^2 > 0.99995$) however there is a small consistent difference between the two instruments particularly for the P_H values.

(c) Detailed recalibration of the flow controllers

As the flow meters are active devices, unlike the pressure transducers, it was not possible to undertake a simple check with both connected to the one instrument. Instead, given the confidence in the equivalence of the pressure readings, the six HRS readings were determined on both instruments separately and this data used to check and calibrate the flow meters as follows.

Given the good agreement between the pressure transducers from the two instruments (e.g. Figure 10) it was assumed that the observed small but statistically significant differences from 1.0 in the slopes in Figures 11 and 12, i.e. the comparison of the two instruments arose from small differences in the calibration of the two flow controllers. Equally the small non zero intercepts in Figures 11 and 12 are interpreted as arising from small differences in the 'internal resistance' to airflow of individual instruments due to minor differences in the length or size of components of the 'plumbing' systems. Based on this, the nominal flow rates of the second instrument were adjusted in an iterative manner in an endeavor to bring the two instruments into better alignment. The criterion was that the slopes in the equivalent to Figure 11 and 12 should be within 0.5% of 1.00). This was achieved in two iterations with an adjustment of the flow rates less than 5%. With this small recalibration of the flow controller of the second instrument , Figures 13 and 14 show the results of five new repeat measurements of the HRS plotted this time against the nominal values (Montalvo et al 2001). In these two figures individual results are plotted but the scatter between the 5 replicates is smaller than the symbols using in the figures and so it is not visible. The magnitude of the variation between replicates is depicted in Figure 15, the residuals from the four regression lines. The small differences from 1.00 in the slopes of the regression lines in Figures 13 and 14 can be interpreted as small differences in the 'calibration' of the flow rates in the current instruments as compared to the instrument used to determine the nominal values. Secondly the small non-zero intercepts of the regression lines can again be interpreted as arising from small differences in the 'internal resistance' to airflow of individual instruments due to minor differences in the length or size of components of the 'plumbing' systems. Given the experimental precision of the values of the slopes in Figures 13 and 14 it would appear that a further small iteration of the nominal flow rates in the second instrument could achieve an even better alignment of the two instruments if required.

Conclusion

A second upgraded FMT prototype instrument incorporating a 10 gram sample size has been manufactured and the results of comparative tests between the two instruments are satisfactory.

Acknowledgements

The authors gratefully acknowledge that the work presented in this paper has been financed by Cotton Incorporated- the research and marketing company representing America's cotton producers. The authors would also like to acknowledge the expert technical assistance of N. Phair and S. Miller

References

Abbott, A.M., S.R. Lucas, G.R.S. Naylor and C.R. Tischler. 2004. Design and Implementation of an Upgraded FMT Incorporating a 10 Gram Sample. Proc. Beltwide Cotton Quality Conference, San Antonio (CD).

Montalvo, J.G. and S.E. Faught. 1999. Headspace resistance standards for the Shirley Developments Ltd FMT. Text. Res. J. 69(4):269-277.

Montalvo, J.G., T.M. Von Hoven, S.S. Reed, D.L. Francois and S. Faught. 2001. Organizational and instructional manual for the Micromat Tester. USDA, ARS, Southern Regional Research Center, New Orleans, LA.

Montalvo, J.G., S.E. Faught, and S.M. Buco. 2002. Sensitivity of the Shirley Developments Ltd. Micromat Tester to operators and sample preparation. J. Cott. Sci. 6:133-142.

