Performance Review of Public Outdoor Pool Solar Thermal Heating Systems in the City of Toronto

January 2012

Technology

Monitoring

Best Practices

SolarCity Partnership

SUMMARY

The SolarCity Partnership was established in 2008 to undertake third-party monitoring and performance verification of large solar installations. Results are used to help optimize the performance of solar facilities and establish best practices and tools needed to continuously improve standards for use of solar energy in an urban context. The initial phase of this project, funded by Federation of Canadian Municipalities, focused on installations on City of Toronto facilities only. However, the project has now expanded to consider private and public installations across the GTA to provide a more robust project data set for comparison.

Four City of Toronto outdoor public pools were evaluated for this comparative study. The location of each site is presented in Table 1. All four systems were installed in the fall of 2008.

Table 1: Solar City Partnership outdoor pool case study sites

Site Name	Address
Gihon Spring	75 Gihon Spring Drive, Toronto
Park Lawn	340 Park Lawn Rd., Toronto
Rotary Park	25 11th Street, Toronto
Weston Lions	2125 Lawrence Avenue West, Toronto

The performance of the installed equipment at all four sites was hampered by multiple data collection and operational issues. These included: closures due to a municipal strike in 2009; improper monitoring equipment set up; unwanted operation doing times when solar production was low (i.e., overnight), which produced cooling effects for the pools; equipment damage; loss of data due to lack of integration with central data collection systems; and unwarranted shutdowns due to site-operator error.

Despite the many challenges associated with these installations, some key lessons were clearly established, including: the ***importance of sensor placements and set points***, which affect the times at which the pool is programmed to access the thermal heating, in order to ensure the ability of the pool to make full use of available solar energy; the ***susceptibility of solar pool heating systems to add unwanted cooling*** to the pool due to inadequate check-valve systems; and the need to ***ensure that on-site pool staff are engaged*** and have a basic understanding of the system and the ability to ensure that it is functioning throughout the pool season.

As a result of the multiple difficulties affecting data collection, annual solar thermal energy yields per pool ranged broadly and cannot be used for reliable comparison. However, energy produced by an optimized pool solar heating system undergoing intensive monitoring during August of 2011 produced 4515 kWh of energy, outperforming

Photos by Lucio Mesquita

the modelled energy production by 1.7%. ***Based on the optimized energy production experience during August 2011 at Rotary Park pool, simple payback is estimated for this site at 14.8 years.***

All four outdoor pool installations were financed by the City with assistance from grants provided through the Renewable Energy Deployment Initiative managed by Natural Resources Canada (now cancelled). Pool installations ranged in cost from $19,562 - $36,645 and grants received averaged 50 percent of the total installed cost. The cancellation of this generous grants program makes it unlikely that future pool projects would be financed by the City. However, an arrangement made with a private company in 2010 is providing for solar thermal installations on city facilities using a “solar utility” model, where the installer owns and operates the systems and charges the City a fee for energy delivered.

SYSTEM PERFORMANCE

This report presents basic information regarding the performance of solar heating systems installed at four different outdoor swimming pools for the City of Toronto. The sites are: Weston Lions, Gihon Spring, Park Lawn and Rotary Park. All systems were installed in the fall of 2008 and commissioned in October of the same year. However, due to the municipal workers strike, the systems were operational for only a few days in 2009. Table 2 presents the basic characteristics of each installation:

Table 2. Systems characteristics.

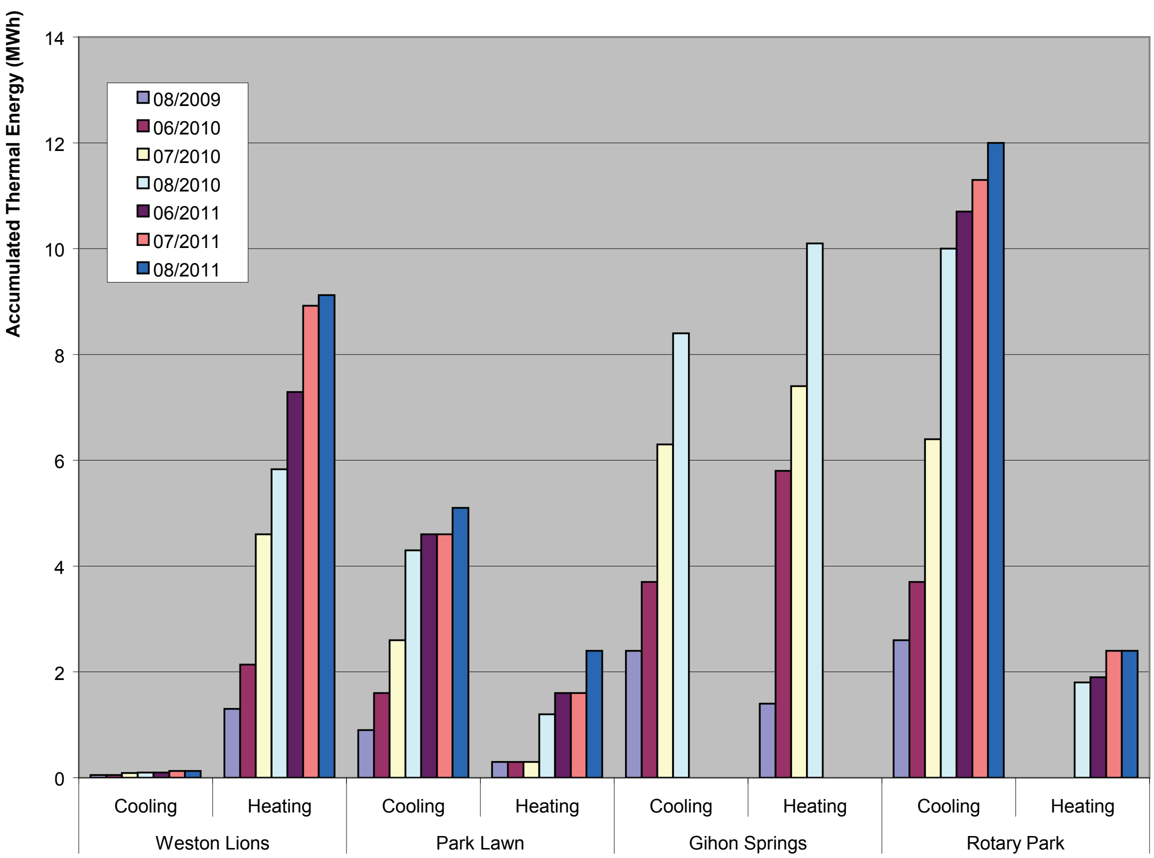
	Weston Lions	Park Lawn	Rotary Park	Gihon Spring
Approx. Pool Size	620 m^2	310 m^2	380 m^2	310 m^2
Collector Area	70.2 m^2	124.9 m^2	133.8 m^2	127.8 m^2
Collector Tilt	10°	15° and 20°	3°	20° and 17°
Collector Orientation	20° SE	17° SE, 107° SE and 73° SW	107° SE	60° SE, 120° SW, 30° SW and 30° NE
Flow Control	2-Way Valve	Solar Pump	Solar Pump	Solar Pump
Observations	BTU sensors inverted	Single sensor for all three batteries.		Single sensor for all three batteries.

