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INTRINSIC ERROR OF INDICATION TEST REPORT

MACE FloPro 3 INSERTION METER S/N 3515 IN DN300 PIPE

Report MHL2123
March 2012

Measuring and Control Equipment Pty Ltd

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Foreword

This report describes testing to determine the error of indication of a MACE FloPro 3 flowmeter at a number of flow rates when installed in a DN300 pipe. The testing described in this report was undertaken by NSW Public Works' Manly Hydraulics Laboratory (MHL) for Measuring and Control Equipment (MACE) Pty Ltd.

Robert Cook was the MHL project manager and undertook all testing described in this report and prepared this report.

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Contents

1. Introduction

Flowmeters used in irrigation are not currently required to be pattern approved but will be in the future. Requirements for pattern approval will be set by the National Measurement Institute (NMI). NMI will be informed of an intention to submit a water meter for pattern approval prior to submission and NMI will set specific testing requirements. General requirements, including testing requirements, for meters in full flowing pipes are described in NMI documents NMI M 10 *Meters Intended for the Metering of Non-Urban Water in Full Flowing Pipes*, *Part 1: Metrological and Technical Requirements, Part 2: Test Methods, Part 3: Test Report Format*. To gain pattern approval flowmeters which are essentially self-contained with their own geometry and which are normally pattern approved and verified as a single unit will be required to operate with a maximum permissible error (MPE) of 2.5%. Meters consisting of one or more measurement transducers and a computational device which are separately pattern approved and verified shall be manufactured and installed such that the maximum expanded uncertainty in the determination of the volume of water shall not exceed ±5%.

MHL has constructed a facility to undertake pattern approval testing of irrigation flowmeters. A necessary requirement for pattern approval testing will be that the facility has NATA accreditation to AS17025. MHL is currently seeking such accreditation and expects to achieve accreditation in the immediate future. MHL currently undertakes testing to establish the errors and head loss characteristics of irrigation meters. Testing is carried out in the facility for which accreditation is being sought, however, the total suite of testing carried out is generally not that required by NMI for pattern approval and is not recognised as pattern approval testing.

NMI defines testing requirements in terms of Q_1 (the lowest flow rate at which the meter is required to operate within the MPE), Q_3 (the highest flow rate within the rated operating conditions at which the meter is required to operate in a satisfactory manner within the MPE) and Q_4 (the highest flow rate at which the meter is required to operate for a short period of time, (1 hour in any 24-hour period), within its MPE, whilst maintaining its metrological performance when it is subsequently operated within its rated operating conditions). Q_1 for this testing was 40 L/s, Q_3 was 400 L/s and Q_4 therefore 500 L/s. Under NMI requirements the manufacturer and the approving authority shall agree upon a desired level (and range) of water quality before the commencement of testing. This was not done in this case and testing was carried out with re-circulated water originally from Manly Dam.

This report describes testing of a MACE FloPro 3 insertion flowmeter (serial number 33515) to determine its intrinsic error of indication under normal flow conditions in a DN300 pipe at pressures less than 253 kPa. The testing described in this report does not describe

performance in any other situation. The meter was in new condition. Testing described in this report was carried out by Robert Cook on 22 December 2011, 3 and 4 January 2012 and 28 February 2012.

The testing methodology is described in Section 2, results are presented in Section 3 and conclusions presented in Section 4. Reference instrument calibrations are presented in Appendix A. Sample uncertainty calculations are presented in Appendix B.

2. Methodology

2.1 General

Testing was undertaken in the Know-the-Flow testing facility with temperature and humidity controlled by air conditioning. Water from a 1.5 ML in-ground tank was re-circulated by pump through the test rig and returned to the in-ground tank. Water temperature, ambient temperature and water conductivity were logged at 1-second intervals throughout testing. Water quality was estimated to be of similar quality to water that the meter would encounter in service.

For all tests the flow rate was measured using a DN300 MHL master flowmeter (3K22/8755). The maximum flow rate at which the reference flowmeter was last calibrated was less than in previous calibrations due to a temporary restriction on maximum flow rate at the calibrating facility brought about by damage to a pump, however from previous calibrations it is believed that the accuracy of the reference flowmeter at higher flow rates is similar to that within the range calibrated.