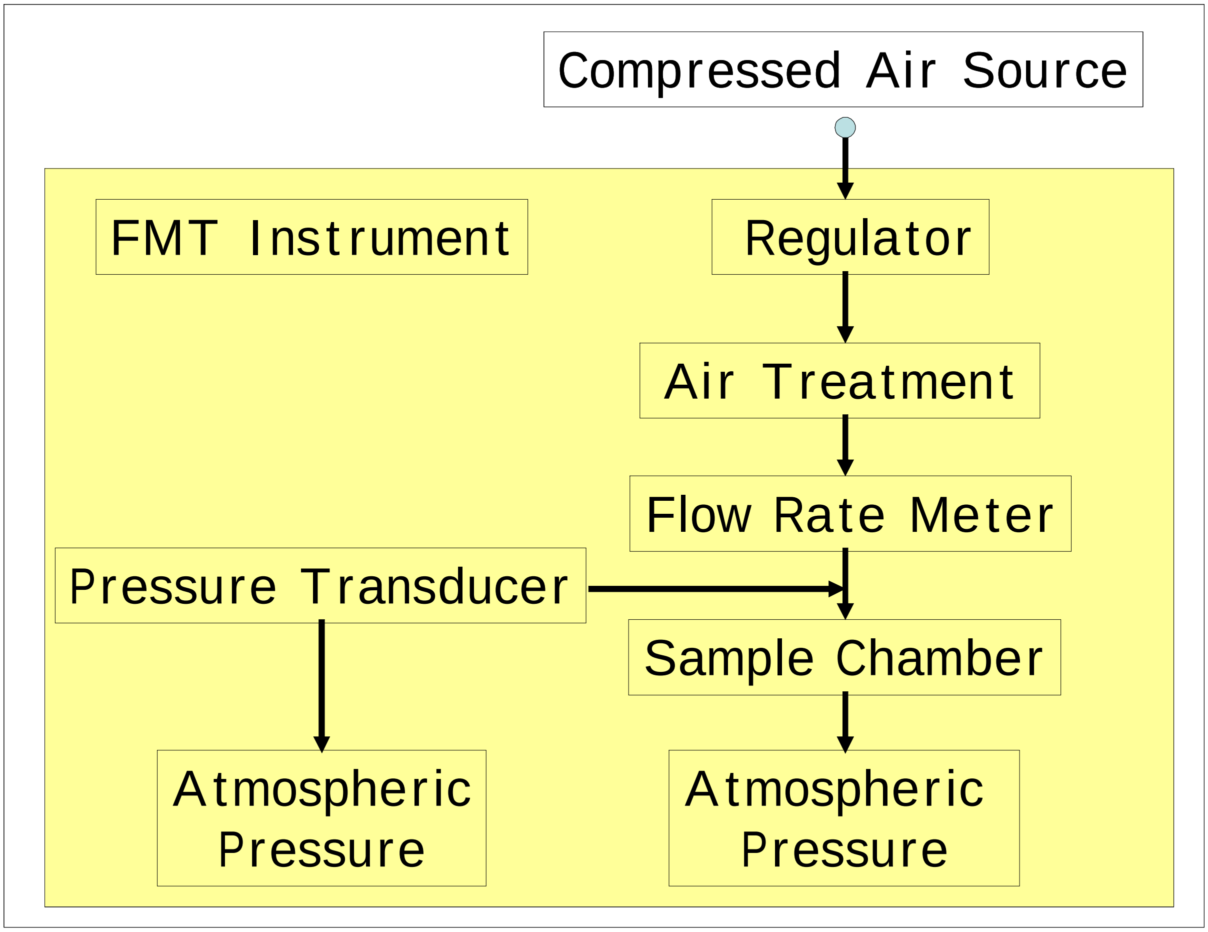

Figure 1. Block diagram of instrument.

Figure 2. The new prototype FMT instrument

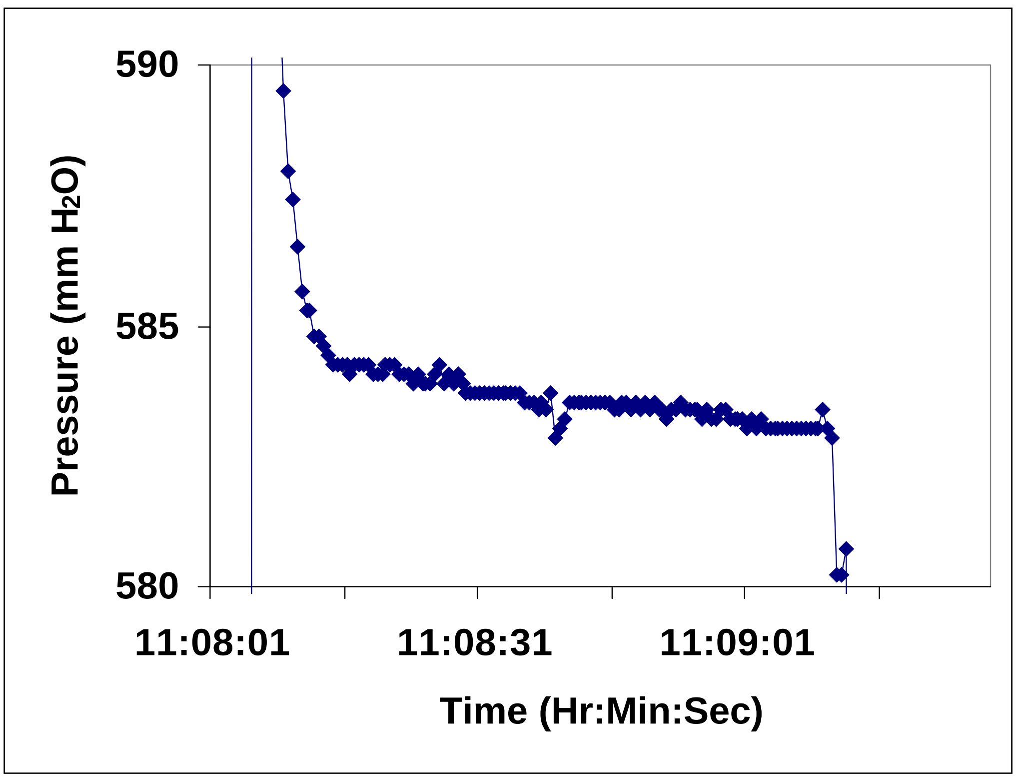

Figure 3. Example of results from a ‘leak’ test.