Each system is equipped with an energy (BTU) meter (Actaris CF Echo II), which measures both the heating and cooling energy and flow delivered through the meter. The BTU meters were not installed by the solar contractor or the City, but by a third party contractor. Some data from the BTU meters is collected through each Building Automation System (BAS), but the systems are not connected to any communication network and data have to be downloaded manually. The BAS have enough data memory for about two weeks of operation.

At the end of the 2010 outdoor pool season, the data from the BTU meters was collected. Initial low energy production results motivated the installation of a detailed monitoring system at Rotary Park, as a way to further investigate the system underperformance. At the end of the 2011 season, it became apparent that all systems had the BTU meters temperature sensors inverted, and they had registered actual heating as cooling and actual cooling as heating. The main issue is that the BTU meter model used only registers cooling once the temperature differential is above 0.5 K and the water temperature where the flow meter is located falls below 25 °C. Since the temperature sensors were inverted and the temperature of the pools is frequently above 25 °C, heating (registered as cooling) was grossly under measured. However, despite the confusion arising from the improperly installed monitoring devices, the data did allow for the observation of significant real cooling effects in three of the four pools analysed. Figure 1 presents the accumulated cooling and heating values for the pools, where heating and cooling values have been reversed.

Weston Lions had negligible cooling and it is the only design that did not rely on a solar pump for flow through the panels. It has a motorized 2-way valve that diverts some of the pool filtering circulation flow to the panels.

Figure 1. **Cumulative thermal energy for each of the outdoor pools evaluated. June (6) also includes the days of operation during September of the previous season. Registered heating is under measured and therefore inaccurate because of an inversion of the temperature sensors.**



Initially, two main causes were suggested for the cooling effects registered:

1. the systems could have been operational when there was no useful heat to be collected, mostly due to the fact that some of the systems employ a single sensor for multiple collector orientations;

2. the existence of unwanted flow during periods of no solar radiation.

For Gihon Spring, Rotary Park and Weston Lions, hourly data for the last few days of the 2010 season operation was available and helped clarify the issues above. There was no hourly data available for Park Lawn.

Figure 2 shows the supply and return temperatures and solar system flow rate for the period between 27/08/2010 and 03/09/2010 for Gihon Spring. The data were used to evaluate the eventual operation of the solar pump during periods of no real useful heat collection. For the period considered, only for four periods of 15 minutes did the system operate under cooling conditions while the solar pump was operational, with a total energy loss of 41 Wh. This would lead to an average of 6.83 Wh/evening and a total of 615 Wh for the season, which would be negligible. Therefore, the sensor position did not appear to introduce significant losses at Gihon Spring. Due to the position of the collectors, one could assume that Gihon Spring would be the worst case for such effect. Weston Lions and Rotary Park have all collectors installed on the same plane. Park Lawn has collectors on different planes, but no data was available for it.

Regarding the second potential cause for cooling, Figure 2 shows that during the evenings there was still flow through the collectors, with a significant drop in temperature of the water flowing through the panels. A somewhat similar pattern is shown on Figure 3, which presents data for Rotary Park. However, Figure 4, which shows the curves for Weston Lions, shows no flow rate during the evenings. Weston Lions was the only system which originally used a motorized 2-way valve to control flow through the panels.

At the beginning of the 2011 season, Gihon Spring and Rotary Park received a spring-loaded check valve as a way to reduce unwanted flow through the panels. Since there was still some unwanted flow being registered even after the check valves installation at Gihon Spring and Rotary Park, Park Lawn received a motorized 2-way valve instead.

Figure 1 shows a significant reduction of cooling for Rotary Park after the check valve installation and the elimination of cooling at Park Lawn after the motorized valve was introduced (the BTU meter registered a small amount of cooling during the last month of the season, but the system had a faulty sensor at that point).

The BTU meter at Gihon Spring was defective at the end of the 2011 season and no data was available for that season. Therefore, it was not possible to evaluate the effectiveness of the check valve to reduce the cooling at that site.

Park Lawn had a leaky collector and then another leakage through one of the temperature sensors in 2010. In 2011, the system had a problem with a faulty sensor. With those problems, the solar heating system did not operate for a significant portion of the 2010 and 2011 seasons.

Using simulation numbers from Enerpool, which is a software package developed by Natural Resources Canada for simulation of swimming pool heating systems, a typical season in Toronto with 71 days of operations would lead to an amount of solar energy collected between 217 kWh/m^2 and 238 kWh/m^2, with an average of 227.5 kWh/m^2. Those numbers assume the same type of collectors as used in the projects analysed here and a pool temperature at 26 C. Table 3 shows the cooling numbers for the 2010 and 2011 seasons for Park Lawn, Gihon Spring and Rotary Park. Cooling is negligible for Weston Lions, but it was significant for Rotary Park and Gihon Spring in 2010. Park Lawn has faced operational issues with collector and sensor issues, so it is difficult to evaluate how representative the numbers are of full operation. There is no data for Gihon Spring in 2011. For Rotary Park there was a significant reduction of cooling after the installation of the spring-loaded check valve, but cooling is not negligible.

Table 3. **Cooling for three of the outdoor swimming pools and the percentage that cooling represents of a typical expected seasonal solar energy production.**

		2010	2011
Park Lawn	**kWh**	4,300	800
	kWh/m^2	34.4	6.4
	% of typical production	15.1%	2.8%
Gihon Spring	**kWh**	8,400	65.7
	kWh/m^2	65.7	NA
	% of typical production	28.9%	NA
Rotary Park	**kWh**	10,000	2,000
	kWh/m^2	74.7	14.9
	% of typical production	32.8%	6.5%

Figure 2. Supply and return temperatures and flow rate for Gihon Spring.