2.2 Intrinsic Error of Indication in DN300 Pipe

The requirements for determination of intrinsic errors of indication for non-urban flowmeters undergoing pattern approval testing are described in NMI M 10-2, March 2011. Part of this testing requires determination of the intrinsic error of indication of a meter at standard reference conditions at the following flow rates with each test undertaken at least twice:

Q_1 - $1.1Q_1$ (40.0–44.0 L/s for this meter)

$0.33(Q_1 + Q_3)$ - $0.37(Q_1 + Q_3)$ (145.2–162.8 L/s)

$0.67(Q_1 + Q_3)$ - $0.74(Q_1 + Q_3)$ (294.8–325.6 L/s)

$0.9Q_3$ - Q_3 (360.0–400.0 L/s)

$0.95Q_4$ - Q_4 (475.0–500.0 L/s).

Testing in this report was carried out using the methodology described in the relevant sections of MHL work instruction MHI_CCOND which complies with the methodology described in NMI M 10–2. Testing was undertaken at the flow rates shown in Table 3.1 which comply with those shown above. All testing reported was undertaken at pressures at the flowmeter less than 253 kPa in compliance with the MACE product manual for this device. The pressure in the pipe was measured manually, at the start and end of each test, upstream and downstream of the meter under test.

The meter was installed in a DN300 steel pipe at Point A as shown in Figure 2.1. Photos of the flowmeter are shown in Figure 2.2.

2.3 Data Logging

The following data was logged to the MHL PC at 1-second intervals utilising Labview software:

- date and time
- number of pulses generated by master meter in preceding second with each pulse representing 1 L
- data generated by the meter under test
- water temperature and ambient temperature and relative humidity in testing building.

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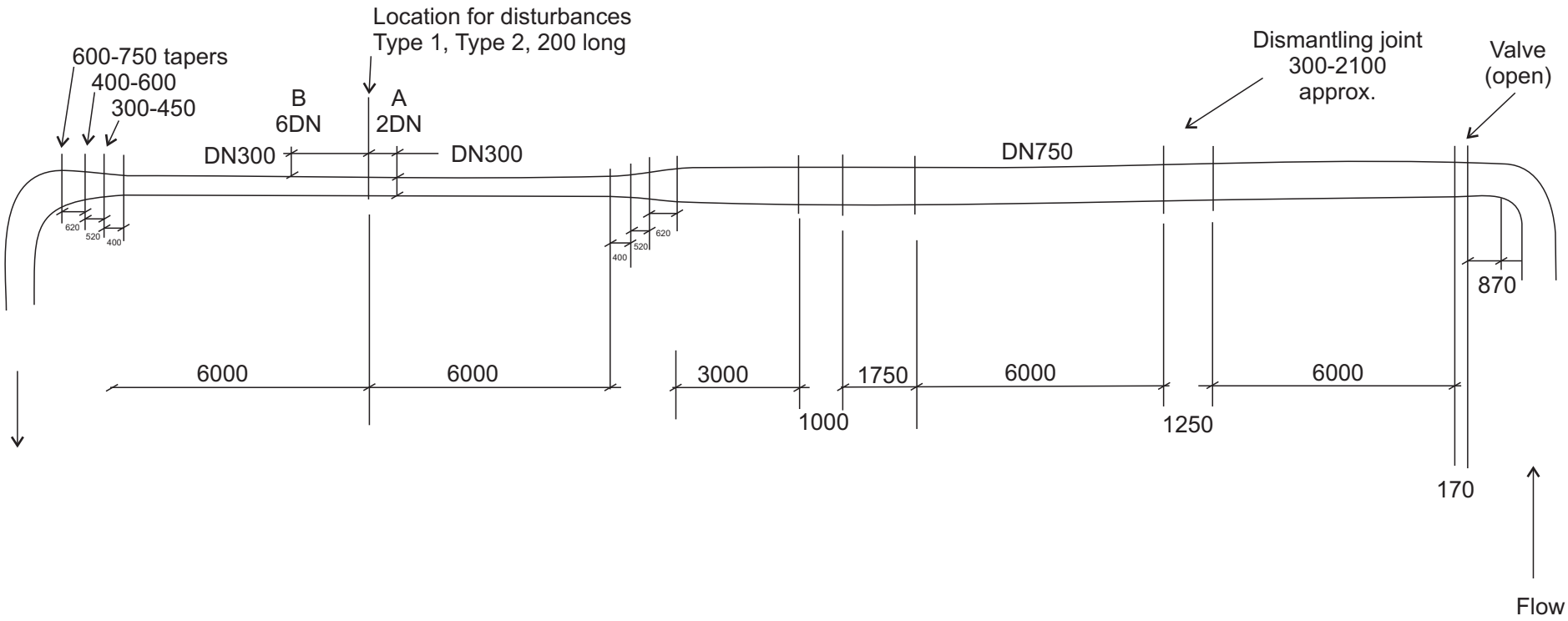
TEST LAYOUT