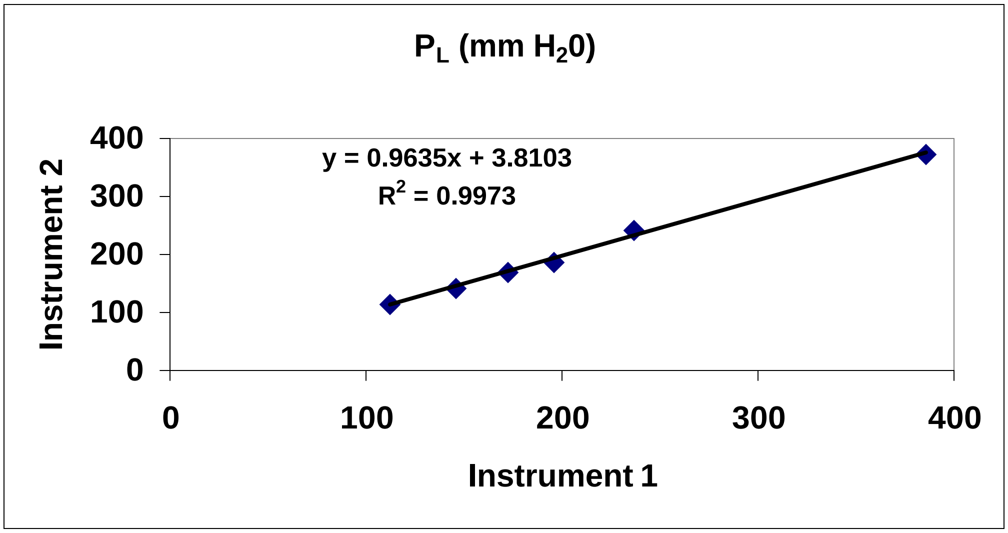

Figure 4. Average P_L results comparing the performance of the two instruments for 6 different cottons (n= 5).

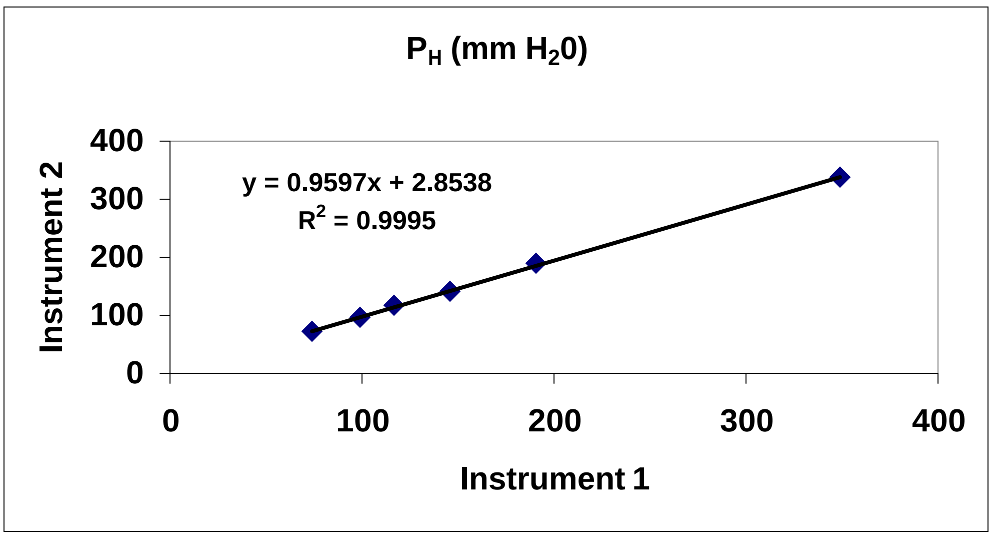

Figure 5. Average P_H results comparing the performance of the two instruments for 6 different cottons (n = 5).

