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INSTRUMENT TEST REPORT
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Evaluation of a RIMCO 9100 automatic evaporation sensor

Don Anderson
Regional Instrument Centre
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Authorisation

Bruce W Forgan
Supervisor
Regional Instrument Centre, OEB

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1. AIM

The aim of this test report is to assess the suitability of a RIMCO 9100 automatic evaporation sensor.

2. BACKGROUND

The RIMCO 9100 is an automatic evaporation transducer supplied by McVan Instruments. A schematic of the instrument is shown in Appendix 1. The instrument is hydraulically connected to a standard A class pan and measures the water level in an internal stilling well using an upward looking ultrasonic detector. The signal from the ultrasonic detector is conditioned and is monitored by a DataTaker 50 programmable controller/data logger. The controller records changes in the water level and activates isolated contact closures when the level changes by 0.1mm. The controller activates solenoid valves to fill and drain water from the evaporation pan when predetermined levels are reached.

During the course of the evaluation, several problems were identified and some overcome. Laboratory testing of the instrument showed that instrument would underestimate evaporation. The hardware configuration of the instrument was unsuitable for field use and it had to be returned to the manufacturer for extensive modification. Field evaluation showed that the instrument was susceptible to ingress of insects and the build up of algae. The instrument responded to wind and intermittently gave fictitiously high evaporation totals. The author carried out a considerable amount of development on the instrument, altering the mechanical configuration and the software extensively from what was originally supplied by McVan Instruments.

The instrument was originally configured so that the ultrasonic detector/stilling well combination, the signal conditioning electronics, controller and the drain and fill solenoids were all housed in the same weatherproof instrument cabinet (labelled as cabinet A in the schematic in Appendix 1).

The weatherproof cabinet containing the stilling well is designed to sit at the same level as the evaporation pan and is mounted on an enlarged wooden palette that supports the evaporation pan. Advice from the Observation and Engineering Branch New Facilities Section indicated that this configuration was not suitable for field use as the instrument would be mounted only 150 mm above ground level and problems would be encountered if the site flooded. Additionally the combination of mains power and mains pressure water inside the one cabinet could lead to problems in the event of a leakage from the mains pressure water inlet. The New Facilities Section recommended that the instrument would be better suited to field use if the components were contained in two separated weatherproof cabinets. The first cabinet (labelled as cabinet A in the schematic in Appendix 1) containing the ultrasonic detector/stilling well combination and the drain and fill solenoids located at the same level as the evaporation pan, the second, mounted on a pole one metre above ground level contained the rest of the electronics (labelled as cabinet B in the schematic in Appendix 1). Only low voltage control lines connect the two cabinets and there would be no mains power in the cabinet at the level of the evaporation pan.

The instrument has three temperature sensors; the first to monitor the water in the pan, the second to monitor water in the stilling well and the third to monitor the signal conditioning electronics. The second sensor is required as the speed of sound in water is a function of temperature; the third sensor is required as the electronics have a temperature coefficient. The ultrasonic sensor only has a limited working range; the manufacturer recommended a maximum working range of 10 mm.

Before the instrument was returned to the manufacturer to separate the components into two weatherproof cabinets it was evaluated in the Regional Instrument Centre under laboratory conditions. When the instrument was returned from the manufacturer it was installed at the Bureau of Meteorology test site at Broadmeadows in October 2000. The evaluation finished in March 2002. This report details the laboratory and initial field testing.

2.1 DESCRIPTION OF OPERATION

The operation of the instrument is based on monitoring the water level in a stilling well. The stilling well is hydraulically connected to the evaporation pan by a length of hosing and must sit at the same level as the evaporation pan. The purpose of the stilling well is to damp oscillations in the water level caused by wind blowing across the evaporation pan. The system can be treated as a damped system, hence when the water level in the evaporation pan changes rapidly from one stable state to another it will take the water level in the stilling well a period of time to reach equilibrium. To account for this effect the software has a "settling" period associated with fill or drain operations.

The water level in the stilling well is monitored every second and the average water level is calculated every 60 seconds. When the "settling" period has passed, a reference water level is set to the average water level.

There are essentially two main functions in the controller software – the first is to log changes in the water level and activate the appropriate isolated contact device, the second is to alter the water level in the evaporation pan when necessary.

Changes in the water level are monitored in the following manner. The average water level is calculated every minute and compared against the reference water level. If the difference is greater than a predetermined amount (originally ± 0.1mm) a change in the water level is logged and either the "evaporation" or "condensation" isolated contact is pulsed depending on the sign of the change[1]. After each pulse the reference level is decremented or incremented by the predetermined amount and the process is repeated until the difference between the average water level and the reference level is less than the predetermined amount. This method of operation ensures that there is no accumulated error in the logging process. As an example if the water level decreased by 0.22 mm the "evaporation" contact closure would be pulsed twice signifying a change of 0.2 mm and the new reference level would be 0.02 mm higher than the average water level. The average water level would only have to decrease by 0.08 mm for the evaporation contact closure device to be pulsed again. The logging of changes in water level continues until a predetermined water level is reached and the fill or drain valves are activated.

The water level in the evaporation pan is altered by opening and closing fill or drain valves at the appropriate times. *A key point is that the operation of the fill and drain valves do not utilize one-minute average water levels. They are "instantaneous"*

[1] "evaporation" is a decrease in the water level. "condensation" is an increase in the water level.

values. The use of instantaneous values to monitor the water level leads to the effect of overshoot during a fill operation. The fill valve is opened when the instantaneous water level reaches a lower limit and closed when it reaches an upper limit. The limits are defined in the algorithm. When the fill valve is opened the water level in the pan increases rapidly and the water level in the stilling well lags behind due to the time constant of the damped system. The water level that controls the operation of the valve is monitored in the stilling well so that when the fill valve is closed the water level in the pan is in fact higher. After the fill valve is closed the water level in the stilling well will continue to rise until it is in equilibrium with the level in the pan. The amount of overshoot is dependent of the filling rate and hence is dependent on water pressure. It is possible that the water pressure in the field could change. At the Broadmeadows test site the overshoot was typically 0.7 mm.

