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TEST REPORT: SEASTAR INSTRUMENTS LTD. IN SITU WATER SAMPLER

by

F.E. Roy

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1.0 SCOPE

This report covers inspection, functional tests, and flow meter accuracy benchmark tests of an in situ water sampler, Seakem Serial Number 83005, manufactured by Seastar Instruments Ltd., Sidney, B.C.

1.1 Purpose

The purpose of these tests was to establish the baseline performance characteristics of this instrument and compare them to the manufacturer's specification.

2.0 REFERENCE DOCUMENTS

1. Operating Manual, Seaster In Situ Water Sampler, Model 82-06.
2. Service Manual, Seastar In Situ Water Sampler, Model 82-06.
3. Seastar Filtration Unit Documentation.
4. Seastar In Situ Water Sampler, Production Methods Manual,
   - Specification
   - Controls
   - Recommended Bench Test Procedure for Flowmeter Calibration Checks
   - Tank Test Procedure

3.0 TEST OBSERVATIONS

3.1 Baseline Inspection

a) Contents of Shipping Case:

Manuals: Operating Manual
Service manual
Filtration Unit Documentation
XAD Resin Column Documentation

Equipment: Model 82-06 Sampler
Filtration Unit
Associated Plumbing Parts

b) Condition of Hardware:

Case finish free of imperfections and scratches. Materials appeared to conform to descriptive data from the manufacturer.

Control labels conformed to manual descriptions, and were clearly and permanently marked.

Mode control knob action was stiff, and detent stops could not be felt.

Elbow fitting on top of the resin column was low quality moulded thread. This was later found to be the source of a leak during the functional test. Better thread sealing techniques, using a thread sealing compound rather than Teflon tape would be an improvement.

c) Physical dimensions conformed to specification, i.e.:

Case Height:	64 cm
Case Diameter:	14 cm
Dry Weight:	13.6 kg

d) Internal Condition:

Opening instructions were clear and opening the case was easily accomplished.

Quality of materials and construction was high.

The unit contained 20 "Duracell" D size cells. Cell voltage was measured:

Pump Power 1	8 cells	12.33 V
Pump Power 2	8 cells	12.29 V
CPU Power	4 cells	6.12 V

These values exceeded the criteria of Section 4 of the Operating Manual, so no battery replacement was required.

The unit contained one "Tadrian" 1/2 AA Lithium cell which had a voltage of 3.32 V.

There was no sign of any internal moisture, dirt, or foreign material.

Closing instructions were clear, and case closing was easily accomplished.

3.2 Functional Test

a) Preparation:

The sampler was prepared for functional tests by attachment of lead wires to TP 9, the pump motor control test point, and installing a 0.5 ohm, 10 watt resistor in series with the pump motor, with lead wires to monitor the pump motor current. The TP 9 hookup was connected to channel 1 of a Phillips PM 5282A strip chart recorder to obtain a record of the pump motor control commands. The pump motor current hookup was connected to channel 2 of the recorder to record the pump motor current.

The sampler was reinstalled in the pressure case for protection, with a suitable wedge between the case and the lid to prevent squeezing of the lead wires.

The filtration unit and the resin extraction column were installed. This ensured that the water supply through the pump and flow meter was clean, per item 3 of the pre-test checks, Recommended Bench Test Procedure. A flexible hose was installed on the pump outlet.

The sampler was placed in an 85 ℓ garbage pail filled with about 50 ℓ of clean tap water, so that the inlet and filter were well immersed, but the top of the pressure case was well clear of the water. The pump outlet hose returned the pump outlet water to the garbage pail reservoir. See Figure 1.

b) Flow Meter Accuracy Benchmark:

The flow meter accuracy benchmark tests were conducted as described in the Recommended Bench Test Procedure. Results were as recorded in Table 1 as Trials 1, 2 and 3.

During these tests, air bubbles were noted in the pump inlet piping downstream of the resin column. The resin column and filter plumbing were disassembled and carefully examined, at which point it was observed that the thread on the elbow fitting was a moulded type, with a small mould mismatch which left a step in the thread, making sealing unreliable. A mould sealant was applied to this thread, and the inlet plumbing tightly reassembled. No recurrance of the air leak was evident.