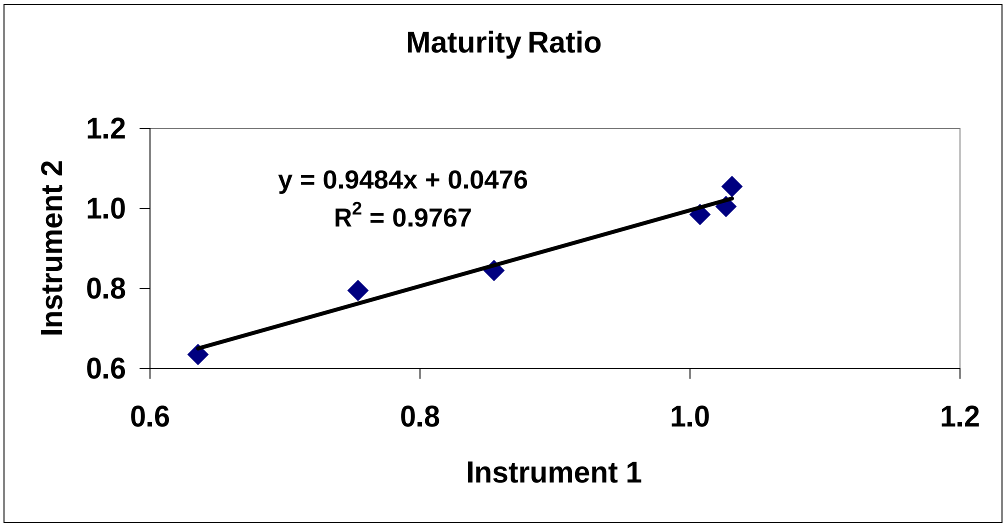

Figure 6. Average maturity results comparing the performance of the two instruments for 6 different cottons (n=5).

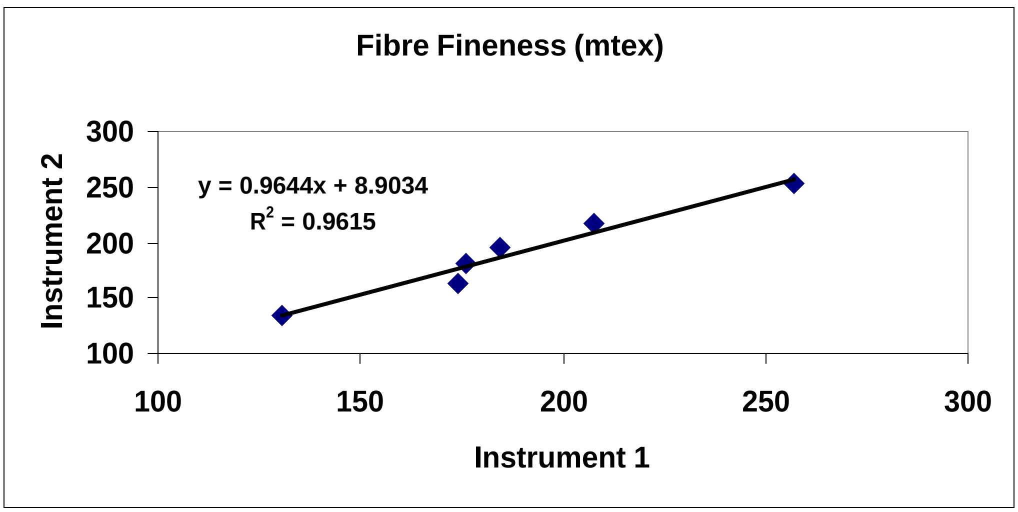

Figure 7. Average fiber fineness results comparing the performance of the two instruments for 6 different cottons (n=5).

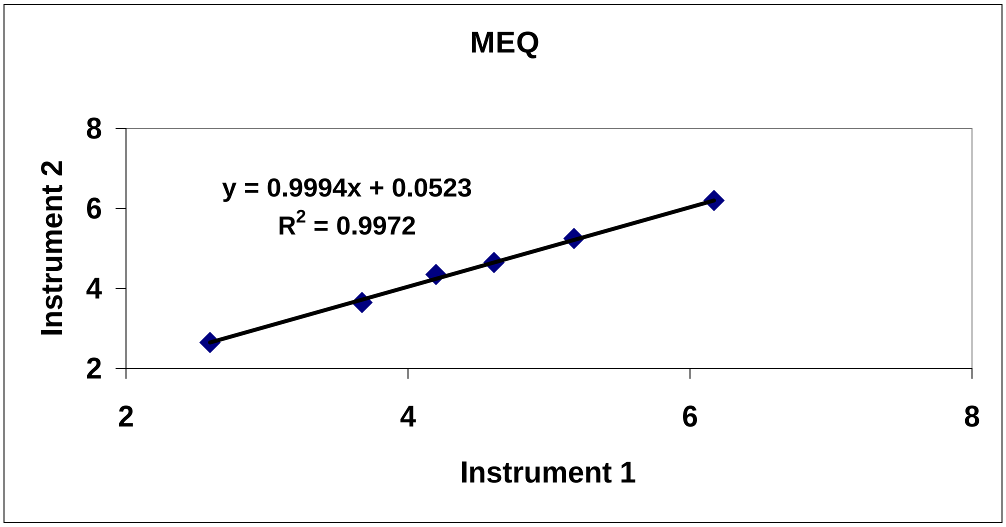

Figure 8. Average FMT Micronaire values comparing the performance of the two instruments for 6 different cottons (n= 5).