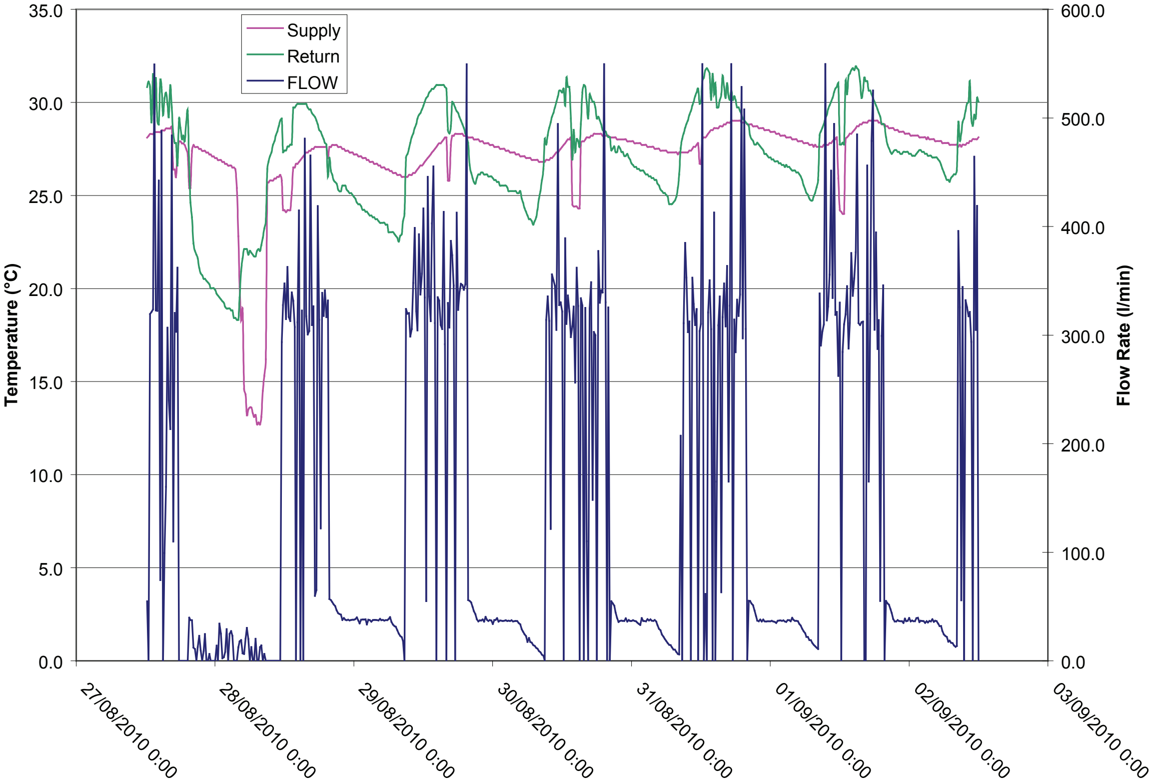


Figure 3. Supply and return temperatures and flow rate for Rotary Park.

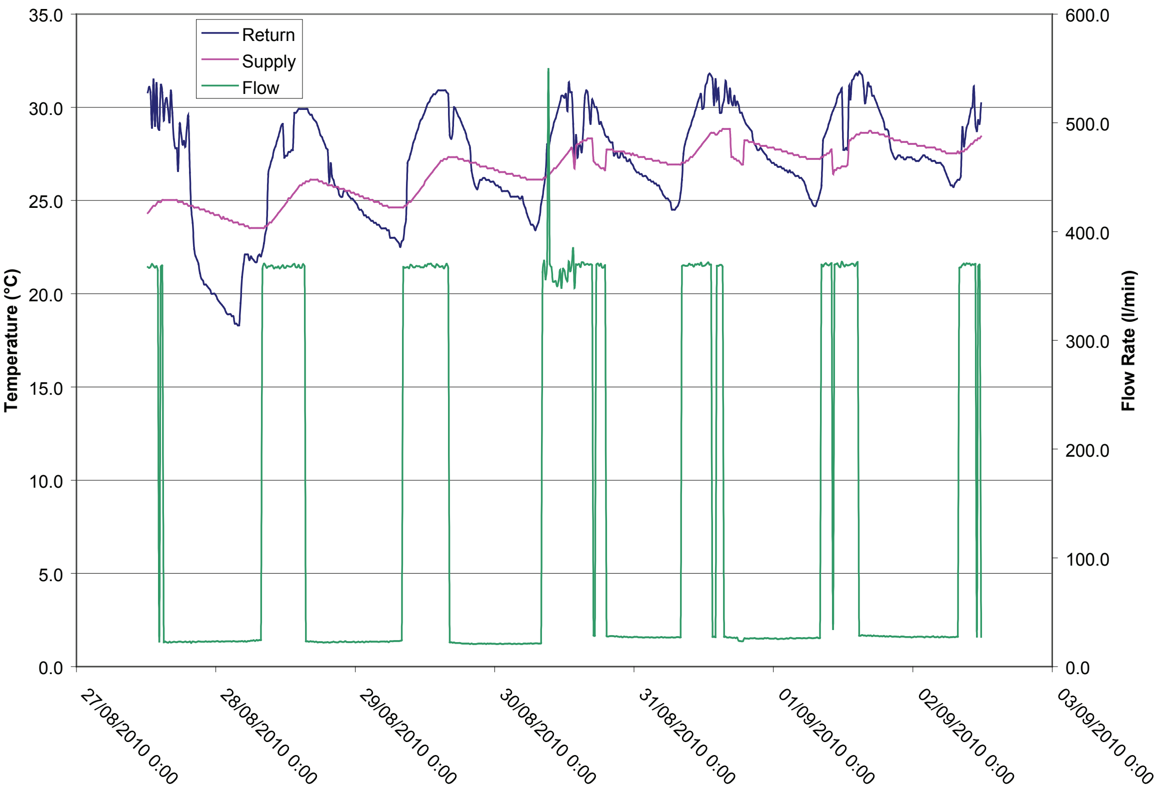
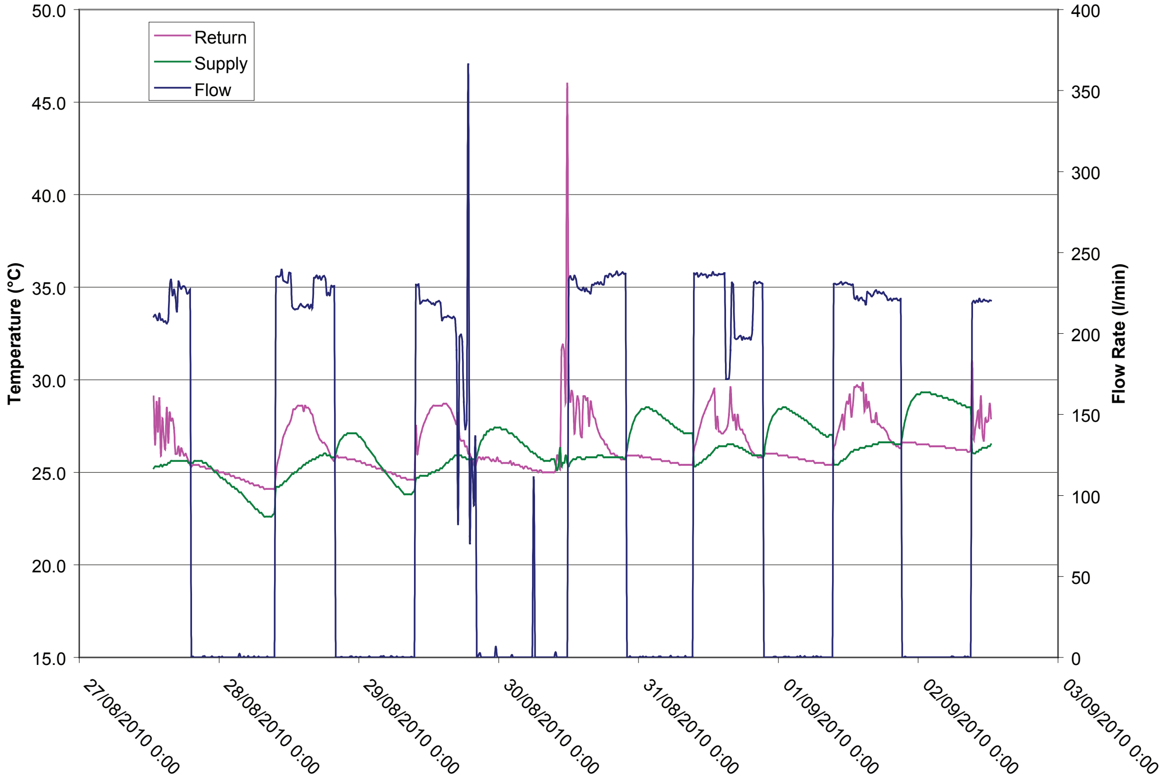


