Addendum to Description of IO Bridge based Control Unit for Swimming Pool Solar Heating

I have now had my IOBridge based system for control of my swimming pool solar heating running for a few weeks. In this time the system has performed completely reliably and given a lot of satisfaction in terms of being able to monitor and manually, if desired, control the system when away from home.

We have had a spell of good weather here in the UK and this, together with the ability to export temperature logs form the IOBridge server, has allowed an initial assessment of the performance of the system in terms of heating the pool.

Figure 1 below shows a dashboard (part) screen shot taken on 12 April with temperature logs for the previous 7 days.

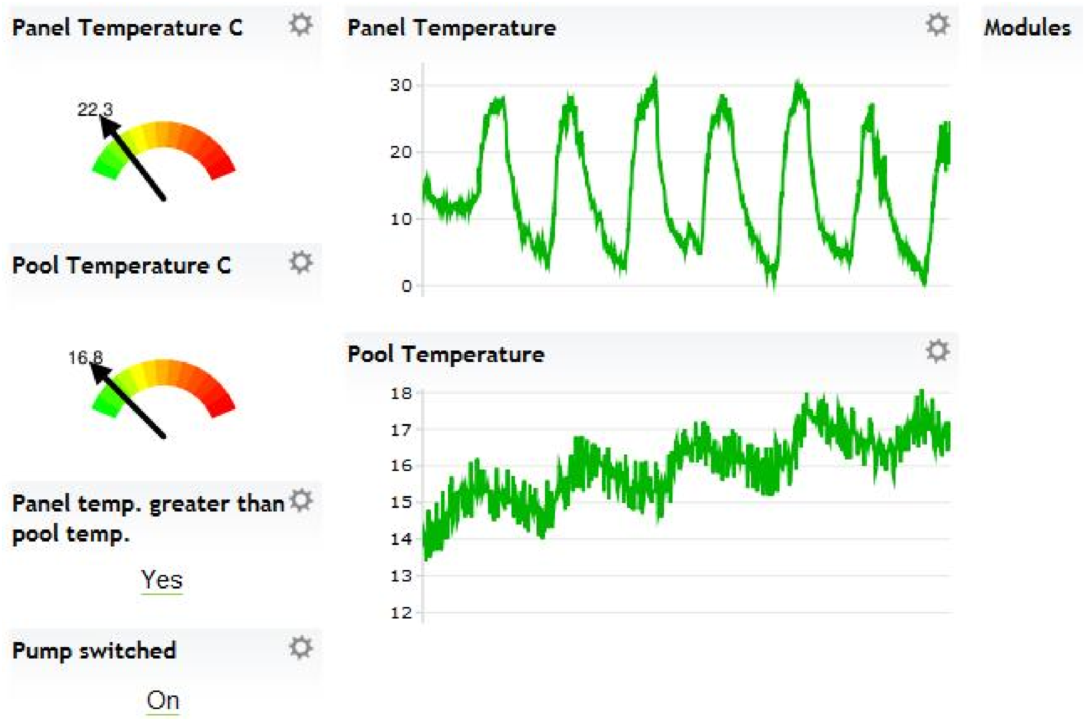

Figure 1 – Part of dashboard showing temperature logs as displayed (logging at 10 minute intervals)

The figure shows the essential characteristics of the system, i.e. the large variation in panel temperature through the day and night with the much smaller variation in pool temperature with a gradual overall rise in pool temperature in the time period. The scatter on the pool temperature measurements is significant in relation to the variation observed.

Downloading the Excel log file from the IOBridge server via the logging widget is straightforward. With the 10 minute logging interval there is almost too much data. After a bit of trial and error it was found that averaging the temperatures on an hourly basis not only gave pool temperature measurements that could be used in subsequent performance analysis but also fitted well with the limit of 255 data points in an Excel chart. Figure 2 shows the same information as above but as an Excel chart using hourly averages of the data.