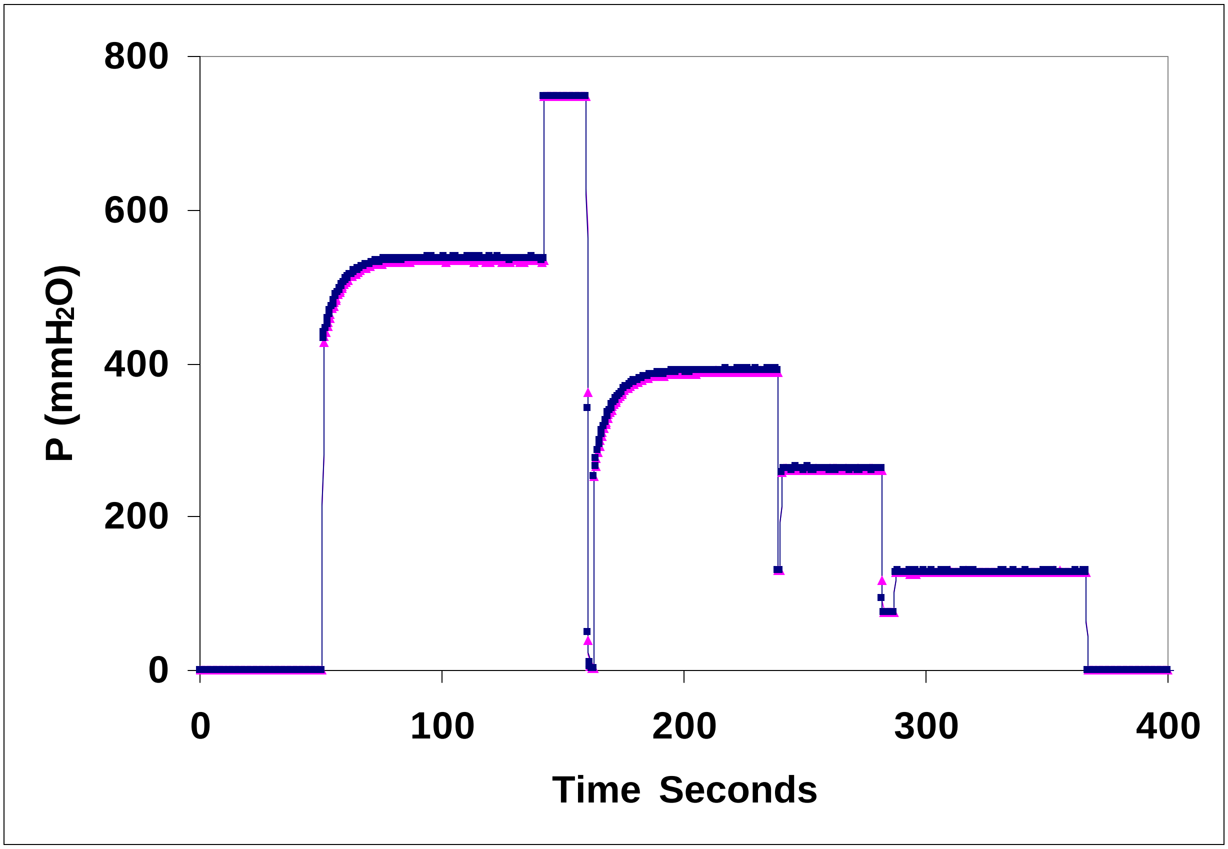

Figure 9. Simultaneous response of both transducers to a series of HRS tests.

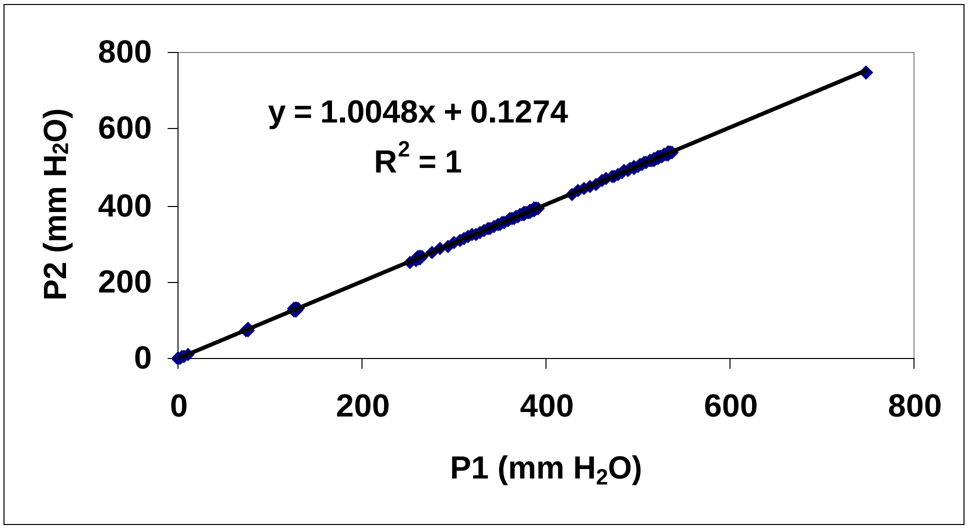

Figure 10. Comparison of the two pressure transducers using the data from Figure 9.