Plan
Not to scale
All dimensions in mm
Dimensions ± 20

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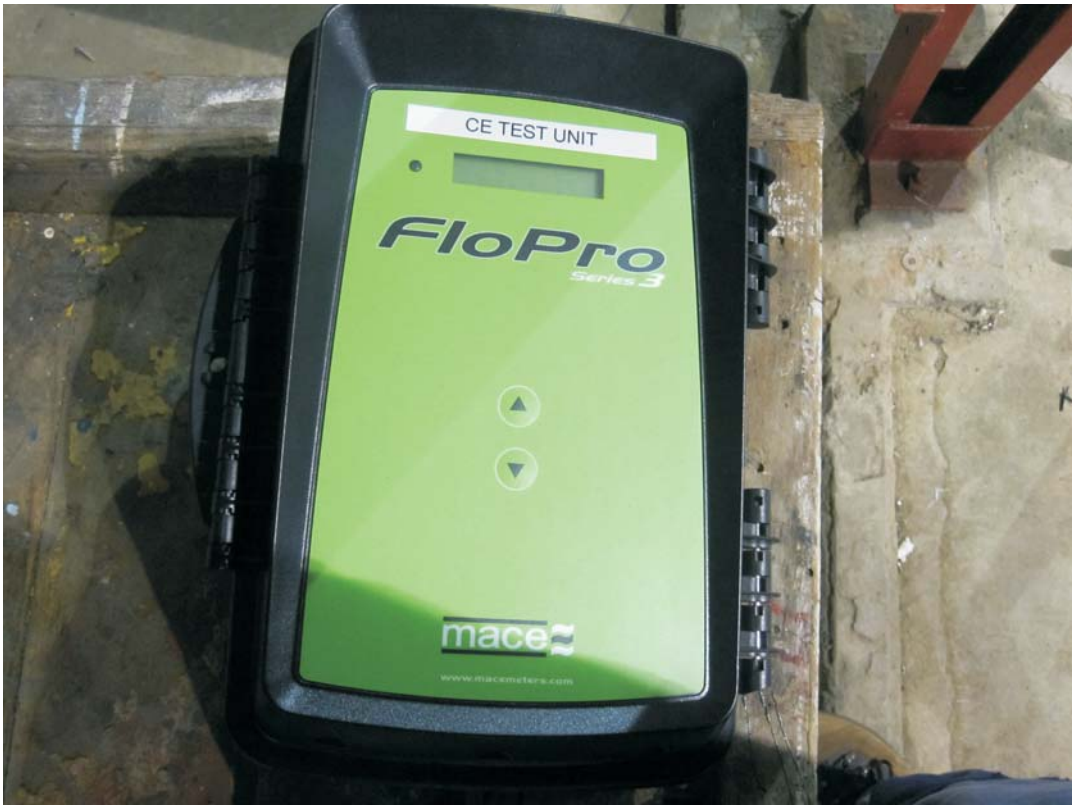
Figure 2.1
DRAWING 2123-02-01.cdr