Figure 4. Supply and return temperatures and flow rate for Weston Lions.



DETAILED MONITORING AT ROTARY PARK

As a way to evaluate a number of operational aspects of the solar heating system, a more detailed monitoring program was introduced at Rotary Park and data were collected for two weeks in August 2011. Figures 5 and 6 show the schematic location of the sensors installed and Table 4 presents the specifications for the sensors.

Table 4. Instrument specifications for Rotary Park detailed monitoring.

Pyranometer	Licor Li-200
Temperature sensors	Prosense Pt-100
Wind speed anemometer	NRG systems #40H
Flow meter	Dynasonics TFXL Strap-on Utrasonic
Data acquisition system	Logic Beach Intellilogger IL-80

Radiation shield for ambient temperature measurements.

A radiation shield was built for the ambient temperature measurements and also a small support was prepared to install the anemometer at the same level of the collectors.

Figure 5. Outdoor sensors at Rotary Park.

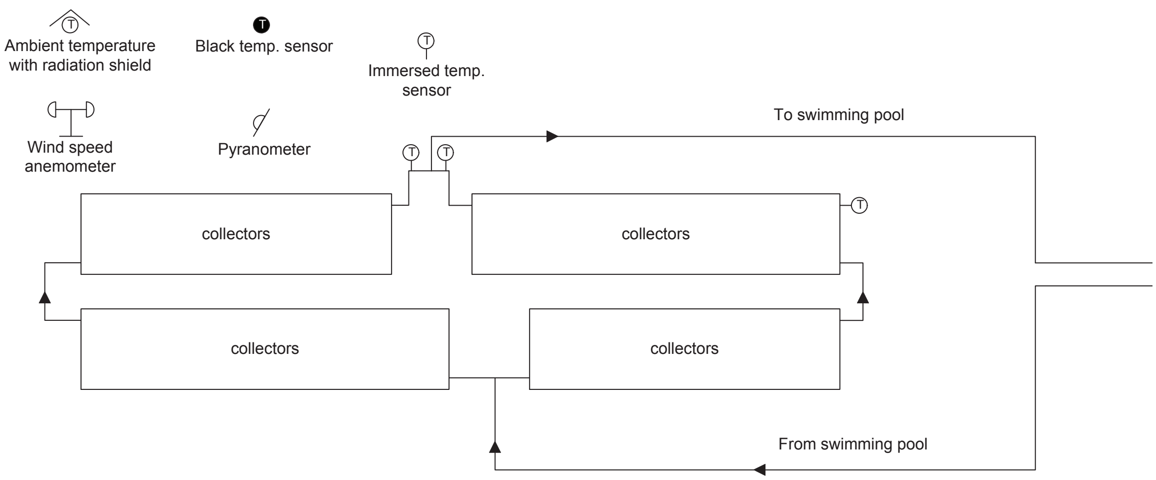


Figure 6. Indoor sensors at Rotary Park.

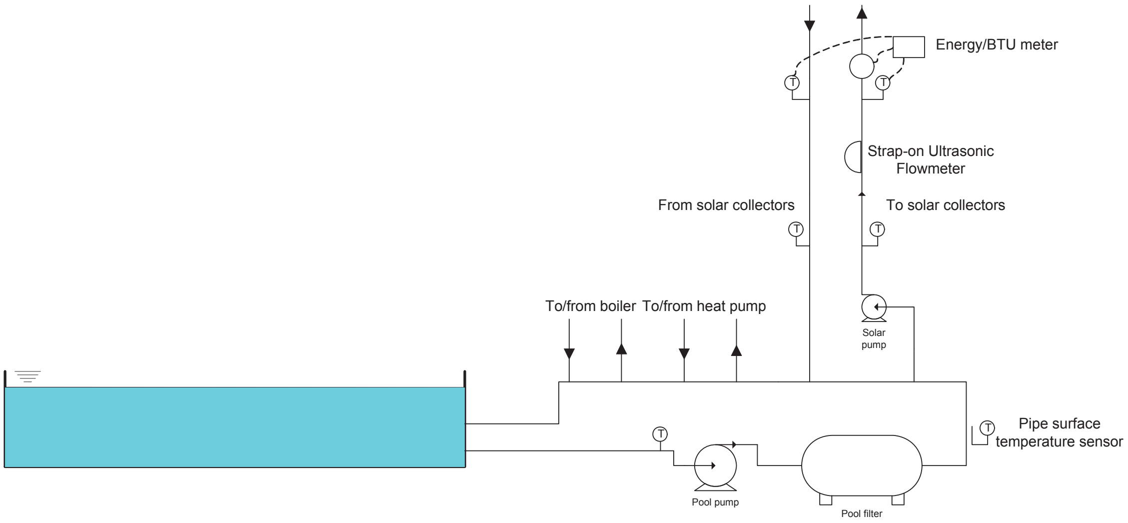
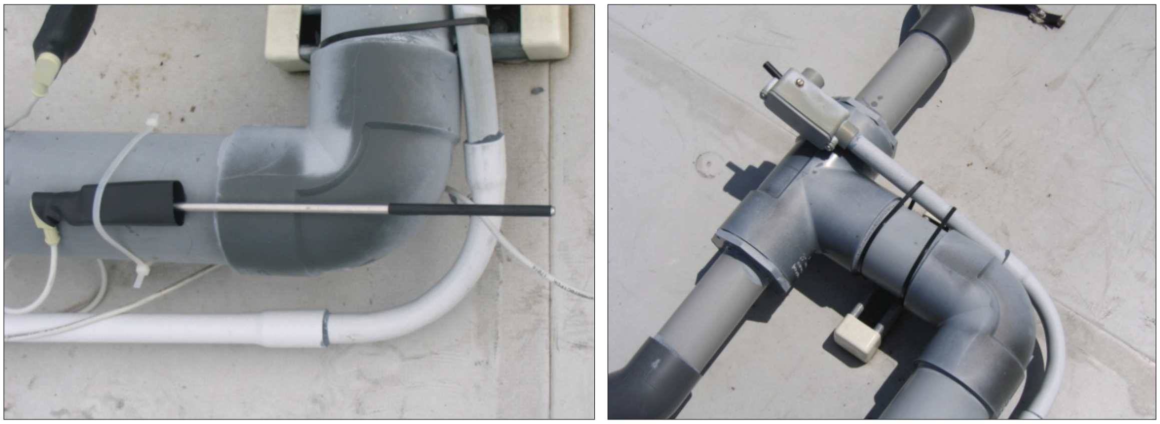


Figure 7. Detail of anemometer support and anemometer installed between solar collector arrays.