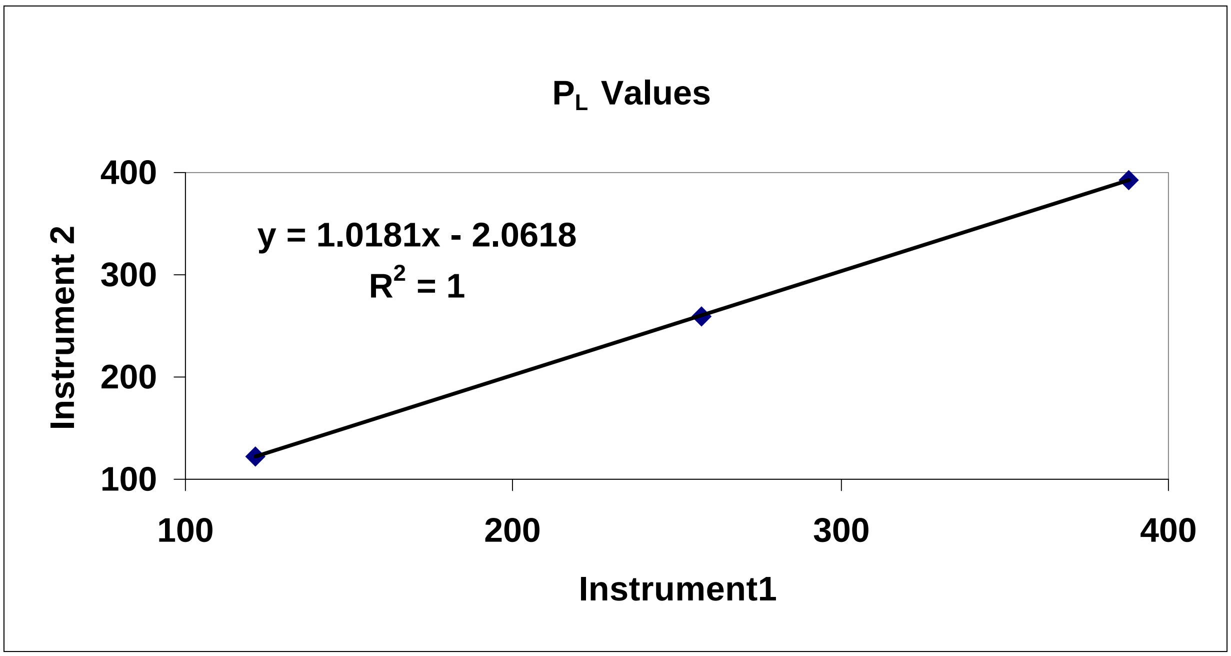

Figure 11. Comparison of average (n=5) P_L values from HRS tests with the initial (factory) calibration of flow meters.

