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TURBIDITY METER TRIAL

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BACKGROUND

United Water is faced with the impending replacement of 20 turbidity analysers over the next two years. Consequently, we set out to determine the most appropriate analyser for the purpose of measuring turbidity of filter outlet and treated water.

Traditionally these instruments have been ranged 0 to 2 NTU which provides suitable accuracy and resolution around the nominal measurement range 0.1 to 0.2 NTU while having enough 'headroom' to providing important data on non-conformances. This range became the first specification for the test requirements. Our QA dictates accuracy and some requirements for calibration. These resulted in the specification used in this test.

1.0 WHAT IS TURBIDITY?

Turbidity is the measure of the light scattering properties of water. It is measured in nephelometric turbidity units (NTU).

The standard for calibration of turbidity measurement devices is by a Formazin suspension. A standard suspension of Formazin is made up using solutions of hexamethylenetetramine [$(CH_2)_6N_4$] and hydrazine sulphate [$(NH_2)_2.H_2SO_4$]. A 4000 NTU primary standard suspension is made using a standard recipe and diluted to an appropriate strength.

So how are Low Range turbidity meters calibrated?

- Formazin standard is diluted for calibration of low range instruments.

There are limitations to how far Formazin can be diluted. The following factors affect how much can be diluted and still be regarded as an accurate standard:

- the turbidity of distilled water used for dilution;
- atmospheric contaminants; and
- the self life of the resultant suspension.

For these reasons we calibrate (or check calibration) at much higher levels than we measure at. We generally calibrate above 10 NTU, yet measure below 0.2 NTU and we rely on an accurate zero and the linearity of the instrument to provide low turbidity accuracy.

Turbidity meters are typically zeroed by one of the following methods:

- calibrate in air;
- turn the off light source; or
- filter process water to 1 micron or less.

There is NO true test for absolute zero NTU.

For the trial some assumptions needed to be made, the major assumption being that our Hach 2100N laboratory turbidity meter is accurate.

This assumption is possible because the meter is:

- calibrated at, 20, 200, 1000, 4000 NTU every 3 months by the Australian Water Quality Centre;
- zeroed in air; and
- verified by "blind" tests administered by the Australian Water Quality Centre every 4 weeks.

2.0 METHOD

A range of suppliers were contacted and invited to provide turbidity analysers for trial based on the following specification:

Range:	0 to 2 NTU
Accuracy:	0.02 NTU
Repeatability:	0.02 NTU
Resolution:	0.01 NTU
Slight source:	White light
Process connection:	Pipe/tube connected

The following six instruments were offered:

- Endress & Hauser Turbimax CUE21
- Yokogawa TB750G
- Sigris
- Hach 1720E series 2
- ABB 4670series
- Rosemount Clarity 11 Model T1055

These instruments shall be referred to as units A, B, C, D, E, & F (in no specific order) in this paper, so that the results remain anonymous.

The instruments were installed at Happy Valley Water Filtration Plant and connected to the discharge of a filter outlet sample stream. All instruments were either delivered calibrated or were calibrated on site upon installation.

A process connection to settled water was later made and a 20 litre vessel installed as a mixing chamber as shown in the diagram below. This allowed mixtures of settled water and filtered water to be used to produce variations in the sample water turbidity.

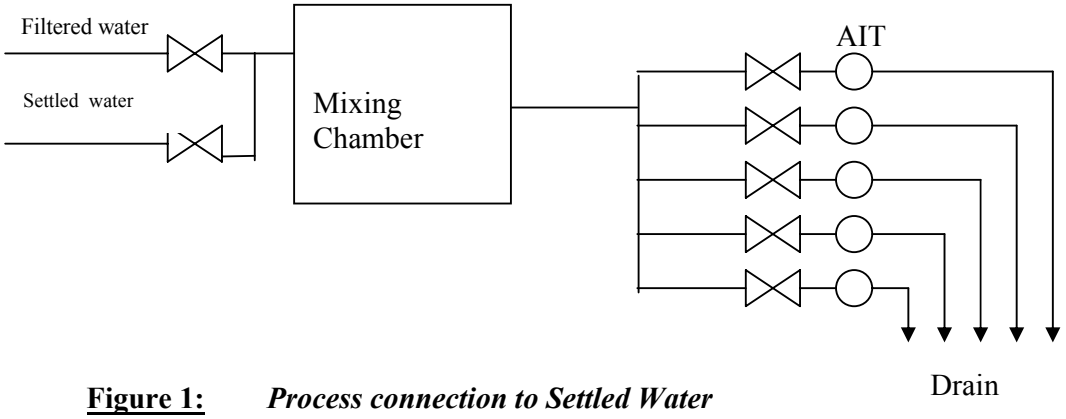

Figure 1: ***Process connection to Settled Water***

The instruments were kept on line and samples were taken for laboratory tests daily. These laboratory tested samples provide a measure of accuracy for our tests. When an instrument deviated from the laboratory reading by 0.05 NTU or more an adjustment was made in accordance with our operations QA methods.