MACE FloPro3 installed in DN300 pipe



MACE FloPro3 transmitter/logger

3. Test Results

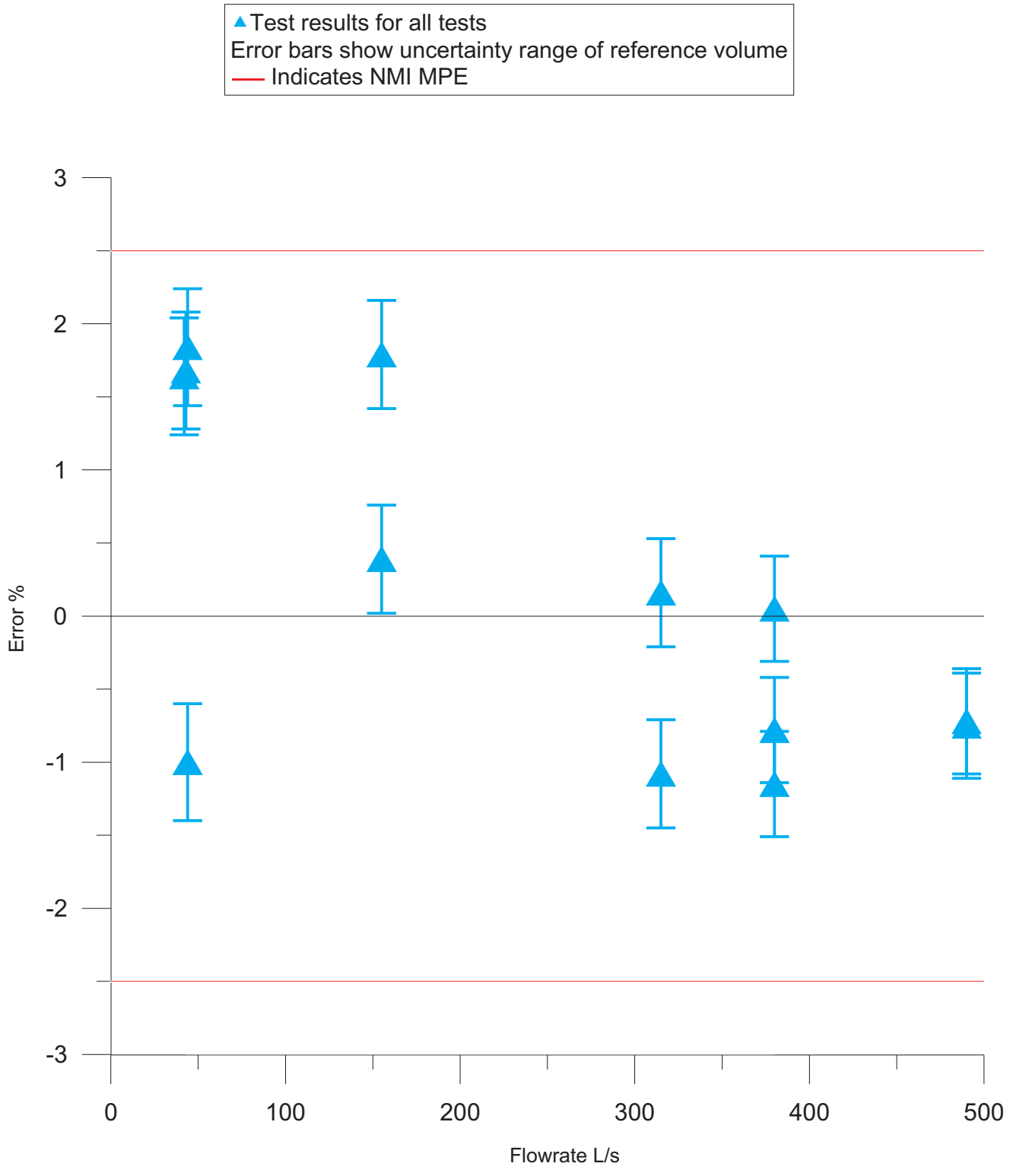
3.1 Intrinsic Error of Indication in DN300 Pipe

Results of testing are shown in Table 3.1. Logged data was transferred to MS Excel spreadsheets and processed within Excel. The total volume delivered over the test period was determined by summing the pulses (each 1 L) logged at 1-second intervals by the calibrated electromagnetic master flowmeter over the period. The volume measured by the meter under test was determined by summing the volumes logged at 1-second intervals in the test period. The uncertainty of measurements by reference instruments was then evaluated and the intrinsic error of indication and flow rate were calculated from the values determined in the uncertainty evaluation. The results of testing are shown in Table 3.1.