Figure 8. Temperature sensor with heat-shrink tubing at its end (left) and the original solar controller temperature sensor (right), which was replaced for the model on Figure 9 for the 2011 season.



One of the temperature sensors was darkened with a black heat-shrink tubing to mimic the response of the sensor previously installed on the system. It is common practice for solar swimming pool heating systems to have the "hot" sensor of the differential temperature controller exposed to the sun and not immersed in the collector.

Although the system operated with the dark sensor shown in Figure 8 (right) during the 2009 - 2010 seasons, in 2011 that sensor was replaced by the solar contractor for a model that is attached to a small dark board.

Figure 9. New solar controller temperature sensor installed at the beginning of the 2011 season.

Figure 10. Collectors outlet immersed, controller and darkened temperature sensors.

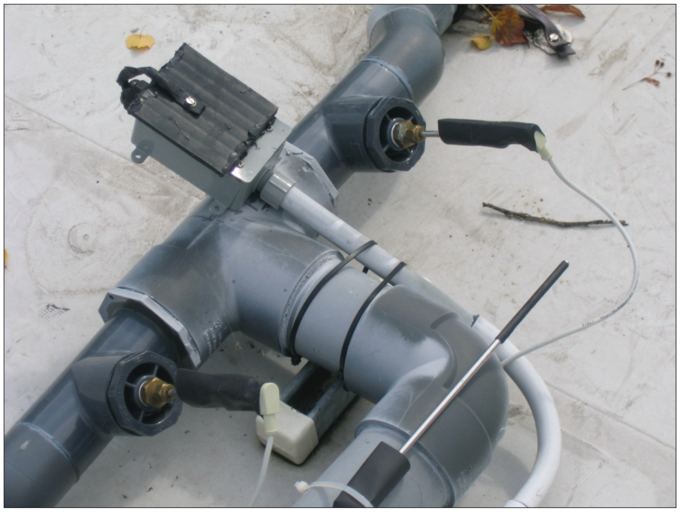


Figure 11. Pyranometer installed on its base and on the roof near the solar collectors.

The pyranometer was installed on the same plane as the collectors (3°, 107° SE) on a rubber base.

It has been a common practice in the industry to install surface temperature sensors and to evaluate the temperature difference between immersed and surface sensors; a temperature sensor was therefore installed on the pipe surface, downstream from the pool filter and close to the pool temperature solar controller sensor.

Figure 12. Surface temperature sensors.

The strap-on ultrasonic flow meter sensors were installed on the collectors' supply piping and the output was calibrated against the BTU meter flow sensor, which is an inline ultrasonic unit. The strap-on ultrasonic flow meter does not have enough sensitivity to capture very low flow rates, as present during the evenings, when the system provides some cooling. At those moments, it registers flow as zero.

Figure 13. **Flow meter and collectors supply temperature sensors.**

RESULTS

The most important data from the analysis is the energy collected. During 15 days of operation the system collected 4515 kWh. The weather data, solar controller output status and collectors supply temperature, along with system and collector characteristics were supplied as inputs for Enerpool Pro simulations.

Enerpool Pro is a software package developed by Natural Resources Canada for simulations of swimming pool heating systems, and it is available free of charge. It has very useful and flexible capabilities for system performance verification, since it allows most of its variables values to be supplied as hourly inputs through an alternate input file.

Using the measured weather, collector supply and controller status as inputs, Enerpool predicts the collected solar energy to be 4436 kWh for the same period of the measurements, which is 1.7% lower than the measured values, and well within accuracies of the measurements and simulations.

The data analysis shows that the system control currently employed leads to a delay of system start-up. This does improve system stability and reduces pumping cycling, but it also reduces the performance slightly. Figure 14 shows the temperature of the blackened sensor, the temperature of the sensor immersed within the collector top header, supply temperature and flow rate for few days during the monitoring period.

Energy collected increases 12.5% when the simulations in Enerpool are performed with a conventional controller set-up, based on collector and pool temperatures, with the differential to turn-on the pump set at 6 °C and the differential to turn it off set at 2 °C. Figure 15 shows ambient temperature, solar radiation and solar pump flow rate for the 19th of August, and Figure 16 show the same variables for three days in a row. Very little pump operation happened when the return temperature was below the supply temperature to the solar collectors. For the period of measurements, only 7.19 kWh of cooling were caused by such operation, which is only 0.16% of the energy collected.

Figure 14. Temperature of the blackened sensor, the temperature of the sensor immersed within the collector top header, supply temperature and flow rate for few days during the monitoring period.