2.1.1 <u>Description of the algorithm to control water level supplied by McVan instruments</u>

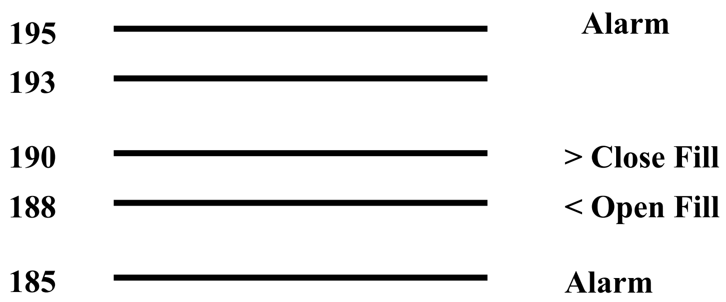


Figure 1. Water levels (mm) used by the algorithm.

Figure 1 illustrates the water levels used in the algorithm supplied by the manufacturer. The numbers on the left represent the water level in the evaporation pan in millimetres. The algorithm can be summarized below.

If the water level is < 185 mm then an alarm state is initiated.

If the water level is > 195 mm then an alarm state is initiated.

If the water level is < 188 mm then the fill valve is opened.

If the water level is > 190 mm then the fill valve is closed.

If the water level is > 193 mm then the drain valve is opened.

If the water level is < 193 mm then the drain valve is closed.

The typical operation of the algorithm can be described as follows. After initialisation the water level will be somewhere between 190 and 193 mm, the water level will then gradually decrease due to evaporation. Whenever the water level decreases by 0.1 mm an evaporation count will be logged. This process continues until the instantaneous water level reaches 188 mm when a fill operation was initiated and the fill valve is opened. The fill valve remains open until the instantaneous water level in the stilling well reaches 190 mm. After a specified settling period has elapsed a new reference level is taken, this reference level will be greater than 190 mm due to overshoot.

Conversely if the water level increases due to "condensation" (i.e. rain) then when the average water level increases by 0.1 mm a "condensation" count is logged, this process continues until the water level is greater than 193 mm when the drain valve is opened. The drain valve is closed when the instantaneous water level is less than 193 mm.

3. LABORATORY EVALUATION

The instrument was connected to a container that was filled with water. The dimensions of the container were much smaller than those of an evaporation pan so the area of the stilling well needs to be considered when calculating the change in water level when a given amount of water is removed. The container also had a much higher filling rate, as a result the overshoot was large and it was very easy to cause a subsequent drain operation or put the instrument into an alarm state. The problem was overcome by adjusting the flow from the mains water tap.

In order to simulate evaporation, water was removed using siphon action through a tube draining into a 1000 ml volumetric flask sitting at a lower level than the container. A 0.35 mm stainless steel nozzle was placed in the end of the tube to limit the flow rate. The flow rate could be adjusted by altering the height of the end of the tube draining into the volumetric flask. The height difference between the water level in the container and the end of the siphon was approximately 300 mm. The top of the container was covered with plastic cling wrap to minimize evaporation. A small opening was left in the cling wrap to allow sufficient airflow so that a partial vacuum would not develop above the water surface when the water level decreased and hamper the siphon action.

A stopwatch was started when the flow commenced and stopped when the water level reached the 1000ml mark on the volumetric flask.

3.1 CALCULATION OF THE CHANGE IN WATER LEVEL WHEN 1000ML OF WATER IS REMOVED.

The change is water level when a given volume of water is removed is given by:

Height = Volume/(Area of container + Area of stilling well)

This relationship can be expressed as

$$H = \frac{V}{(LW) + \pi\left(\frac{D}{2}\right)^2}$$

where

H	is the height of the water
V	is the volume of water removed
L	is the length of the container
W	is the width of the container

D is the diameter of the stilling well

The relevant dimensions where;

$L = 28.5$ cm

$W = 20.0$ cm

$D = 10.2$ cm

The above dimensions were given a tolerance of ± 0.2 cm (Rectangular distribution).

The volumetric flask had a volume and stated tolerance of:

$V = 1000$ ml ± 1ml

Using the values above an uncertainty analysis was performed (see Appendix 2). The expected change in water level with 95% uncertainty is

15.3 mm ± 0.2 mm

Since an evaporation "count" occurs for every 0.1 mm change in water level this is equivalent to;

153 counts ± 2 counts

3.2 LABORATORY RESULTS

Five tests were made with different flow rates. The results are tabulated below.

Time to remove 1000ml (hh:mm)	Estimated rate of change of water level (mm/hr)	Logged change in water level (mm)	Difference (mm)
19:20	0.79	14.9	-0.4
17:31	0.88	14.7	-0.6
5:10	2.97	14.1	-1.2
5:05	3.02	14.3	-1.0
4:29	3.42	14.2	-1.1

Table 1. Results of laboratory tests.

The estimated rate of change of water level in table 1 is analogous to the evaporation rate; it was obtained by dividing the calculated change in water level for a removal of 1000 ml (15.34 mm) by the time it took to remove the water from the container. The actual rate will vary slightly about this value as the height of the water level in the container changes; however the instrument attempts to maintain the water level within a 2 mm interval, and this is small in comparison to the typical height difference of 300 mm between the end of the siphon and the water level in the container.

The instrument underestimated the change in water level and the difference increased with the rate of change in water level.

It is illustrative to examine the difference as a function of time by comparing the logged change in water level with the estimated change in water level. The estimated change in water level at a given time is obtained by multiplying the elapsed time of each logged 0.1mm change in water level by the estimated rate of change of water level in table 1.

Figure 2 shows the difference between the logged and estimated water levels at the highest estimated rate of change of water level. It shows that the difference accumulates in a series of steps occurring at approximately 45-minute intervals. Examination of the data shows that these steps occur when there is a fill operation. In this case the fill operations were typically spaced by 25 counts – indicating that the system overshoot was approximately 0.5 mm.