3.0 SAMPLING METHOD

Samples were taken from the discharge of each of the test instruments. In each case two samples were taken for each test. Readings were recorded from each test instrument before and after sampling to ensure a steady consistent reading during sampling. The sample bottles were cleaned then double rinsed with the sample prior to sample collection. Care was taken to ensure no movement or disturbance to sample pipework before or during sampling. Where the two readings varied by more than 0.05NTU the results were discarded and the sampling was repeated.

4.0 COMPARISON WITH LAB TESTS

Comparisons between laboratory tests on grab samples and test instrument readings are based on the average of the two readings collected as described above. Full results are shown in Appendix 1 and a summary of calculated errors is shown below:

Meter	Average Error (NTU)
A	0.020
B	0.025
C	0.018
D	0.016
E	0.031
F	0.013

5.0 COST

The cost of each instrument is summarised below together with the cost of a replacement light source (one of the few wearing components). Pricing is based on 1off supply.

Table 1: ***Comparison of Purchase and Light Source Replacement Costs***

Instrument:	A	B	C	D	E	F
Purchase Cost:	$3,000	$2,590	$4,445	$3,480	$9,895	$2,950
Replacement Light Source:	TBA	$290	$90	$394	$260	$725

6.0 MAINTENANCE REQUIREMENTS

Periodic maintenance required varies from instrument to instrument. In each case the manufacturer recommends a specific frequency of periodic maintenance and often suggests regulating this based on operator experience. United Water has its own QA requirements which override recommendations for maintenance frequencies lower than ours. The resultant frequency of maintenance is therefore similar for all instruments. The approximate time taken to carry out this maintenance is tabulated below. Times are based on my personal experience during the trial and may differ once experience with each instrument is gained.

Frequency of two point calibration is also recommended by the manufacturer, although frequencies less than three monthly are over ridden by United Water's QA requirement for quarterly calibration. As a consequence all instruments tested can be regarded as requiring two point calibration every three months, with the exception of one instruments which self calibrates daily. Times taken to complete a calibration are also tabulated below.

Table 2: ***Comparison of Purchase and Light Source Replacement Costs***

Instrument:	A	B	C	D	E	F
Calibration	20 min	60 min	30 min	**90 min	N/A	30 min
Maintenance	10 min	15 min	30 min	20 min	30 min	15 min

***Unit 'D' requires a 1 micron in line filter to provide "zero" NTU Water, when installed this will greatly reduce calibration time (est 40-60 min)*

7.0 SPEED OF RESPONSE

During the test period a number of step changes were made by introducing settled water. This typically produced a short duration spike in turbidity as biofilm/sediment in the sample lines is disturbed. The turbidity then settles to the new value. Because each instrument has differing sample flow rates and detention times each has a different response characteristic. Typical response to change is indicated by the graphs below. In each case Unit 'F' and 'D' respond the quickest while unit 'B' is consistently the slowest to respond.