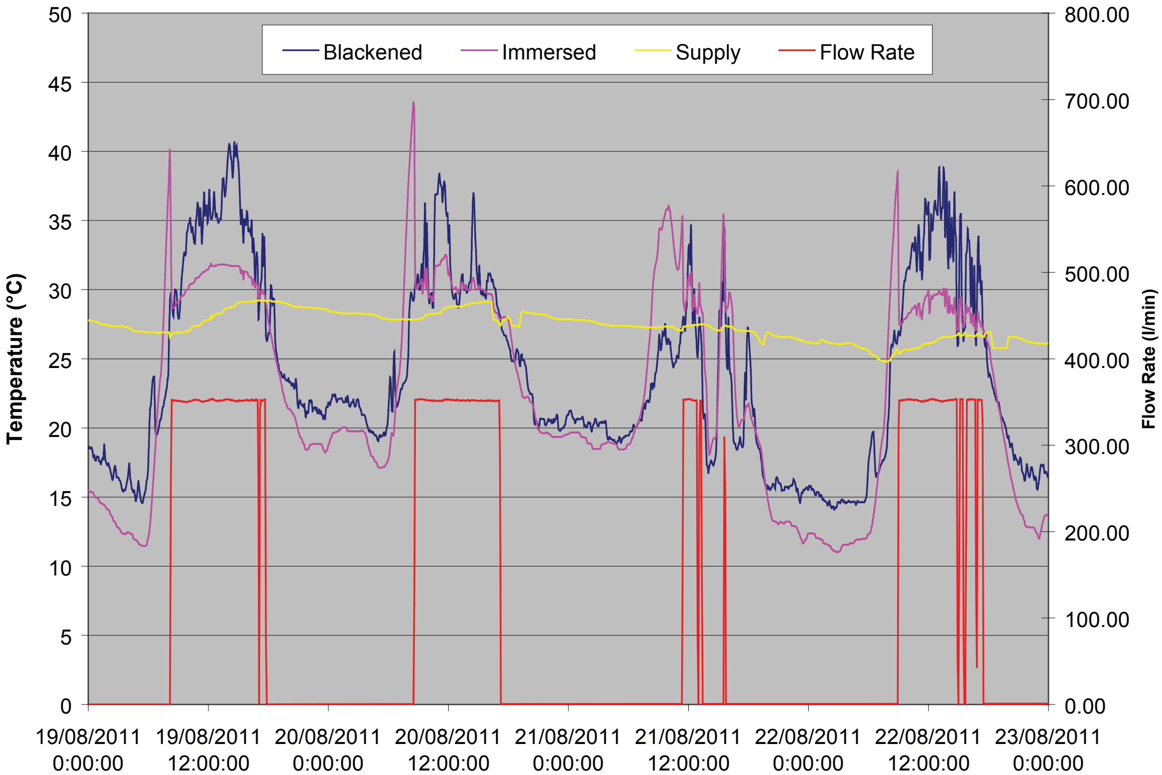


Figure 15. System operation for 19th of August, 2011.

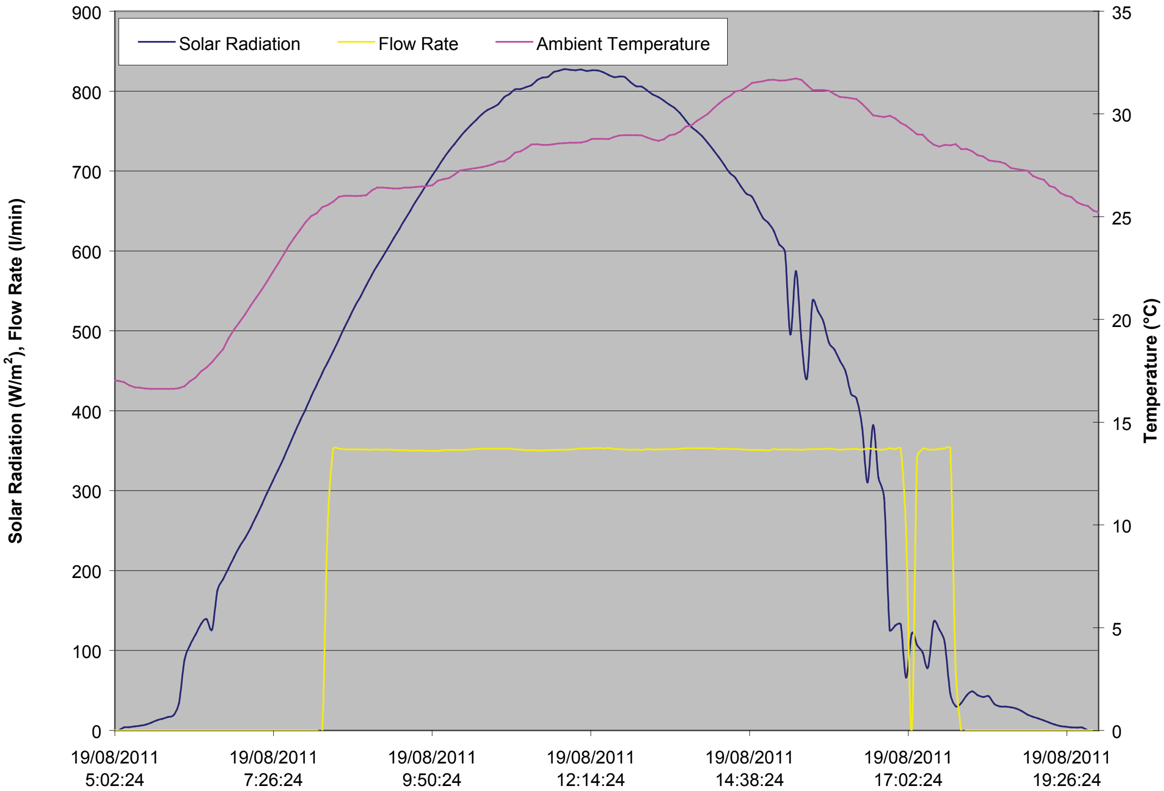
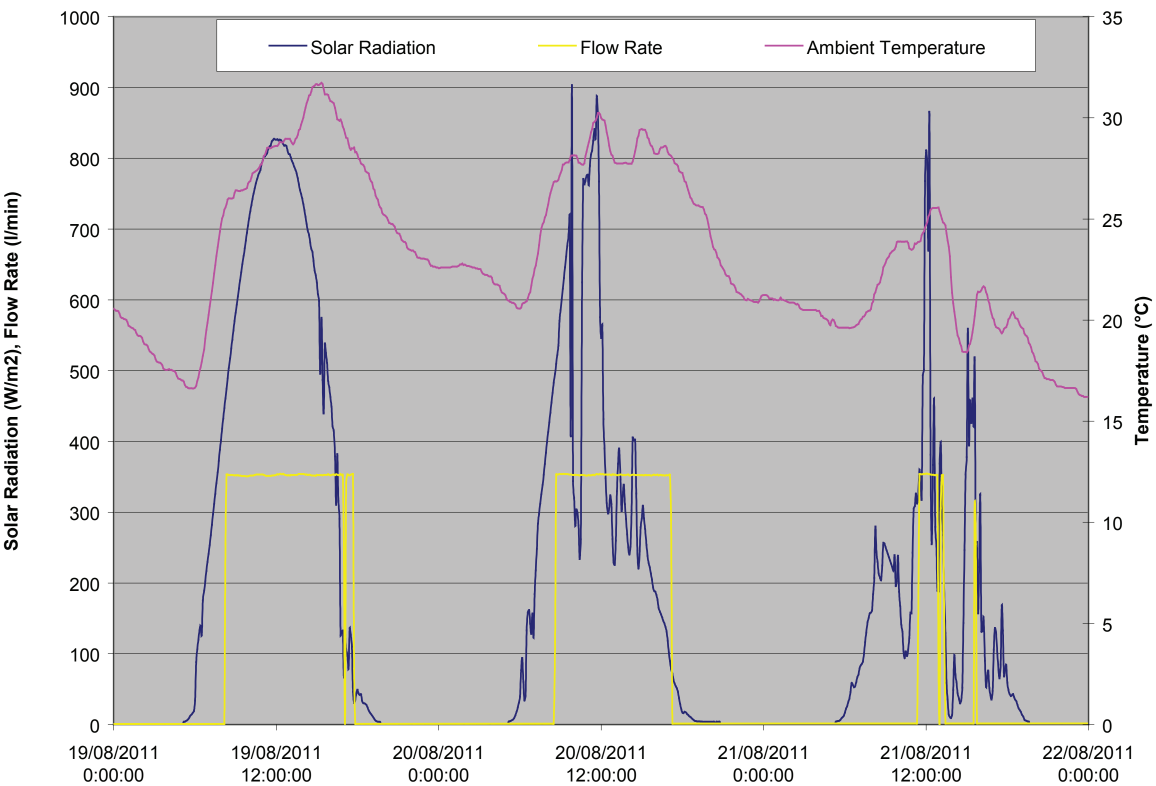


Figure 16. System operation from 19th to 21st of August, 2011.