A graphical representation of the error in measurement (test meter volume -MHL volume)/ MHL volume) against flow is shown in Figure 3.1.

Table 3.1 Test Results

MHL Test	Q_{nom} L/s	Start			End		Duration min	Master Meter	Disturbance	$H2_O$ Temp °C	Ambient Temp °C	Q_{actual} L/s	$V_{MHL\ raw}$ L	$V_{MHL\ corr}$ L	V_{MACE} L	Error %	Unc. % at 95%	Comments
		Date	Data	Test	Date	Time												
7	42	22/12/11	1518	1551	22/12/11	1621	30	300	NO	22.4	23.2	42.14	75811	75843	77100	1.66	0.40	Intrinsic error
18	44	25/01/12	1010	1040	25/01/12	1110	30	300	NO	24.3	24.2	43.75	78725	78756	80200	1.84	0.40	Intrinsic error
T250112_2	44	25/01/12	1010	1119	25/01/12	1149	30	300	NO	24.3	24.4	43.71	78656	78686	77900	-1.00	0.40	Intrinsic error
19	43	28/02/12	1006	1040	28/02/12	1110	30	300	NO	24.4	23.9	42.68	76799	76830	78100	1.66	0.40	Intrinsic error
6	155	22/12/11	1410	1441	22/12/11	1511	30	300	NO	22.1	23.3	154.79	278449	278621	283600	1.79	0.37	Intrinsic error
12	155	3/01/12	1508	1538	3/1/12	1608	30	300	NO	25.5	25.0	159.64	271003	271163	272200	0.39	0.37	Intrinsic error
4	315	22/12/11	1142	1211	22/12/11	1241	30	300	NO	21.9	22.5	314.38	565881	566036	566900	0.16	0.37	Intrinsic error
11	315	3/01/12	1401	1432	3/1/12	1502	30	300	NO	25.2	25.0	309.96	557753	557925	551900	-1.08	0.37	Intrinsic error
3	380	22/12/11	1038	1108	22/12/11	1138	30	300	NO	22.0	23.0	379.48	683128	683060	677800	-0.78	0.36	Intrinsic error
9	380	3/01/12	0913	0945	3/1/12	0945	30	300	NO	24.0	25.4	379.96	683992	683923	676100	-1.15	0.36	Intrinsic error
2	490	22/12/11	0932	1005	22/12/11	1035	30	300	NO	21.9	22.8	487.21	876971	876547	870200	-0.73	0.36	Intrinsic error
10	490	3/01/12	1021	1051	3/1/12	1121	30	300	NO	24.4	25.2	494.26	890174	889666	883200	-0.73	0.36	Intrinsic error



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PLOT OF ERROR vs. FLOWRATE

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Figure 3.1

DRAWING 2123-03-01.cdr

4. Uncertainty

Uncertainty is a measure of the confidence in the accuracy of a measured quantity by providing an estimate characterising the range of values within which the true value of a measurement lies. Uncertainty calculations are performed to give a quantitative assessment of the accuracy achievable by the test setup and instrumentation. NMI 2011 requires that facilities carrying out testing for pattern approval of irrigation meters are capable of carrying out measurement of the volume of water passing through the meter with an expanded uncertainty one-fifth of the MPE of the irrigation flowmeter under test. A thorough analysis of the contribution of uncertainty of each element in the test system allows specification of an interval within which the true value lies and the level of confidence in the specification of the interval.

The primary source of uncertainty in the MHL facility is the master electromagnetic flowmeter, with minor contributions from other sources such as recording equipment. The uncertainty of the master electromagnetic flowmeter on the calibration certificate (shown in Appendix A) is ± 0.25% at 95% confidence level. The error at flow rates other than those shown on the calibration certificate was estimated by interpolation (and in the current situation also by extrapolation where necessary) from the calibration certificate.