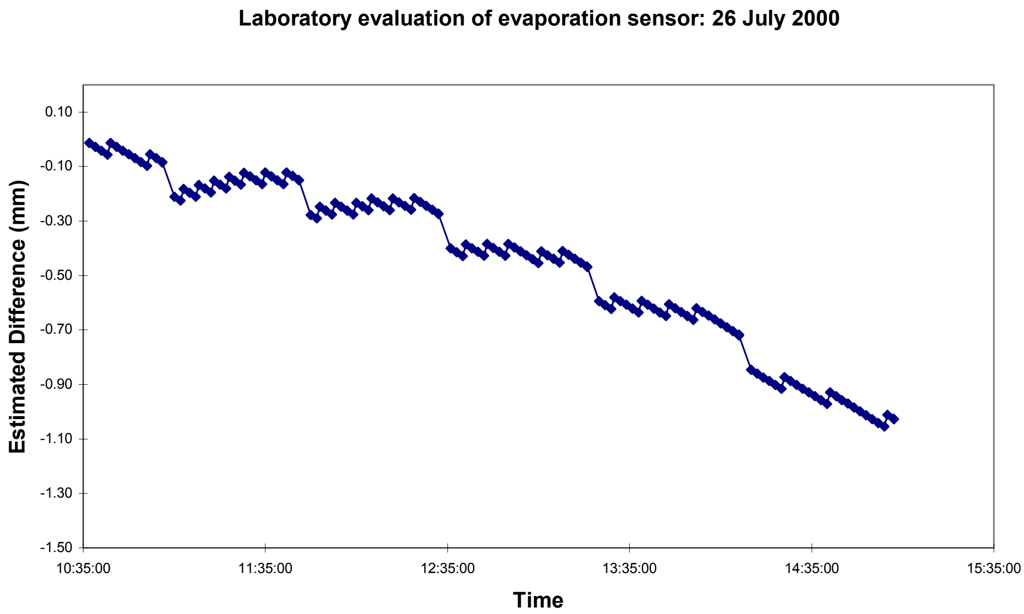


Figure 2. Estimated difference as a function of time.

The difference arises because the water removed by the siphon cannot be monitored during a fill operation. It follows then that a fill operation has an associated error that is proportional to the removal rate (i.e. evaporation rate) and the time it takes to perform the fill operation. The accumulated difference will be proportional to the number of fill operations.

3.3 SIMPLE MODEL TO ESTIMATE ERRORS

In order to estimate the error under field conditions a model is required that accounts for the changing evaporation rate throughout a day. There are a few models that could be employed to estimate evaporation rate[2], but the models require estimated values of solar radiation, water temperature, humidity and wind speed. In this study a very simple model was developed, the evaporation rate was modelled as a simple

[2] Shuttleworth, W.J. 1993. Evaporation, Ch.4, In D.R. Maidment (ed.), Handbook of Hydrology, McGraw-Hill. ISBN 0-07-039732-5

trapezoidal function. The model also needs to consider the operation of the instrument. A fill operation consists of two components – the addition of water to the container and a settling time to allow the water level in the stilling well to equilibrate.

In order to use reasonable values of daily evaporation the climate records of Mildura Airport (Bureau Number 076031) were examined. The Mildura Airport records showed that the highest daily evaporation observations occurred in January. The daily evaporation readings had an average value of 10.4 mm, a 9^{th} decile value of 14.6 mm and the highest recorded value of 23.4 mm.

The model was used to assess the effect of altering the water levels at which the fill valve was opened and closed at different evaporation rates. The software described in Section 2.1.1 opens the fill valve at a water level of 188 mm and closes the fill valve at 190 mm (i.e. a 2 mm working range). The manufacturer recommended 10 mm as the largest working range of the instrument.

The assumptions in the model were;

Evaporation started at the time of 08:00 and the water level was at the top limit of its working range.

The evaporation rate reached a maximum at 12:00 and remained constant until 14:00.

The evaporation rate started to decrease at 14:00.

Evaporation stopped at 18:00.

A fill operation caused no overshoot.

The filling rate was 2.00 mm/min.

The settling time was 3 minutes (as specified by the manufacturer).

Four values of daily evaporation and two values that the instrument attempted to keep the water level within were assessed with the model. The results are tabulated below.

	Water level maintained within	
	2 mm	10 mm
Daily Evaporation (mm)	Estimated error (mm)	
25	-2.6	-1.0
12	-0.6	-0.2
6	-0.1	0.0
<6	0.0	0.0

Table 2. Assessment of errors using a simple model for evaporation rate.

Table 2 shows that increasing the working range from 2 to 10 mm reduces the estimated error; particularly when the daily evaporation is greater than 12 mm.

4. FIELD EVALUATION

The manufacturer modified the software to increase the working range to 10 mm. The modified instrument was returned and installed at the Broadmeadows test site in October 2000 and connected to a modified Class A evaporation pan. Although this site has manual evaporation pans, routine daily observations are not made so it was not practicable to do a comparison of the instrument against manual evaporation pans. Instead the field evaluation focussed on identifying problems that might be encountered with unattended field operation. To test the effects of algae build up no algaecide was used and the evaporation pan was never cleaned.

Rather than interface the unit to an AWS, advantage was taken of the data logging capabilities of the instrument; with the addition of a 1 megabyte memory card the instrument was capable of storing several weeks of data.

The software was configured so that the instrument;

Logged the evaporation and condensation events.

Logged fill and drain operations.

Reported the daily evaporation and daily condensation at 9 a.m.

After installation at the test site the instrument reported very large, and clearly fictitious, daily evaporations of up to 140 mm. The large daily evaporation values were always associated with correspondingly large daily condensation values. Diagnosis was not possible, as the logged data did not provide appropriate information. The manufacturer was contacted and they supplied modified software that logged the 1-minute average water level.

The modified software revealed that the 1-minute average water level measurements seemed to switch from one stable state to another. When it switched from a higher stable state to a lower one, evaporation was registered, when it switched back, a correspondingly large condensation was recorded. An example of the logged 1-minute average water level is shown in Figure 3.