Water flow is quite uniform between the two arrays, as measured by the temperature difference between the sensors located at the arrays' outlet. Assuming equal performance of the panels in each array, there was a 9% average difference in flow rate for the hours of solar pump operation. Figure 17 shows the temperature at the outlet of the two arrays for 19, 20 and 21 of August 2011. "Tlake" corresponds to the array closer to the lake or south side of the system, and "Tcity" is on the north side.

Figure 17. **Temperatures at the outlet of each collector array.**

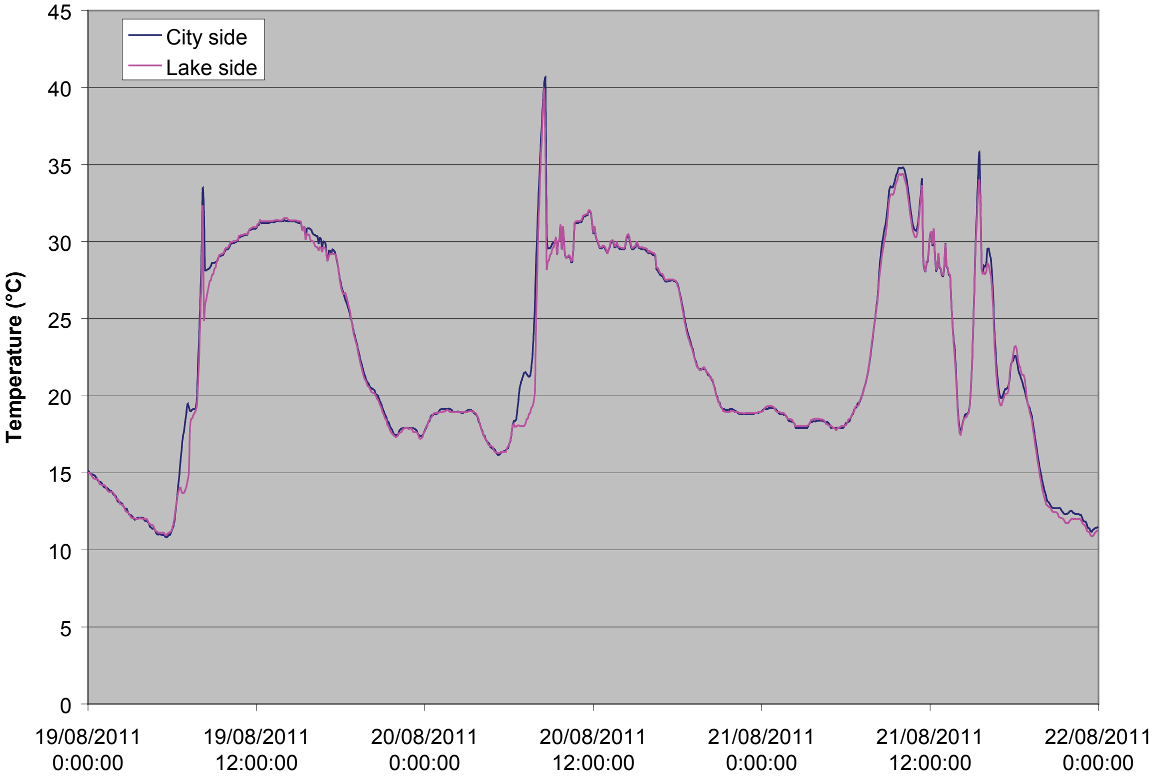
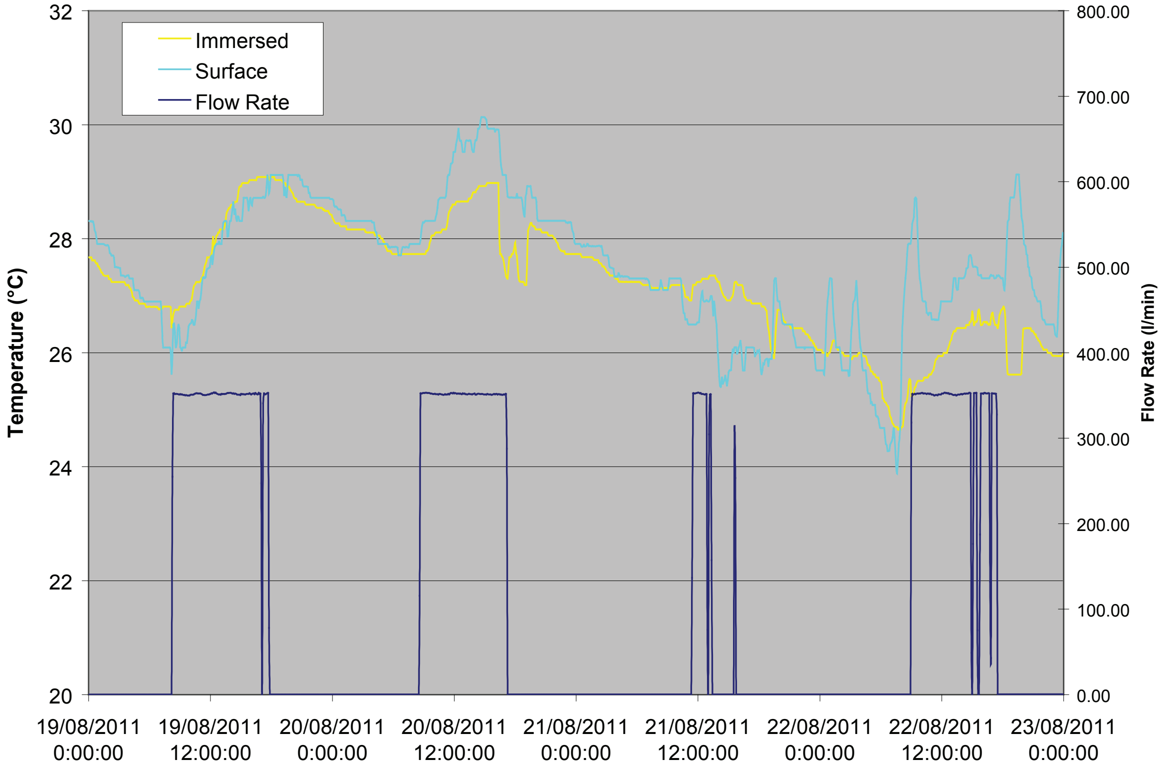


Figure 18 shows temperatures registered by the sensors located at the pipe surface and immersed, both inside the mechanical room and in the supply side of the system. In some instances the difference is significant, especially considering that the system operates within small temperature differentials.