The Flow Accuracy Benchmark tests were repeated without measurement of the start delay time. The results are recorded in Table 1 as Set 2, Trials, 1, 2, and 3.

c) Program Function - Room Temperature:

The tests of program function were conducted as described in the Seastar Tank Test Procedure, with the exceptions that:

- The sampler was only partially submerged, so that the inlet and filter were well immersed, as in the flow meter accuracy benchmark.
- The NOTE of Step 2 was not followed, since this is inconsistent with the deployment instruction in the Operating Manual. There is no instruction to pre-circulate 250 ml of water to allow the control system to stabilize and eliminate air from the system.
- Time interval was recorded on the chart recorder, as displayed by the output of TP9.
- Pumped water was collected in a graduated beaker and weighed to obtain both sampling elements and the total amount pumped.
- For the shorter sampler modes, the quantity pumped was less than 4 l.

The results are recorded in Table 1 as Set 3, Trials 1 through 11. Mode 9 was repeated to confirm the initial result.

d) Repeat of Program Function Tests

As evident from Table 1, the results of the initial program function test were questionable in comparison to the manufacturer's specification. The problem was discussed with J.M. Boyson, Head of Production at Seastar.

The influence of air bubbles in the flow on the operation of the flow meter was emphasized. It was decided that the test should be repeated, with stricter observation for presence of air bubbles in the fluid stream which might affect results.

The hookup to TP9 and the resistor for monitoring pump motor current were removed, and the unit was fully sealed to permit the program function test to be conducted with the unit completely immersed in an observation tank to preclude problems from air leakage.

During pre-test inspection for this repeat trial, it became evident that the flowmeter readout circuit assembly had failed. On investigation, it was found that the current drain of this circuit from the Tadrian battery was 210 microA with the sampler in ON condition and 330 microA with the sampler in the OFF condition. This much exceeded the normal current drain of 10 microA for this circuit.

The sampler was returned to Seastar for inspection and repair. At the same time, the stiff mode select switch was replaced, and unit calibration was checked by the factory. The performance was found to be within specification, further suggesting that the results of Table 1 were suspect.

The program function test was repeated. The Seastar Recommended Bench Test Procedure was followed. Water supply was from a laboratory sink with a continuing small overflow to ensure clean tap water for the test. A 1/2" tygon tube was fitted to the filter inlet to pipe water from the sink reservoir to the sampler inlet.

The results of this test are shown in Table 2, Runs 1 through 6.

Large numbers of air bubbles were observed in the pump outflow during Run 1. On examination, it was clear that this was trapped air in the Filtration Unit. The Filtration Unit was unclamped and flooded then resealed under water to ensure that all air traps were removed. Furthermore, the Sampler was tilted, rolled, and rocked while pumping until no air bubbles were evident in the outflow. This ensured that all air traps in the interior flow circuit were removed.

As evident from Run 2, the performance following this pretest preparation was much improved. Results at the low flow rates in Runs 3, 4, and 5 continued to be disappoint however.

A final test with the Sampler fully submerged in an observation tank was conducted. The results of this are shown in Table 3. Once again, air trapped in the Filtration Unit at the start of the test resulted in a large volume error. The Filtration Unit was unclamped and flooded as before, with improved results.

On completion of this tank test, the Sampler was cleaned following the Manufacturer's Cleaning Procedure No. 2.

The Unit was then opened and the battery voltages were measured as follows:

	No Load	Pump Running
Pump Power 1	11.293	10.960
Pump Power 2	11.285	10.980
CPU Power	5.380	
Tadrian	3.699	

The Unit was then closed and stored in its transport case.

4.0 DISCUSSION OF RESULTS

4.1 Delay Function

Delay times averaged 11 sec. long on 0.1 min. delay, 13 sec. long on 1 min. delay, and 27 sec. long on 10 min. delay.

Although these delay errors are not large enough to be operationally important, their size and consistency suggest that there is something not right in either the microprocessor software, or in the microprocessor operation, since it should be possible to obtain more accurate interval counting than this.

4.2 Mode Function

All mode functions performed in the specified manner. Again, the average pump on times were slightly longer than specified (page 8, Operating Manual), as follows:

Mode 3	.64 min in 30 min
Mode 4	.48 min in 20 min
Mode 5	.23 min in 12 min
Mode 6	.19 min in 6 min
Mode 9	.50 min in 20 min
Mode 10	.08 min in 10 min
Mode 11	not adequately measured
Mode 12	not adequately measured

4.3 Flow Meter Accuracy

In operation, the microprocessor operates with the signal from the flow meter to control the pump motor so that measured flow rate is equal to the command flow rate set on the Rate knob. The microprocessor also controls the on time period to the command period set on the Mode knob.

There are three definitions of volume arising from the operation of the Sampler.

Theoretical Volume, Vt, which is command Rate x command On period as set by Mode selected.

Counter Volume, Vc, which is the volume displayed on the Sampler display, recording flow as measured by the flow meter.