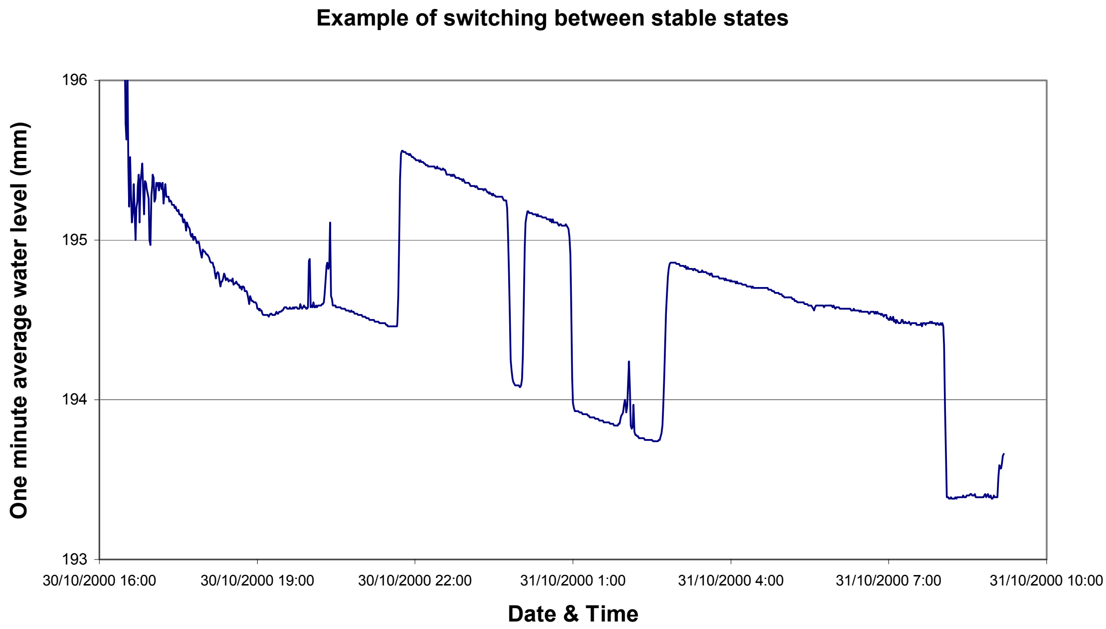


Figure 3. Example of switching between stable states

Some adjustments were made at the test site with advice from the manufacturer. These did not eliminate the problem so the unit was returned to the manufacturer in early November 2000. The unit was reinstalled at the test site in late December 2000. The logged record recommenced on January 2001.

After permission from the manufacturer was granted on 25th Jan 2001, the software was modified so that;

- When a conditional statement was met an identifying number and the "instantaneous" water level were logged. This meant that significantly more data were logged. The memory card could store approximately 3 weeks of data.
- At 9 am the instrument refilled the evaporation pan. This was implemented to mimic the behaviour of a manual evaporation pan and to have the evaporation pan near capacity in the morning to minimize the possibility of underestimation.

From January to February 2001 several problems were identified and some eliminated. They are listed below.

- The stilling well overflow tube acted as a pathway for ants. The ants would make their way into the stilling well and would perish. It is possible that the ants upset the sensing of the water level. This problem was overcome by putting a fine mesh on the overflow tube.
- The instrument was supplied with mesh filters on the fill/drain and level sensing inlets to the evaporation pan. The mesh acted as a site for algae build up, this slowed the system response and caused the system to overfill after a fill operation. This effect was observed as a fill operation followed by a drain operation. The drain operation has a settling period associated with it and two different problems could be introduced. The first problem arises from real evaporation not being monitored during the additional drain operation. The second problem arises when the system response has been slowed to such an extent that the water level in the stilling well has not reached equilibrium when the settling period has ended. The effect is observed as fictitious evaporation counts following a drain operation.
- The settling period was too short – instead of the 3 minutes indicated by the manufacturer it was 2 minutes and 1 second. This resulted in false condensation counts after a fill operation and false evaporation counts after a drain operation. Increasing the settling period to 4 minutes and 1 second overcame this problem.
- The system responded to wind. This was observed as an evaporation count closely followed by a condensation count. This problem was overcome by decreasing the system resolution from 0.1 mm to 0.2 mm (the same as for the graduated cylinder used for manual evaporation observations) and specifying that the maximum minus the minimum “instantaneous” water levels within the minute must be less than 0.2 mm.
- When the water level was close to the level at which the drain valve was opened, small natural variations in the measured water level could cause multiple drain operations (each with an associated settling period) to be triggered. The drain operation uses instantaneous values; when the water level rose above the limit a drain operation would be triggered - the conditions for a drain operation might only last for 1 second – however a 4 minute settling would be initiated regardless. Each settling period would increase the underestimation of the daily evaporation. This problem was overcome by separating the “start drain” and “stop drain” levels by 1 mm. However this introduced a different type of problem. If the water level is between 198 and 197 mm at 9 a.m., changes in the water level will not be logged until water level decreases to 197 mm or increases to 198 mm. It may take hours for the conditions to be met and there is the potential for up to 1mm error.

The diagram below illustrates the water level control algorithm after it was modified.

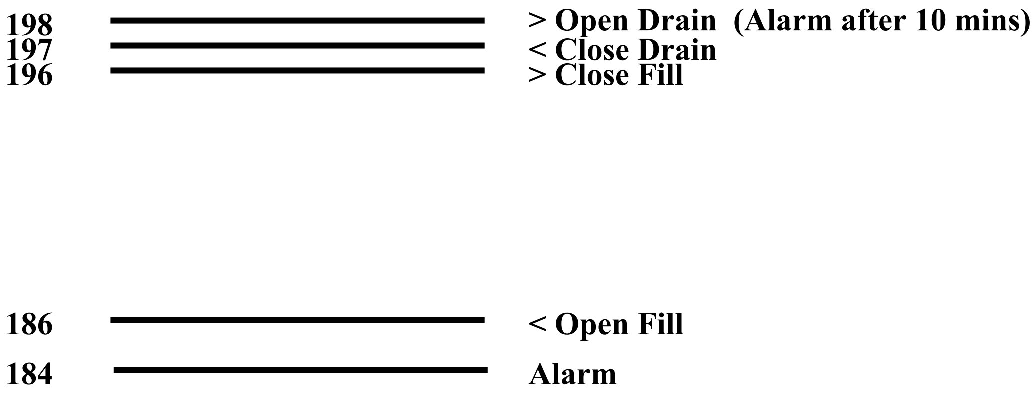


Figure 4. Water levels (mm) used by the modified algorithm.

4.1 FALSE VALUES AND THEIR EFFECT

During the field evaluation several events were logged that caused abnormal behaviour of the instrument. Forty five of these events were logged in the period 1st Jan 2001 to 26th Mar 2002. Each event could be characterized as an episode usually lasting 10 to 20 minutes. The only common feature was that they made the water level appear lower. The source of the false values could not be determined. The manufacturer was notified but could not provide an answer. An example of the false values is shown in the Figure 5; the false values are indicated with a black triangle. The water level shown is the "compensated water level" which is the result after temperature corrections have been applied.