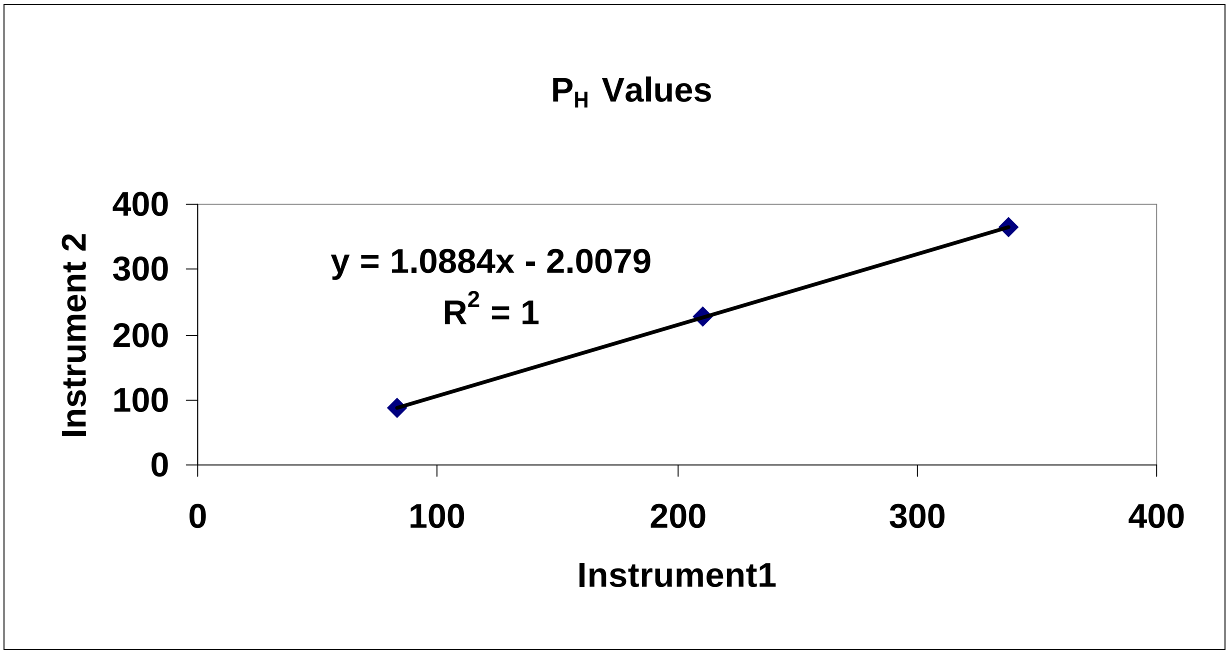

Figure 12. Comparison of the average P_H values (n=5) from HRS tests with the initial (factory) calibration of flow meters.

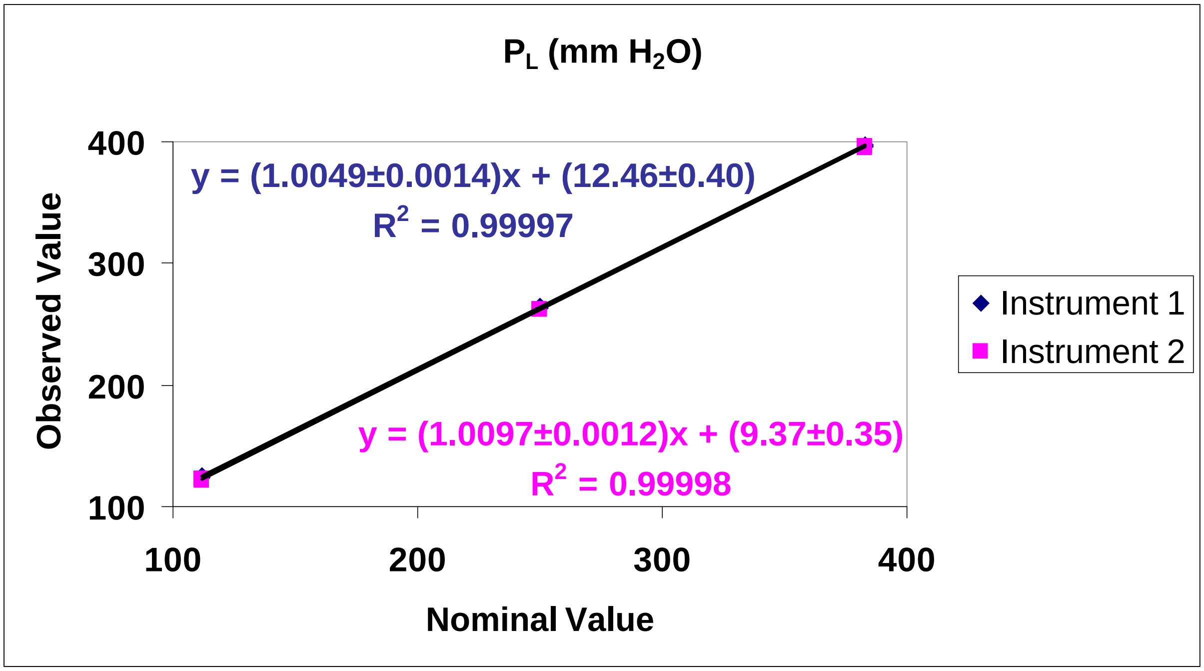

Figure 13. Comparison of P_L values from HRS tests with the nominal values after re-calibration of flow meters (n=5).