Pumped Volume, Vp, which is the actual volume pumped as measured by collection of the out flow of the Sampler during the test run.

Two errors were defined to evaluate the Sampler performance.

$$\text{Control Error} = \frac{(Vc - Vt)}{Vt} \times 100$$

This is an indication of how well the microprocessor controls the pump speed to produce the command flow rate as measured by the flow meter.

$$\text{Volume Error} = \frac{(Vp - Vt)}{Vt} \times 100$$

This is an indication of how well the flow meter measured the actual flow through the system relative to the flow set on the control knobs.

The results of Tables 1, 2, and 3 show that the microprocessor control function performed consistantly well during all the tests, with the control error being less than 3% in all cases.

However, the performance of the flow meter, especially under bench test conditions as distinct from tank test conditions, was quite variable.

The flow meter is seriously affected by air bubbles in the flow.

In the bench and tank test procedures used here, the Filtration Unit was found to be a significant air trap. By ensuring that the filter cavity was totally flooded before starting the test, the volume error at the high (150 ml/min) rate was generally less than 6%.

At medium (100 ml/min) and low (50 ml/min) rates, the performance of the flow meter was less accurate. The best bench test result (Table 2, Run 4) was outside the specification claimed by the manufacturer.

The results of long term (Mode 12) bench tests were not satisfactory. This appears to be caused by the de-gassing of the water in the lines during the 55 minute pump off periods between the 5 minute on intervals each hour. The problem is exerbated by room temperature changes overnight which cool the water in the Sampler and increase the de-gassing. This problem could be reduced by using distilled or flat water for the test.

The bench test procedure is not an adequate test to evaluate the performance of the Sampler in simulation of field use conditions. The fact that the Sampler is not totally submerged makes the test result highly dependent on the amount of gas in solution in the water, and on the absence of even small leakages in the external plumbing.

For this reason the results of the tank test (Table 3) are considered to be more indicative of probable field results.

In this case, once the air trapped in the Filtration Unit was cleared out of the system, the volume actually pumped was within ± 5% of the value on the volume counter. The total volume pumped over the 96 hours of the Mode 12 operation at the high flow rate was 3.65% greater than the theoretical or command value, and 4.47% greater than the value indicated by the counter.

In view of the sensitivity of the flow meter to entrained gas, and recognizing the high probability of trapping air in the Filtration Unit as well as other parts of the pumping circuit, it appears that extreme care must be taken prior to deployment of the Sampler to ensure that the total circuit of filter, resin column and piping are totally flooded in order to obtain a reliable reading of pumped volume.

5.0 CONCLUSION

The Seastar IN SITU WATER SAMPLER Serial No. Seakem 83005 tested was found to be well constructed, and to operate in all of the specified operational modes.

The accuracy of the flow meter readout was found to exceed the manufacturer's specification of ± 1.0% in all tests.

The microprocessor control of the pumping rate as measured by the flow meter to equal the command pumping rate was found to be within 3%.

The accuracy of the flow meter was found to be very sensitive to air bubbles entrained in the flow, causing the flow meter to indicate generally lower volumes than those actually pumped. However, when sufficient care was taken to ensure that no gas bubbles were entrained in the through flow, the volume measuring accuracy of the Sampler at the high flow rate was found to be within 5%. Performance at medium and low flow rates were considerably larger than this.

A major defect found was that the Filtration Unit was a significant air trap, and it was required to ensure that this assembly was totally flooded to remove air bubbles before reliable results could be obtained.

The bench test procedure was found to be generally unsatisfactory for evaluation testing, since this method emphasizes problems caused by entrained gas in the test water and produces unreliable results. The tank testing method is a more reasonable simulation of the Sampler operating environment and produces results which are less dependent on conditons external to the Sampler.