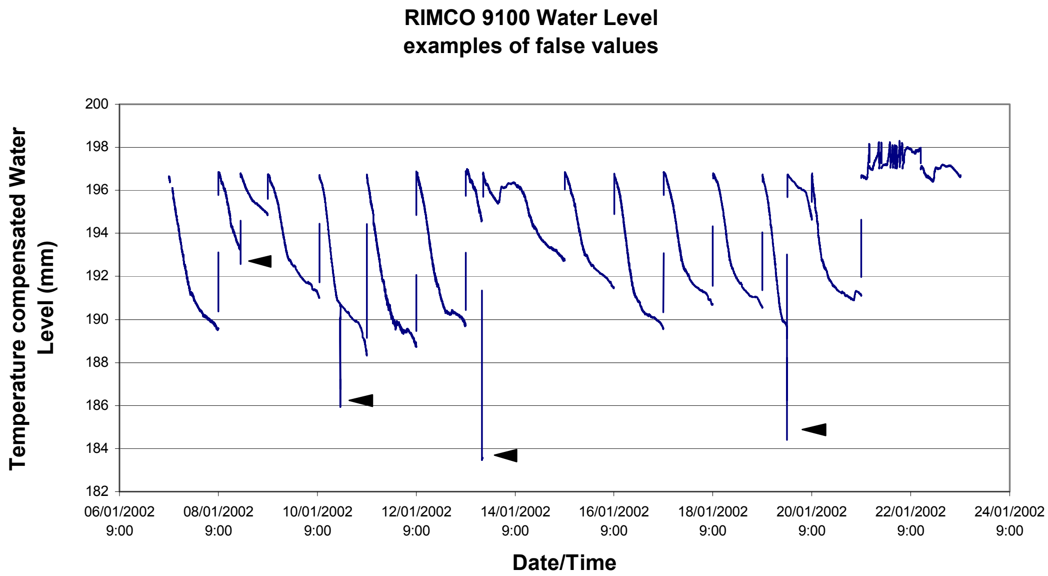


Figure 5. Examples of false values.

To gather more information the software was modified so that the 1-minute average, minimum, maximum and a parameter called "standard deviation" were logged. The original software used only a 1-minute average to log changes in the water level. It made no checks on the stability of the water level within the one-minute period. In order to minimize the effect of the false readings a requirement was placed on the stability of the water level within the minute. Initially the "standard deviation" calculated by the DataTaker 50 was used – however this did not provide consistent results. Instead the peak-to-peak value was used (i.e. maximum - minimum). A requirement was placed that the peak-to-peak value must be less than 0.2 mm before the evaporation or condensation would be registered and the fill and drain operations enabled.

Figures 6 and 7 show two examples of abnormal events after the software had been modified. The water level is the "uncompensated water level" which is the result before temperature corrections have been applied. During an abnormal event the 1-minute minimum value would start to become unstable and decrease.

Figure 6 shows a case where the one-minute maximum water level is relatively unaffected. The "standard deviation" calculated by the DataTaker is shown on a secondary axis on the right of the plot (labelled as DataTaker "SD"). Notice that the DataTaker "SD" at Time = 4:18 during the abnormal event is zero, yet the peak-to-peak value was 0.46 mm. There are 11 other occasions in figure 6 where the DataTaker "SD" is zero yet the peak-to-peak value is non-zero. This why the peak-to-peak value was chosen as a stability requirement rather than the "standard deviation" calculated by DataTaker 50.

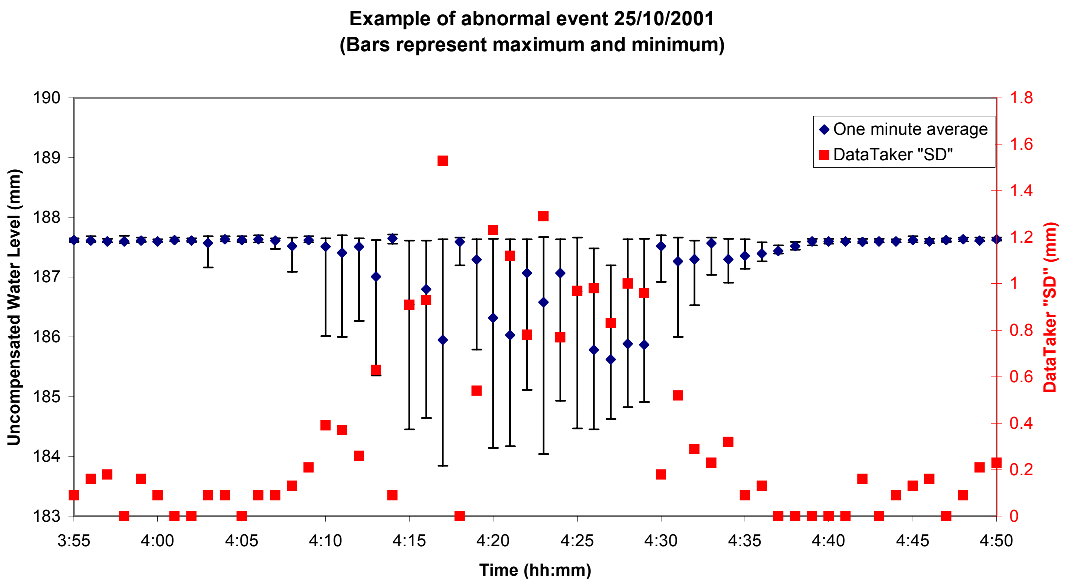


Figure 6. Abnormal event where the one-minute maximum was not greatly affected. DataTaker "SD" is the result of the "standard deviation" function.