The uncertainty assessment conducted for the MHL volumes used ISO (1995) as a guide. Calculated uncertainties are shown in Table 3.1. Sample calculations are presented in Appendix A. The uncertainty assessment took into account time measurement, temperature and pressure effects on the master meter, master meter drift, master meter resolution, leakage, repeatability and instrument calibrations.

5. Conclusions

This report presents the results of testing for intrinsic error of indication of a MACE FloPro 3 flowmeter installed in a DN300 pipe at flow rates between 40 L/s and 500 L/s.

The relative errors of indication of the meter under test did not exceed the MPE of ± 2.5% defined in 3.2 of NMI M 10-1.

It is pointed out that accurate measurement of flow rate by a MACE FloPro 3 flowmeter requires expert installation of the meter, accurate knowledge of the cross-sectional area at the site and adherence to specifications.

6. References

AS ISO/IEC 17025:2005, General requirements for the competence of testing and calibration laboratories.

International Organisation for Standardization (ISO) 1995, ISO Guide to the Expression of Uncertainty in Measurement 1993, (corrected and reprinted 1995), ISBN 92-67-10188-9.

NMI 2009, NMI M 10 Meters Intended for the Metering of Non-Urban Water in Full Flowing Pipes, Part 1: Metrological and Technical Requirements, Part 2: Test Methods, Part 3: Test Report Format, Second Edition, first revision, August 2009.

NMI 2004, Uncertainty in Measurement: the ISO Guide, National Measurement Institute Monograph 1: NMI Technology Transfer Series, Ninth Edition, December 2004, author Robin E Bentley.

Appendix A

Calibration Certificates

Reference Flowmeter

Flowmeter Calibration Certificate

Power and productivity for a better world™

NATA accredited Laboratory Number 1251
Accredited for compliance with ISO/IEC 17025
This document is issued in accordance with NATA's accreditation requirements.
The results of the test, calibrations and/or measurements included in this document are traceable to Australia/National standards.
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Customer:	Manly Hydraulics	**Item no:**	1	**Our ref:**	A031578
Address:	110B King Street, Manly Vale NSW 2093	**Revision:**	1	**Job no:**	J505372
		Test date:	29/09/2011	**Issue date:**	05/10/2011
Report no:	6308/011	**Level:**	1		
Work Area:	SN# 3K22/8755				

FLOWMETER PRIMARY DATA

Make:	ABB	**Type:**	Electromagnetic	**Size:**	300mm
Code/Model no:	MagMaster	**Serial no:**	3K22/8755		
Specified flow range:	*250 L/s	**Process connections:**		Flange	
Other details:	F1= 0.7816, F2= -3, F3= 5, F4= 1.0000				

FLOWMETER SECONDARY DATA

Make:	ABB	**Type:**	Transmitter	**Output:**	Digital
Code/Model no:	MagMaster	**Serial no:**	3K22/8755		
Other details:	-				

CALIBRATION DATA

Range of calibration:	30 to 360 L/s	**Test rig no:**	A	**Water temp:**	15.1 (°C)
Calibration procedure:	EDM095	**Method:**	Gravimetric		
Other details:	*Specific flow rates requested...400 L/s unachievable.				

CALIBRATION RESULTS

Test no.	Nominal flow rate (L/s)	Measured quantity (L)	Indicated quantity (L)	Error (%)
1	340	41039	41043	+0.01
2	250	41758	41789	+0.07
3	200	40887	40918	+0.08
4	125	40448	40463	+0.04
5	50	20230	20237	+0.03
6	20	10072	10082	+0.10

Measurement uncertainty: ±0.25% of measured quantity at 95% confidence level and a coverage factor (K) equal to 2.

Calibrated by:	Stuart Peck	**Certified by:**	Russell Fry
Position:	Calibrator	**Position:**	NATA Signatory
Signature:		**Signature:**	

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Appendix B

Calculation of Uncertainty

KTF Full Flowing Pipe Meter Testing

Uncertainty Calculator

This excel document is to be used to calculate the systematic uncertainity of Open Channel water meters tested on MHL KTF rig, it is assumed that the uncertainity of each component of t measuring system is know and understood.