File sitsamp0

JULY 1985
S. CAMERON

SEAKEM S/N 83005
INSITU WATER SAMPLER

BENCH TESTS

Control Error = (Vc-Vt)/Vt * 100
Volume Error = (Vp-Vt)/Vt * 100

Trial	Sampler Switches MODE	DELAY (m:s)	RATE	DELAY TIME (m:s)	ON TIME (min)	Vt THEORY (l)	dVc COUNTER (l)	dVp WEIGHED (l)	CONTROL ERROR %	VOLUME ERROR %
Set 1 Flow Meter Accuracy Benchmark										
1.1	2	1:00	H	1:13	10.00	1.50	1.54	1.45	2.7	-3.3
1.2	2	1:00	H	1:12	10.00	1.50	1.55	1.40	3.3	-6.7
2.1	2	0:06	M	0:17	20.00	2.00	1.95	2.06	-2.5	3.0
2.2	2	0:06	M	0:17	20.00	2.00	1.97	2.20	-1.5	10.0
3.1	2	10:00	L	10:25	10.00	0.50	0.50	0.60	0.0	20.0
3.2	2	10:00	L	10:24	10.00	0.50	0.54	0.70	8.0	40.0
3.3	2	10:00	L	10:30	10.00	0.50	0.50	0.81	0.0	62.0
3.4	2	10:00	L	10:29	10.00	0.50	0.50	0.81	0.0	62.0
Set2 Flow Meter Accuracy Benchmar k (Repeat)										
1	2	-	H	-	10.00	1.50	1.56	1.51	4.0	0.3
	2	-	H	-	10.00	1.50	1.51	1.48	0.7	-1.3
2	2	-	M	-	10.00	1.00	0.98	1.00	-2.0	0.0
	2		M	-	15.00	1.50	1.47	1.46	-2.0	-2.7
3	2	-	L	-	30.00	1.50	1.61	1.87	7.3	24.4
Set 3 Program Function										
1	3	1:00	L	1:25	(3 hr)	4.50	6.74	7.31	49.8	62.4
		On cycle data		(	30.42	1.52	1.60	2.45	5.2	61.1
		On cycle data		(	30.75	1.54	1.67	2.44	8.6	58.7
		On cycle data		(	30.74	1.54	3.47	2.42	125.8	57.2
2	4	1:00	L	01:24	(2.5hr)	3.00	3.43	4.51	14.3	50.3
		On cycle data		(	20.53	1.03	1.15	1.52	12.0	47.7
		On cycle data		(	20.47	1.02	1.13	1.51	10.4	47.8
		On cycle data		(	21.43	1.07	1.15	1.48	7.3	38.1
3	5	1:00	L	01:25	(2.2hr)	1.80	2.06	2.58	14.4	43.5
		On cycle data		(	12.08	0.60	0.66	0.86	9.3	41.6
		On cycle data		(	12.30	0.62	0.70	0.87	13.8	41.5
		On cycle data		(	12.32	0.62	0.70	0.86	13.6	39.3
4	6	1:00	L	01:06	(3.3hr)		1.30	-	-	-
		On cycle data		(	6.16	0.31	0.33	0.64	7.1	107.5
		On cycle data		(	6.20	0.31	0.31	0.84	.0	170.0
		On cycle data		(	6.20	0.31	0.32	-	-	-

				(	6.20	0.31	0.34	0.60	9.7	92.3
5	7	1:00	L	01:12	124.25	6.21	6.48	–	–	–
				0 hr	15.00	0.75	0.75	0.74	0.0	-1.3
		On cycle data		1.0 hr	10.00	0.50	0.52	0.53	4.0	6.2
		at approx. :		1.4 hr	10.00	0.50	0.53	0.53	6.0	5.6
				1.8 hr	10.00	0.50	0.57	0.53	14.0	5.0
6	8	1:00	L	1:13	491.50	24.58	26.38	30.31	7.3	23.3
				1.0 hr	10.00	0.50	0.53	0.54	6.0	7.4
				2.5 hr	10.00	0.50	0.54	1.08	8.0	116.4
		On cycle data		5.0 hr	10.00	0.50	0.58	0.55	16.0	9.2
		at approx. :		7.0 hr	10.00	0.50	0.54	0.52	8.0	3.6
				7.5 hr	10.00	0.50	0.52	0.51	4.0	2.6
7	9	1:00	L	1:12	480.00	24.00	26.81	39.97	11.7	66.5
8	9 Retry	1:00	L	1:12	480.00	24.00	26.04	24.97	8.5	4.1
				2 hr	20.00	1.00	1.11	1.14	11.0	13.5
		On cycle data		3 hr	21.00	1.05	1.11	1.16	5.7	10.6
		at approx. :		4 hr	20.00	1.00	1.07	1.16	7.0	16.0
				7 hr	21.00	1.05	1.71	1.17	62.9	11.0
9	10	1:00	L	–	480.00	24.00	26.68	38.77	11.2	61.5
				0 hr	10.30	0.52	0.52	1.07	1.0	107.0
				4 hr	9.90	0.50	0.55	0.94	11.1	90.3
				5 hr	10.00	0.50	0.56	1.19	12.0	137.6
				21 hr	10.00	0.50	0.57	0.55	14.0	9.4
		On cycle data		22 hr	10.10	0.51	0.55	0.56	8.9	10.5
		at approx. :		25 hr	10.10	0.51	0.56	0.55	10.9	9.3
				27 hr	10.10	0.51	0.57	0.94	12.9	85.5
				28 hr	10.10	0.51	1.10	1.94	117.8	284.2
				45 hr	10.10	0.51	0.55	1.09	8.9	115.6
				46 hr	10.10	0.51	0.55	0.93	8.9	84.8
10	11	1:00	L	–	504.00	25.20	28.19	29.81	11.9	18.3
				63 hr	7.00	0.35	0.37	0.68	5.7	92.9
		On cycle data		64 hr	14.00	0.70	0.78	1.42	11.4	102.3
		at approx. :		66 hr	7.00	0.35	0.39	0.64	11.4	83.7
				67 hr	14.00	0.70	0.75	0.71	7.1	1.9
				69 hr	14.00	0.70	0.77	0.80	10.0	14.6
11	12	1:00	L	01:12	480.00	24.00	31.29	44.13	30.4	83.9
				1 hr	6.00	0.30	0.29	0.47	-3.3	56.0
		On cycle data		57 hr	6.00	0.30	0.30	0.64	.0	113.0
		at approx. :		87 hr	6.00	0.30	1.10	0.89	266.7	197.0