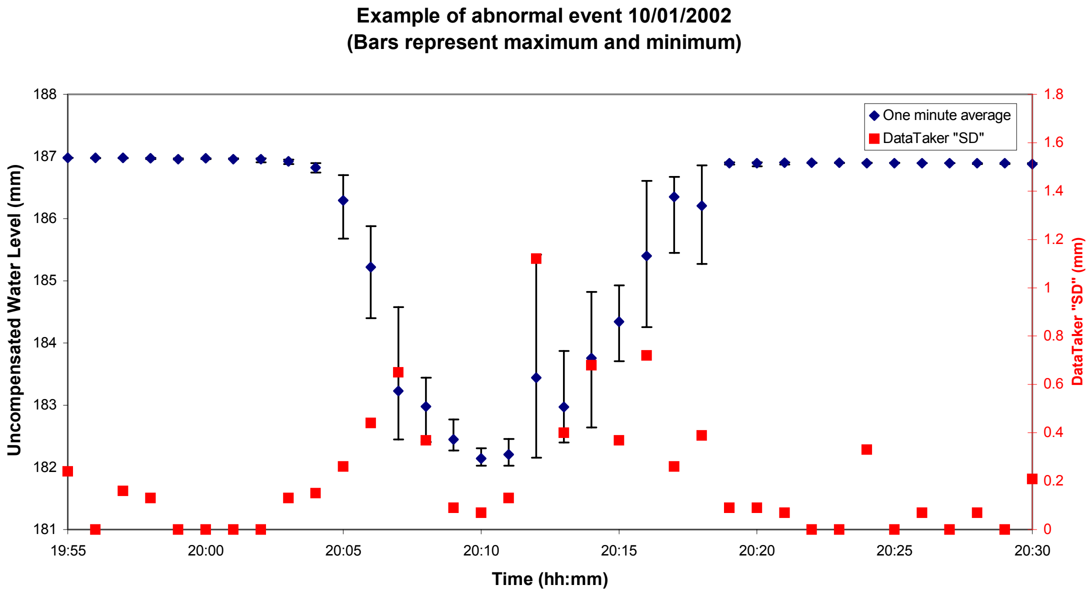


Figure 7. Abnormal event where the one-minute maximum was strongly affected. DataTaker “SD” is the result of the “standard deviation” function.

Figure 7 shows a case where the one-minute maximum water level was strongly affected. In the above two cases no false evaporation counts were logged and no fill operations triggered as the peak-to-peak value within any minute was always greater than 0.2 mm.

If the peak-to-peak value became less than 0.2 mm during an abnormal event, false evaporation would be logged and the fill and drain operations enabled. Figure 8 shows a case where there were two abnormal events, the first triggered a refill. The peak-to peak value is plotted on a secondary axis on the right of the plot.

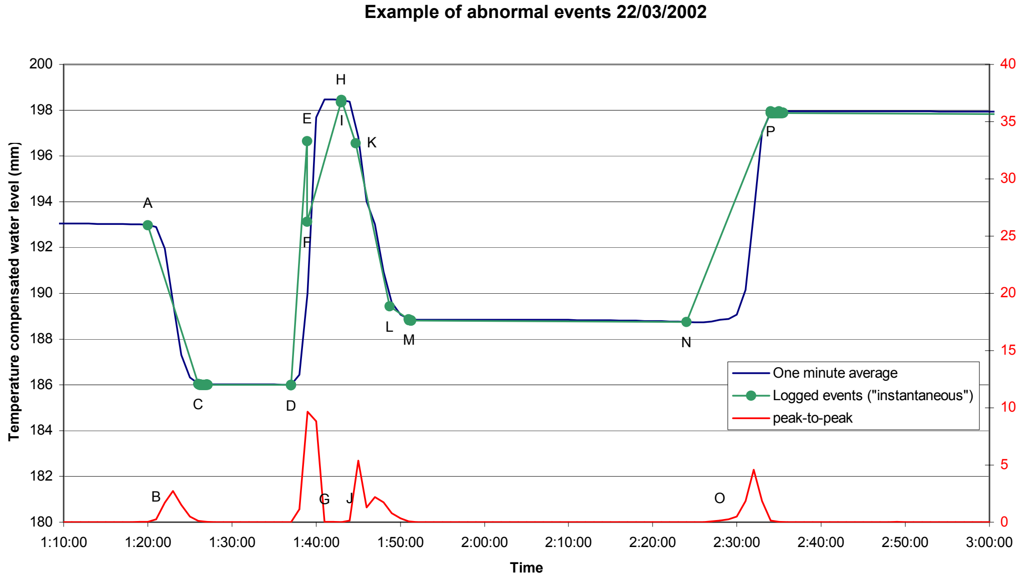


Figure 8. Example where false evaporation was logged and fill and drain operations triggered.

In figure 8 the sequence of events is as follows;

Label	Time	Comment
A	1:20:00	0.2 mm of evaporation is logged. The average level = 193.0 mm.
B	1:21:00	First abnormal event starts.
C	1:26:00	The peak-to-peak value is less than 0.2 so 6.8 mm of evaporation is logged.
D	1:37:02	The peak-to-peak value is still less than 0.2 mm. The instantaneous water level becomes less than 186.0 mm and a fill operation is started.
E	1:38:56	The fill valve is closed. The instantaneous water level is 196.7 mm.
F	1:38:57	The settling period is started. The instantaneous water level is 193.1 mm.
G	1:41:00	First abnormal event ends.
H	1:42:57	Reference level is set to 198.4 mm.
I	1:43:00	Drain valve opened. The instantaneous water level is 198.4 mm.
J	1:44:00	Second abnormal event starts.
K	1:44:43	Drain valve closed. Settling period started. The instantaneous water level is 196.6 mm.
L	1:48:43	Reference level is set to 190.9 mm.
M	1:51:00	Peak-to-peak value is less than 0.2 so 2.0 mm of evaporation is logged.
N	2:24:00	0.2 mm of evaporation is logged.
O	2:28:00	Second abnormal event starts to end.
P	2:34:00	The peak-to-peak value is less than 0.2 mm so 9.2 mm of condensation is logged.

There are several items that indicate that the water level that was recorded by the instrument was false;

- Between 1:22:00 and 1:26:00 (A and C) the water level appeared to drop by 6.8 mm yet there is no indication of the drain valve being opened. Examination of earlier data had shown that at the test site the expected drain rate was 0.17 ± 0.03 mm/min. If the drain valve were open the water level should have only decreased 0.7 mm in 4 minutes; the apparent decrease is much larger than this.
- At 1:37:02 (D) the fill valve was opened and then closed 1minute and 54 seconds later. Examination of earlier data had shown that at the test site the expected filling rate was 2.82 ± 0.06 mm/min; using this value the level should have increased by 5.3 mm yet it appears that it has changed by 12.5 mm.
- The fill valve was closed at 1:38:56 (E) with an instantaneous water level of 196.7 mm yet only one second later the instantaneous water level was 193.1 mm – a drop of 3.6 mm in one second is not physically plausible.
- At 1:43:00 the drain valve was opened and closed 1 minute and 43 seconds later, using the drain rate of 0.17 mm/min the level should have decreased by 0.3 mm yet comparison of the reference levels taken at H and L indicate that the level appears to have changed by 7.5 mm. Additionally comparison of the instantaneous levels at H and L indicate a change of 1.8 mm.
- From 2:28:00 to 2:34:00 (O and P) the water level apparently increased by 9.2 mm yet there was no indication of the fill valve being opened.