Date Change made	Change made by	Change Approved by	Rev #	Change Description
30/06/2011	Andrew J	Bob C	-	Original
28/10/2011	Andrew J	Bob C	2	

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Reference GUM
Password : Potable

MHL KTF Closed Conduit Uncertainty Calculator

Test Inputs

Test Reference	12				Inital Water Temperature	25.2	Deg C
Test Start Time/Date	03/01/2012 15:38	hh:mm			Final WaterTemperature	25.2	Deg C
Test End Time/Date	03/01/2012 16:08	hh:mm			Mean Water Temp	25.5	Deg C
Test Time	0.02	Days					
Test Time	1800.00	Sec					
					Mean Air Temp	25	Deg C
Raw Pressure at Ref Meter	50.000	Correction	2.000	kPa	Relative Humidity	63	% SaT
Raw Pressure at Test Meter	50.000	Correction	3.000	kPa			
Pressure at Ref Meter	52.000	Uncertainty	0.050%	%			
Pressure at Test Meter	53.000	Uncertainty	0.100%	%			
Mag meter Indicated Volume	271003	L					
Corrected Test Volume	271163	L					
Raw Flow Rate	150.56	l/s			Mag Meter Indicated Flow F	271162.961	L/S
					Test Flow Rate	150.646	L/S
						13.016	ML/D
Reference Meter Make/Model	ABB 300mm MagMeter						
Reference Meter Serial No.	S/N 3K22/8756						
Reference Meter Resolution	1	L		L			
Meter No.	2				Flow Rate Uncertainty	0.37%	
					k	2.0	

Equipment Under Test

						0.003824413	
Repeatability	0.05%	%			ETU Error	0.39%	
Resolution	1	L					
					Test Uncertainty	0.51%	
Indicated Test Volume	272200	L			k	2.0	
Pressure Correction Required	No						
Density at Ref Meter	0.997						
Density at Eut	0.997						

Meter 1 correction
Meter 2 Correctio

Item	Description		Cited Uncertainity	Units	Vi (Deg Freedom)	Ui	Ki	u(xi)	ci	ci*u(xi)	[ci*u(xi)]^4/vi	Comments
Inflow Uncertainity										L		
Reference Meter Uncertainity		0.0025	0.0025	L	60	0.0025	2.00030	0.00124981	271003	338.7033163	219344397.2	From ABB cal certificate
Mag Meter Drift	Ui=R		0.05%	L	60	0.0005	2.00030	0.00024996	1	0.000249963	6.50654E-17	
Resolution uncertainty		0.0001	0.0001	L	100	0.0001	1.14545	8.7302E-05	1	8.73022E-05	5.80899E-19	From Reference Meter read-out
Leakage	1 L/Hr		1.0000	L/h	30	1.0000	2.04227	0.48965063	30.00	14.68951903	1552.061942	Estimate from observations
TOTAL										353.39	219345949.2	Unit L
Time Uncertainty												
Calibration uncertainty	0.001383333sec/minute		2.0000	S	60	2.0000	2.00030	0.99985112	150.56	150.5348072	8558476.704	Note Flow Rate l/s
Resolution uncertainty	0.5sec		0.5000	S	60	0.5000	1.15487	0.43294823	0.00	0	0	
TOTAL										150.5348072	8558476.704	
Density Uncertainty												
Pressure	500 kPa		0.0010	kPa	60	0.0008	2.00030	0.00039994	0.997099067	0.00039878	4.21486E-16	
Temparature	1 Deg		1.0000	Deg	60	0.0008	2.00030	0.00039994	1	0.00039994	4.26413E-16	
TOTAL										0.000798721	8.47899E-16	
									TOTAl l/s	################	###############	
									eff deg freedom		282.959	
									k		1.968864019	
									U=ku		992.1672402	L
									Uncertainty at 95%	0.366%	**%**	
EUT Uncertainty												
Repeatability	% Flow Rate		0.0005	%	60	0.0005	2.00030	0.00024996	272200.00	68.03986872	357192.7353	Note Flow Rate l/s
Resolution uncertainty	Discharge L		1.0000	L	60	1.0000	1.15487	0.86589647	151.22	130.9427884	4899763.17	
TOTAL										198.9826571	5256955.906	
									TOTAL L/S	702.91	2.33161E+08	
									eff deg freedom		1046.998	
									k		1.962389879	
									U=ku		1379.386288	L
									Uncertainty at 95%	0.51%	**%**	