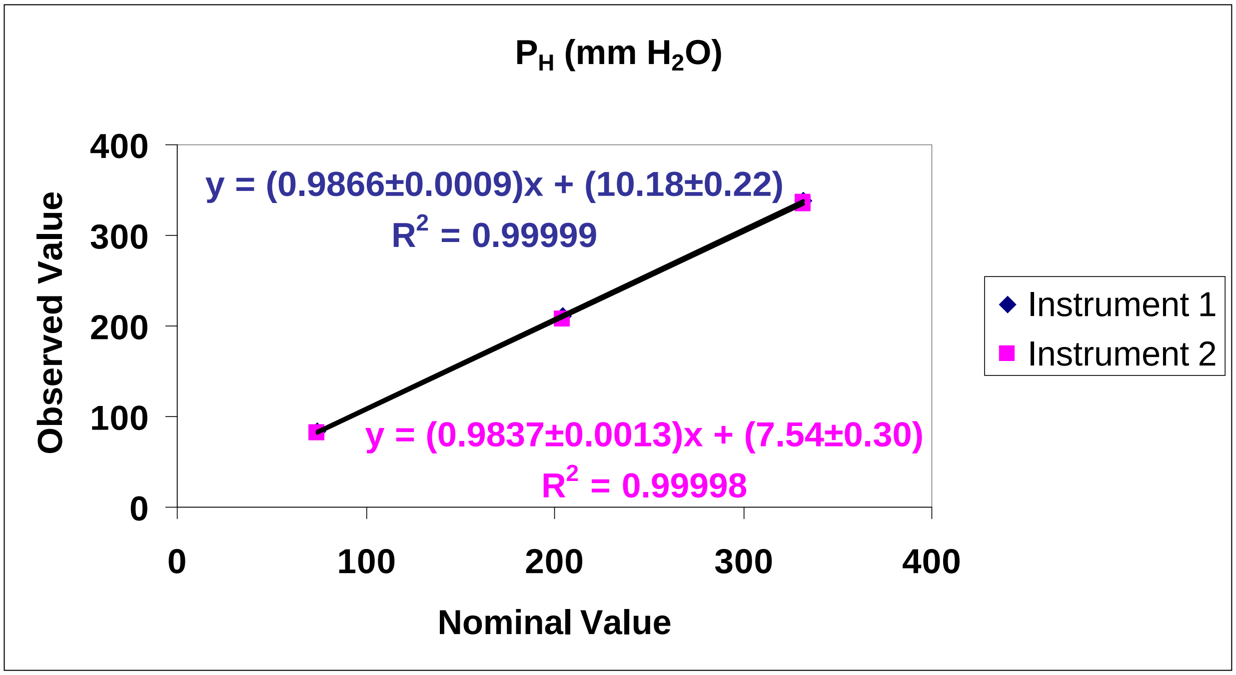

Figure 14. Comparison of P_H values from HRS tests with the nominal values after re-calibration of flow meters (n=5).

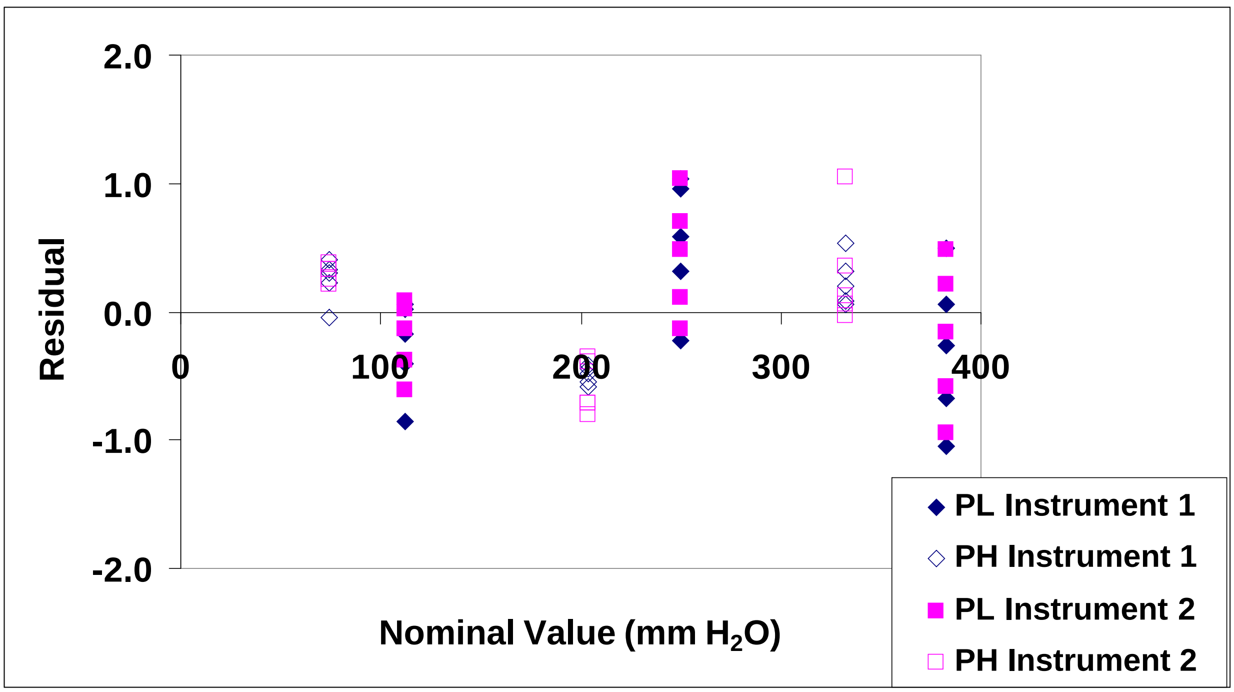

Figure 15. Residuals from the regressions in Figures 13 and 14.