The example in figure 8 shows that false readings can trigger fill operations and cause the instrument to log false evaporation and condensation. The impact of the false readings on the daily evaporation totals could vary; they ranged from 0.2 to 8.6 mm throughout the evaluation. Table 3 summarizes the number of abnormal events that were recorded during the evaluation and their effect.

Month	Number of abnormal events	Number that caused a refill	Number that caused false evaporation readings
Jan 2001*	10	10	7
Feb 2001	2	2	1
Mar 2001	4	2	3
Apr 2001			
May 2001	2		
Jun 2001			
Jul 2001			
Aug 2001			
Sep 2001			
Oct 2001	1		
Nov 2001			
Dec 2001	2	1	
Jan 2002	4	3	1
Feb 2002	10	3	3
Mar 2002	10	3	8

* Jan 2001 used an older version of software that did not have the stability requirement.

Table 3. Monthly summary of number of abnormal events.

4.1.1 Other reasons for false readings

There is an apparent increase in water level when the electronics cabinet door is opened. The temperature sensor that monitors the signal conditioning electronics senses the temperature decrease and the temperature compensation turns this into an apparent increase in the water level. If the temperature drop is large enough this can cause false condensation counts.

Over time it was noticed that very thin iridescent flakes were developing on the surface of the stilling well. It was initially thought that the flakes might have been the source of the false readings. To test this, on several occasions the flakes were disturbed to see if they could cause a false reading, no conclusion could be drawn. It is suspected that the flakes are “calcite rafts” which develop when dissolved calcium in the supply water comes out of solution.

5. DISCUSSION

The RIMCO 9100 operated at the test site for 15 months and in that time never had to be reset. It recovered from power outages and heavy rain. It has the potential to show the effect of wind speed on the evaporation rate and provide hourly evaporation measurements.

The concept of using a data logger/controller to monitor and control the operation of the instrument is good – it allowed the field trial to occur without actually interfacing to and developing algorithms for an AWS. The control logic resides with the instrument and reduces the demand on the AWS processor. The availability of a communications port on the data logger/controller could prove very useful when AWS systems are developed in the future and more communications ports are available.

There are three major problems with the RIMCO 9100: the first is the issue of how it logs evaporation in the presence of false readings, the second is that the control of the fill and drain valves are operated using "instantaneous" values and the third is the possibility of the logging being inhibited after reporting the daily total at 9 a.m. All of these problems could be minimized if better algorithms could be implemented. The limitation to this approach is the severe restrictions of the DataTaker 50 programming space. There are only 4090 bytes available; a point was reached where no further software development was practicable. Given that the parameters of wind run and rainfall are always associated with evaporation measurements, a more powerful data logger/controller would overcome the programming space limitation and could possibly incorporate a wind run sensor and a tipping bucket rainguage into a complete unit for monitoring evaporation.

The daily condensation totals provided by the instrument are not a reliable measure of rainfall. The increase in water level can only be monitored up until a drain operation is initiated, and the change in water level required to do this depends on the initial water level in the pan. The required increase in water level could range from less than 0.2 mm to 10 mm.

The drain rate of the instrument is only 0.17 ± 0.03 mm/min (10.2 mm/hr). During heavy rain when the precipitation rate is greater than this, the water level will increase even if the drain valve was open. If it rains long enough the water level increases to greater than 198 mm, and if the water level remained above 198 mm for 10 minutes an alarm condition occurs. On 11 days during the field trail the water level did stay above 198 mm for more than 10 minutes after heavy rain. The instrument did recover but it took up to 50 minutes to do so.

Because the instrument cannot monitor evaporation during a fill operation, it will underestimate daily evaporation totals greater than 12 mm. The climate records of Mildura Airport indicate that 20 to 30% of the summertime daily evaporation totals are greater than 12 mm.

The ideal system would let the user specify the filling time and the reporting time separately. This would allow the user to either fill at 5 a.m. when the evaporation rate is lowest to minimize the understimation when the daily evaporation total is greater than 12 mm or fill at 9 a.m. to mimic a manual system for climatological purposes.

The manufacturer should consider controlling fill and drain operations based on time using one minute statistics to determine if there are false readings. A successive approximation method could be used to overcome changes in water pressure.