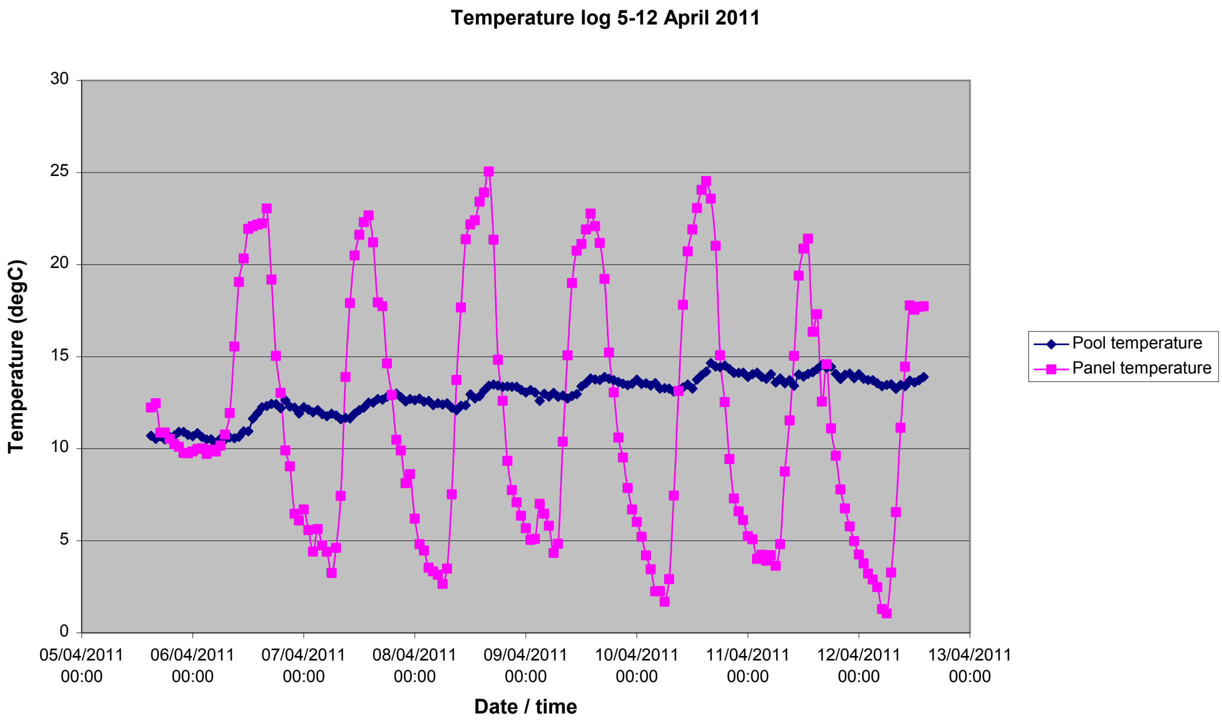

Figure 2 – Excel plot of panel and pool temperatures for the period

Having the data available in a spreadsheet allows some simple analysis of the system performance. My pool is 14 x 28 ft with a nominal water capacity of 40,000 litres (or kg). My panel area is 15.5m^2. The period being considered consists of 6 heating (i.e. day) and 6 cooling (i.e. night) cycles:

Date	Duration of heating *(hours)*	Increase in pool temperature *(°C)*	Net heat input to the pool *(kW.hr)*	Average net power input *(kW)*
6 April	12.6	1.91	88	7.0
7 April	12.4	1.10	51	4.1
8 April	10.0	1.25	58	5.8
9 April	10.2	0.96	44	4.4
10 April	9.3	1.33	61	6.6
11 April	5.5	0.95	44	8.1

Table 1 – Heating cycles for the period

Date	Duration of cooling *(hours)*	Decrease in pool temperature *(°C)*	Heat loss from the pool *(kW.hr)*	Average power loss *(kW)*
6 April	11.4	0.61	28	2.5
7 April	13.6	0.77	36	2.6
8 April	13.9	0.60	28	2.0
9 April	14.4	0.64	30	2.1
10 April	16.3	0.90	42	2.6
11 April	17.4	1.07	49	2.8

Table 2 – Cooling cycles for the period

The values in the tables, and in particular the cooling table, are considered very consistent given the small changes in pool temperature involved and the scatter on the absolute measurements. One can see that conditions for pool heating were generally more favourable early in the period, mainly because the heating cycles were longer.

The values derived for heat and power in Tables 1 and 2 are based on two significant assumptions. The assumption is made that the pool is at a uniform temperature given by the pool temperature reading. It is possible that some of the effective heat loss is mixing of the pool water taking place during the cooling period, noting though that the pump is off during this period. Secondly the assumption is made that there is no direct heat gain at the surface of the pool. The pool had two covers over it during the period considered – a floating solar cover and the winter cover above it. There will no doubt be some gain but this would be expected to be small in relation to the heat gained by the panel. In retrospect it would have been straightforward, with the capacity available on the IOBridge module, to include temperature measurement of the inlet and outlet water to and from the collector panels. This would be desirable in providing extra data for system analysis though I would not envisage (at present) the information being used for the control scheme.

Assuming for simplicity that the derived values in Table 1 and 2 are realistic then estimates of the total heat collected by the panel can be made, both as a gross figure and per unit area of panel:

Date	**Net heat input to the pool** ***(kW.hr)***	**Net heat to the pool per unit area of panel** ***(kW.hr/m²)***	**Gross* heat input to the pool** ***(kW.hr)***	**Gross* heat to the pool per unit area of panel** ***(kW.hr/m²)***
6 April	88	5.7	119	7.7
7 April	51	3.2	83	5.4
8 April	58	3.7	78	5.0
9 April	44	2.9	65	4.2
10 April	61	4.0	85	5.4
11 April	44	2.8	59	3.8

(* Based on adding loss scaled for relative durations from Table 2)