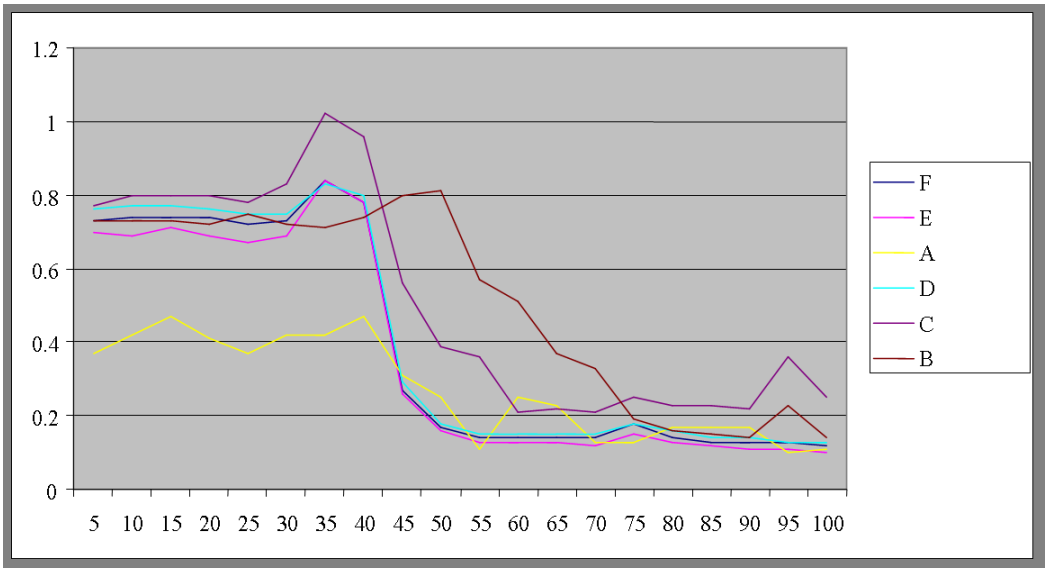

Figure 2: ***Typical Response Curve Version 1***

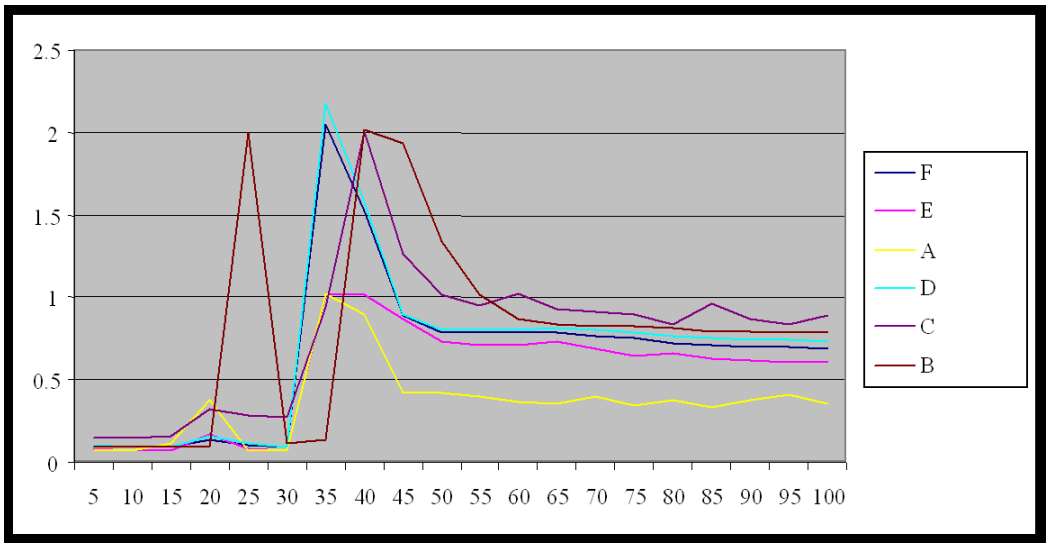

Figure 3: ***Typical Response Curve Version 2*** (NB x-scale in minutes)

8.0 CONCLUSIONS

These are all 'top-end' instruments and all perform similarly.

- Unit E was most expensive, had no means of comparative calibration and was the least accurate.
- Unit D had the least efficient (for time) zero method, which required filtering the sample stream and laboratory testing the resultant water. Yet the supplier suggests they have the only true zero calibration.
- Of the others you can take your pick based on experience, pricing (for the project at hand), etc.

…. Which is precisely what we did

APPENDIX 1: TRIAL RESULTS

	A	B	C	D	E	F	Lab
	0.11	Not yet received	Not yet received	Not yet received	0.0115	0.11	0.096
	0.11				0.109	0.11	0.094
Error	-0.024				0.020	0.015	
	0.080	0.092	0.128	0.123	0.101	0.140	0.105
	0.080	0.090	0.122	0.124	0.104	0.130	0.103
Error	-0.024	-0.013	0.021	0.020	-0.001	0.031	
	0.320	1.698	0.360	0.358	0.361	0.360	0.318
	0.320	1.321	0.355	0.354	0.360	0.350	0.322
Error	0.000	1.190	0.038	0.036	0.041	0.035	
	0.22	0.267	0.277	0.277	0.23	0.26	0.266
	0.21	0.267	0.273	0.273	0.226	0.25	0.267
Error	-0.052	0.001	0.009	0.009	-0.039	-0.012	
	0.22	0.195	0.164	0.213	0.168	0.2	0.203
	0.21	0.195	0.167	0.21	0.174	0.2	0.204
Error	0.0115	-0.0085	-0.038	0.008	-0.0325	-0.0035	
	0.17	0.166	0.111	0.165	0.219	0.15	0.168
	0.17	0.159	0.109	0.161	0.128	0.15	0.173
Error	0.000	-0.008	-0.061	-0.007	0.003	-0.021	
	0.1	0.07	0.08	0.08	0.062	0.08	0.087
	0.1	0.072	0.081	0.081	0.066	0.08	0.084
Error	0.015	-0.015	-0.005	-0.005	-0.022	-0.005	
	0.11	0.068	0.082	0.085	0.071	0.09	0.084
	0.12	0.066	0.082	0.087	0.072	0.09	0.087
Error	0.030	-0.019	-0.003	0.001	-0.014	0.005	
	0.17	0.156	0.173	0.169	0.132	0.16	0.172
	0.17	0.058	0.164	0.169	0.135	0.16	0.178
Error	-0.005	-0.068	-0.007	-0.006	-0.042	-0.015	
	0.1	0.069	0.085	0.138	0.064	0.08	0.094
	0.11	0.069	0.085	0.082	0.06	0.08	0.092
Error	0.012	-0.024	-0.008	0.017	-0.031	-0.013	
	0.61	0.762	0.665	0.694	0.579	0.66	0.67
	0.6	0.738	0.651	0.692	0.57	0.66	0.655
Error	-0.058	0.087	-0.005	0.030	-0.088	-0.003	
	0.68	0.693	0.687	0.724	0.632	0.7	0.705
	0.69	0.678	0.705	0.736	0.66	0.71	0.7
Error	-0.017	-0.017	-0.006	0.028	-0.056	0.003	