No.	Size	Serial No	% Uncertaint	Drift	
1	ABB 150 mm MagMeter	S/N V/42692/2/15	0.15%	0.05%	28/06/2011
2	ABB 300mm MagMeter	S/N 3K22/8756	0.25%	0.01%	5/10/2011
3	ABB 750 mm MagMeter	S/N 3K22/8755	0.16%	0.01%	14/01/2010
4					
5					

Meter 1

ABB 150 mm MagMeter		S/N V/42692/2/15	Cal Date	28/06/2011
Flow Rate l/s	Adjustment from cal %	Fitted Adjustment	Residual Diff	
5	0.00%	0.04%	-0.04%	
10	0.15%	0.10%	0.05%	
20	0.14%	0.16%	-0.02%	
35	0.09%	0.08%	0.01%	
45	0.04%	0.04%	0.00%	
60	0.06%	0.06%	0.00%	
150.557	Raw Test Flow Rate l/s	0.06%	Correction	
Raw Test Vol	271003.000		Corrected Volume	
Error from Correction	0.20%			

Meter 2

ABB 300mm MagMeter		S/N 3K22/8756	Cal Date	5/10/2011
Flow Rate l/s	Adjustment from cal %		Residual Diff	
20	0.10%	0.10%	0.00%	
50	0.03%	0.03%	0.00%	
125	0.04%	0.04%	0.00%	
200	0.08%	0.08%	0.00%	
250	0.07%	0.07%	0.00%	
340	0.01%	0.01%	0.00%	
150.557	Raw Test Flow Rate l/s	0.06%	Correction	
Raw Test Vol	271003.000	271162.9609	Corrected Volume	
Error from Correction	0.25%			

Meter 3

ABB 750 mm MagMeter		S/N 3K22/8755	Cal Date	14/01/2010
Flow Rate l/s	Adjustment from cal %		Residual Diff	
128.936	0.24%	0.24%	0.00%	
309.89	0.10%	0.10%	0.00%	
616.896	-0.09%	-0.09%	0.00%	
900.438	-0.02%	0.01%	-0.03%	
907.438	0.04%	0.01%	0.03%	
1171.66	0.02%	0.02%	0.00%	
150.557	Raw Test Flow Rate l/s	0.23%	Correction	
Raw Test Vol	271003.000	271626.1538	Corrected Volume	
Error from Correction	0.19%			

Meter 4

			Cal Date	
Flow Rate l/s	Adjustment from cal %		Residual Diff	
	0.24%		0.24%	
	0.10%		0.10%	
	-0.09%		-0.09%	
	-0.02%		-0.02%	
	0.04%		0.04%	
	0.02%		0.02%	
150.557	Raw Test Flow Rate l/s	0.23%	Correction	
Raw Test Vol	271003.000		Corrected Volume	
Error from Correction	0.24%			

Meter 5

			Cal Date	
Flow Rate l/s	Adjustment from cal %		Residual Diff	
	0.24%		0.24%	
	0.10%		0.10%	
	-0.09%		-0.09%	
	-0.02%		-0.02%	
	0.04%		0.04%	
	0.02%		0.02%	
150.557	Raw Test Flow Rate l/s	0.23%	Correction	
Raw Test Vol	271003.000		Corrected Volume	
Error from Correction	0.24%			

Temp reading (Deg C)	Corrected Temp (Deg C)	Correction (Deg C)
0	0.00%	0.00
5	505.00%	0.05
10	1010.00%	0.10
15	1515.00%	0.15
20	2020.00%	0.20
25	2525.00%	0.25
30	3030.00%	0.30
35	3540.00%	0.40
40	4050.00%	0.50

Public Works
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