File SITSAMP1

NOVEMBER 1985
F.E.ROY

SEAKEM S/N 83005
INSITU WATER SAMPLER

SUBMERGED IN 1 M OBSERVATION TANK
NWRI HYDRAULICS LAB

Control Error = (Vc-Vt)/Vt * 100
Volume Error = (Vp-Vt)/Vt * 100

MODE 12
RATE H (.150 l/min)

DATE	MONITOR TIME hh:mm:ss	ELAPSED TIME hours	Vt THEORETIC L	Vc COUNTER L	Vp WEIGHED L	CONTROL ERROR %	VOLUME ERROR %
22 Nov	(Trial)	2 min	0.30	0.30	0.36	0.00	18.33
22 Nov	15:12	0	0.00	0.00	0.00		
	16:40	2	1.50	1.52	1.70	1.33	13.33
23 Nov	18:16	27	20.25	20.71	22.00	2.27	8.64
25 Nov	08:36	65	48.75	48.99	---	0.49	
	08:44(on)						
	08:47off	66	49.50	49.72	52.50	0.44	6.06
	12:48	69	51.75	51.66	54.80	-0.17	5.89
	13:50 on						
	13:55off	71	53.25	52.88	56.18	-0.69	5.50
	16:54 on						
	16:59off	74	55.50	54.89	58.13	-1.10	4.74
26 Nov	09:15 on	88	66.00	65.26	68.53	-1.12	3.83
	09:20off	89	66.75	66.03	69.28	-1.08	3.79
	10:18 on						
	10:23off	90	67.50	66.78	70.03	-1.07	3.75
	15:56	95	71.25	70.67	73.88	-0.81	3.69
		96	72.00	71.44	74.63	-0.78	3.65

File SITSAMP2

SEAKEM S/N 83005
INSITU WATER SAMPLER

NOVEMBER 1985
S. BATCHELOR

BENCH TESTS

Control Error = (Vc-Vt)/Vt * 100
Volume Error = (Vp-Vt)/Vt * 100

RUN	RATE 1/min	ON TIME min	Vt THEORETIC L	Vc COUNTER L	Vp WEIGHED L	CONTROL ERROR %	VOLUME ERROR %
1	0.15	109.00	16.35	15.28	17.51	-6.54	7.09
2	0.15	96.73	14.51	14.52	14.60	0.07	0.61
3	0.15	30.00	4.50	4.51	4.69	0.22	4.11
	0.15	30.00	4.50	4.63	4.77	2.89	6.00
	0.10	30.00	3.00	3.04	3.34	1.33	11.33
	0.10	30.00	3.00	3.03	3.45	1.00	14.83
	0.05	30.00	1.50	1.51	2.05	0.67	36.67
	0.05	30.00	1.50	1.54	2.33	2.67	55.00
4	0.15	30.00	4.50	4.60	4.89	2.22	8.56
	0.15	30.00	4.50	4.62	4.73	2.67	5.11
	0.10	30.00	3.00	3.07	3.22	2.33	7.33
	0.10	30.00	3.00	3.09	3.25	3.00	8.33
	0.05	30.00	1.50	1.52	1.65	1.33	10.00
	0.05	30.00	1.50	1.53	1.69	2.00	12.33
5	0.05	MODE 12	24.00	24.53	36.57	2.21	52.38
6	0.15	MODE 12	36.00	36.96	41.93	2.67	16.47

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