6. SUMMARY AND CONCLUSIONS

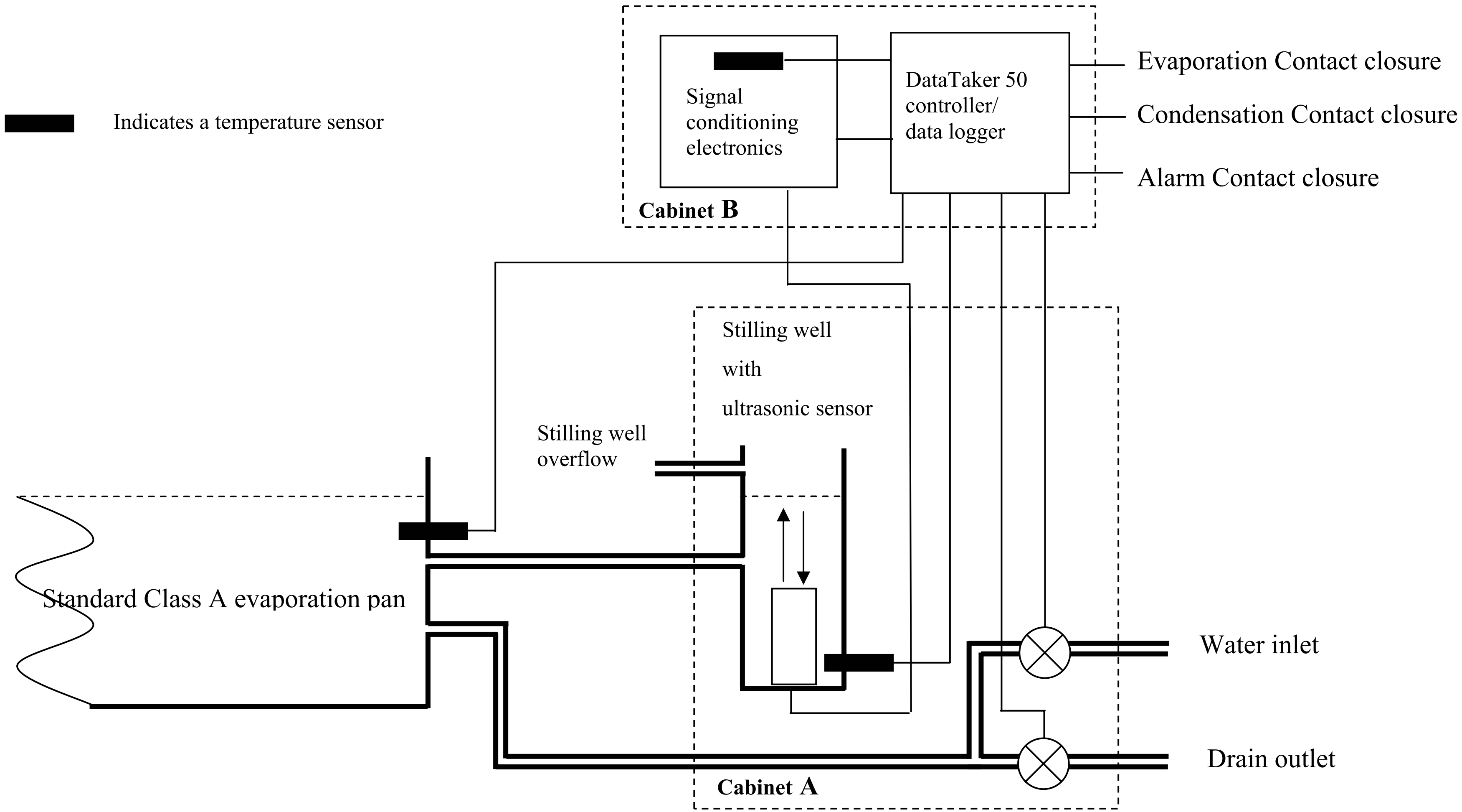
A McVan RIMCO 9100 automatic evaporation transducer was received in July 2000 and evaluated under laboratory conditions that highlighted some shortcomings of the software and the hardware configuration for field use. The instrument was returned to the manufacturer for modification in August 2000 and installed at the Broadmeadows test site in October 2000. The instrument failed to perform and it was returned to the manufacturer in early November 2000 and reinstalled at the test site in late December 2000. During the period January to February 2001 several undesirable effects were observed and the software was altered in an attempt to overcome them. Not all effects could be handled due to programming memory limitations of the instrument controller. The unit operated in the field from late December 2001 to Mar 2002 and never had to be reset.

On 45 occasions during the evaluation the instrument recorded false values of the water level. On 23 of these occasions the daily evaporation totals were affected, the amount added to the daily totals ranged from 0.2 to 8.6mm. The cause of the false values was not identified. The instrument will underestimate the daily evaporation total when the daily total is greater than 12 mm. The condensation counts are not a reliable measure of rainfall. If the water level is greater than 197 mm at 9 a.m. evaporation will not be logged until the water level becomes lower than this value – there is a potential for a 1 mm error to be introduced.

This evaluation has shown that logging the 1-minute data was extremely useful in characterizing the behaviour of the instrument. Any deployment of the current configuration should maintain a log of the 1-minute statistical data.

It is not recommend that the McVan RIMCO 9100 automatic evaporation sensor be put on a full comparative field trial.

APPENDIX 1: MODIFIED RIMCO 9100 AUTOMATIC EVAPORATION SENSOR SCHEMATIC



APPENDIX 2: ISO GUIDE TO THE EXPRESSION OF UNCERTAINTY IN MEASURMENT TYPE B UNCERTAINTY ANALYSIS TABULATION OF COMPONENTS

Quantity	Nominal Value	$\frac{\partial H}{\partial \text{Quantity}}$	Sensitivity Coefficient (c)	Uncertainty Limit ($\pm a$)	Distribution Type	Standard Uncertainty Equation	Standard Uncertainty (u)
V	1000 ml	$\frac{1}{(LW)+\pi\left(\frac{D}{2}\right)^2}$	+1.53 x 10^{-3}	±1 ml	Rectangular	$u=\frac{a}{\sqrt{3}}$	0.577
L	28.5 cm	$\frac{-VW}{\left((LW)+\pi\left(\frac{D}{2}\right)^2\right)^2}$	-4.71 x 10^{-2}	±0.2 cm	Rectangular	$u=\frac{a}{\sqrt{3}}$	0.115
W	20.0 cm	$\frac{-VL}{\left((LW)+\pi\left(\frac{D}{2}\right)^2\right)^2}$	-6.71 x 10^{-2}	±0.2 cm	Rectangular	$u=\frac{a}{\sqrt{3}}$	0.115
D	10.2 cm	$\frac{-V\pi D}{2\left((LW)+\pi\left(\frac{D}{2}\right)^2\right)^2}$	-3.77 x 10^{-2}	±0.2 cm	Rectangular	$u=\frac{a}{\sqrt{3}}$	0.115

The combined uncertainty is given by

$$u_c = \sqrt{\sum_{1}^{n} (c_i u_i)^2}$$

$$u_c = \sqrt{(1.53\times10^{-3}\times0.577)^2 + (-4.71\times10^{-3}\times0.115)^2 + (-6.71\times10^{-2}\times0.115)^2 + (-3.77\times10^{-2}\times0.115)^2}$$

$$u_c = \sqrt{(7.79\times10^{-7}) + (2.93\times10^{-5}) + (5.95\times10^{-5}) + (1.88\times10^{-5})}$$

$$u_c = 1.04\times10^{-2}$$

The expanded uncertainty is given by

$$U = ku_c$$

where k is the coverage factor, a coverage factor of 2 is used, leading to

$$U = 2.08\times10^{-2} \approx 0.021\text{ cm} \approx 0.2\text{ mm}$$