Table 3 – Heat gain by the solar panel

I would like to think that the above represents fairly efficient collection of available heat. This is because the weather for the period was relatively cloudless and the whole control scheme is based on collecting heat at (strictly less than) the prevailing ambient temperature and hence at maximum collection efficiency. I am not familiar enough with solar gain calculations and do not have access to the ISO standard for determining collector efficiency however I can make a comparison against the solar insolation figure at the top of the atmosphere which data is available and should represent an upper limit (I say should as I am not sure if reflected heat could add to it as the sun will always be at an angle). The solar insolation figure is a function of latitude and time of year with the values for my latitude (52^o North) given as a function of time of year in Figure 3 overleaf. The daily insolation figure for the period examined here is 8.0kW.hr/m^2. Neglecting the 6 April gross figure (which seems to represent near 100% collection of the solar isolation figure) the heat collected works out between 50-70% of the insolation figure if heat loss in the pool is realistically allowed for and 35-50% if the net heat collection figure is used

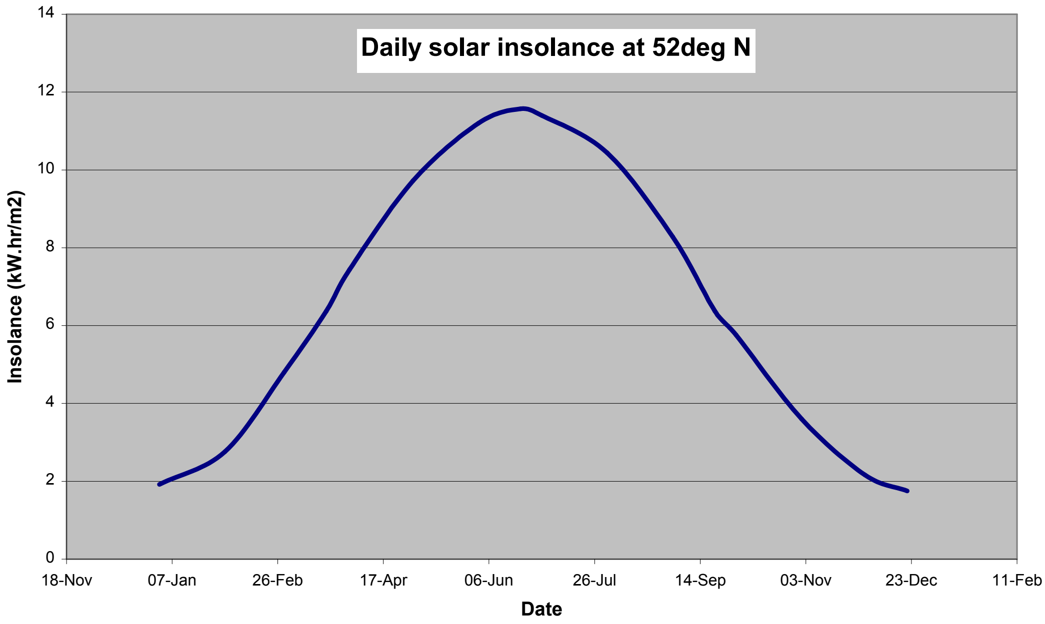

Figure 3 – Daily solar isolation at top of atmosphere (at 52^o N)

Whether or not the above analysis is completely realistic, it is useful in illustrating aspects of the system performance. The main one is the small daily increase in pool temperature that can be expected even with optimum heating conditions (even in mid summer the increase can be predicted from the analysis to be somewhat less than 2^{o}C per day). Getting the pool to a working temperature relies on ratcheting the temperature up over spells of good weather (as was apparent a priori).

This period of operation and its analysis has also highlighted the fundamental nature of my solar heating system, i.e. it cannot raise the temperature of the pool water above some average of the ambient temperature. The temperature would appear to be able to rise to this equilibrium value relatively quickly given good weather. From a practical point of view, this means that I have probably started warming my pool earlier than I need have done. Once I have more data it should be possible to decide the optimum time for starting the solar heating.

Whilst the IOBridge based control system undoubtedly improves the performance of the overall solar heating arrangement that I have, it would be very nice to be able to extend the swimming season beyond what would appear possible with my system as it stands. The surest way would be to increase the collector area to give a pro-rata increase in daily heat input. If the above analysis is largely correct then the heat loss from the pool is quite significant in relation to the solar heat input however there would not seem to be much scope for reducing this heat loss further. The present control scheme, i.e. switching the pump on if the unshaded ambient temperature is greater than the pool temperature, although simple, will be the one that maximises the solar heat gain (but may not be most economic as the pump will be running when the heat input is small). This leaves making some change in the collector, i.e. insulating it from the ambient air. At the moment I have not convinced myself of the cost benefit of doing this. For the conditions analysed in this note, i.e. with the ambient temperature over the whole day generally exceeding the pool temperature, the simple uninsulated collector will outperform any more sophisticated and expensive type of insulated collector. However if the (unshaded) ambient temperature is less than the desired pool temperature during the day then there will be some advantage in having some form of insulated collector. However insulation generally comes at a cost, and one has to consider that although the solar efficiency may have improved, the solar insolation at ground level may be that much lower such that the absolute gain in heat input is of little benefit. Also the advantage in performance is at a time when the ambient conditions are generally less attractive for swimming.

Overall the control and logging feature of the IOBridge based system has not only optimised control of my solar heating within the constraints that exist but has allowed a much better understanding of its performance.

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