Figure 18. **Temperature of immersed and surface sensors on the supply side of the system in the mechanical room.**



Figures 19, 20 and 21 present flow rate, ambient temperature and solar radiation for the full period of measurements.

Figure 19. System operation from 18th to 22st of August, 2011.

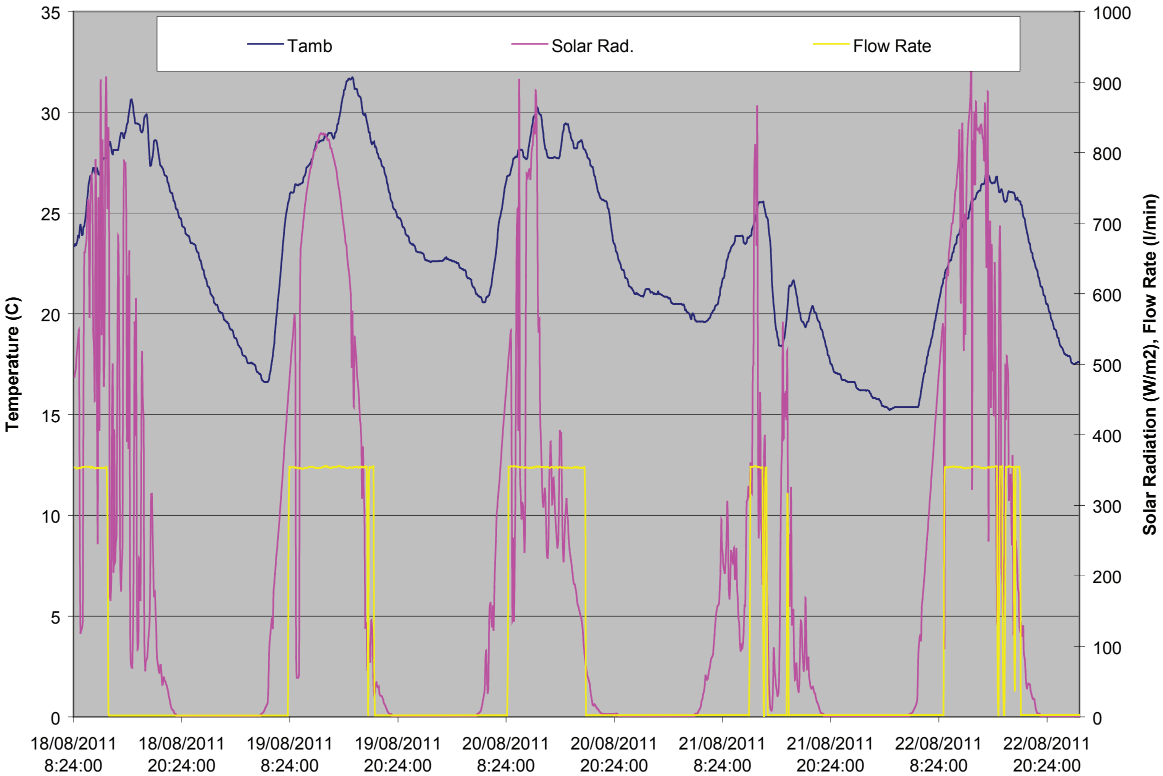


Figure 20. System operation from 28th August to 2nd of September, 2011.

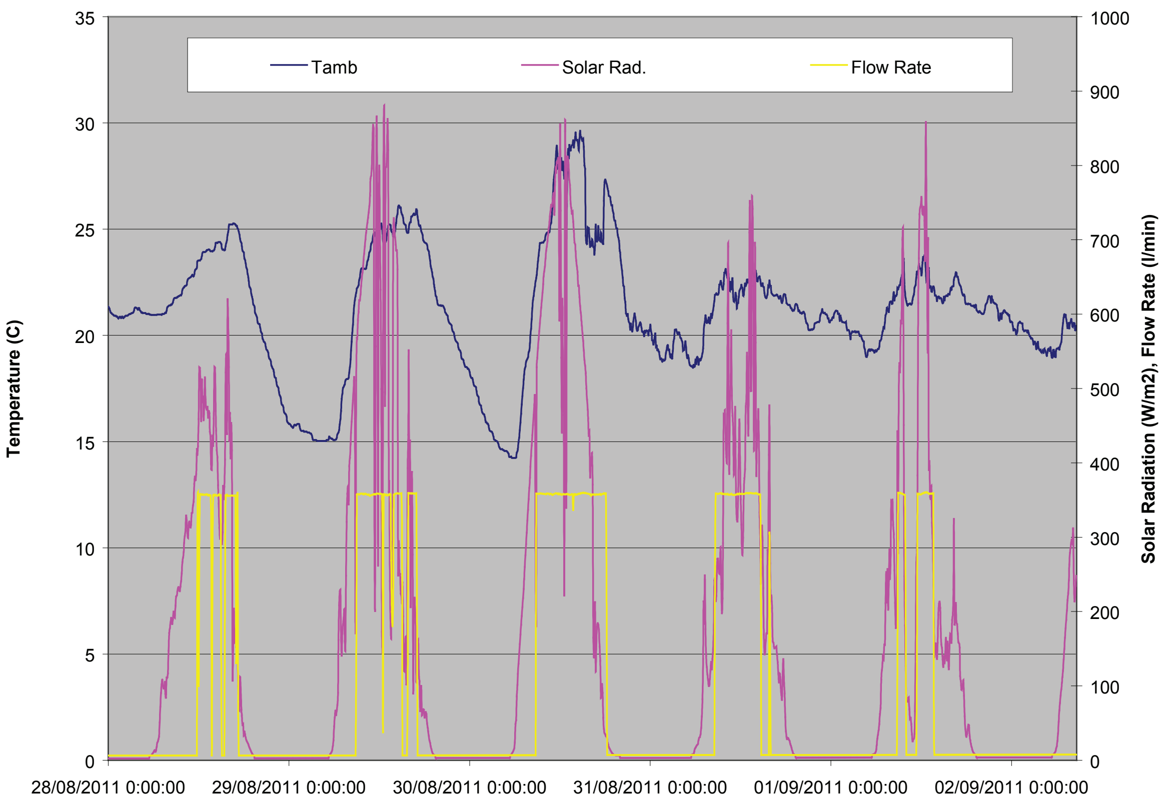
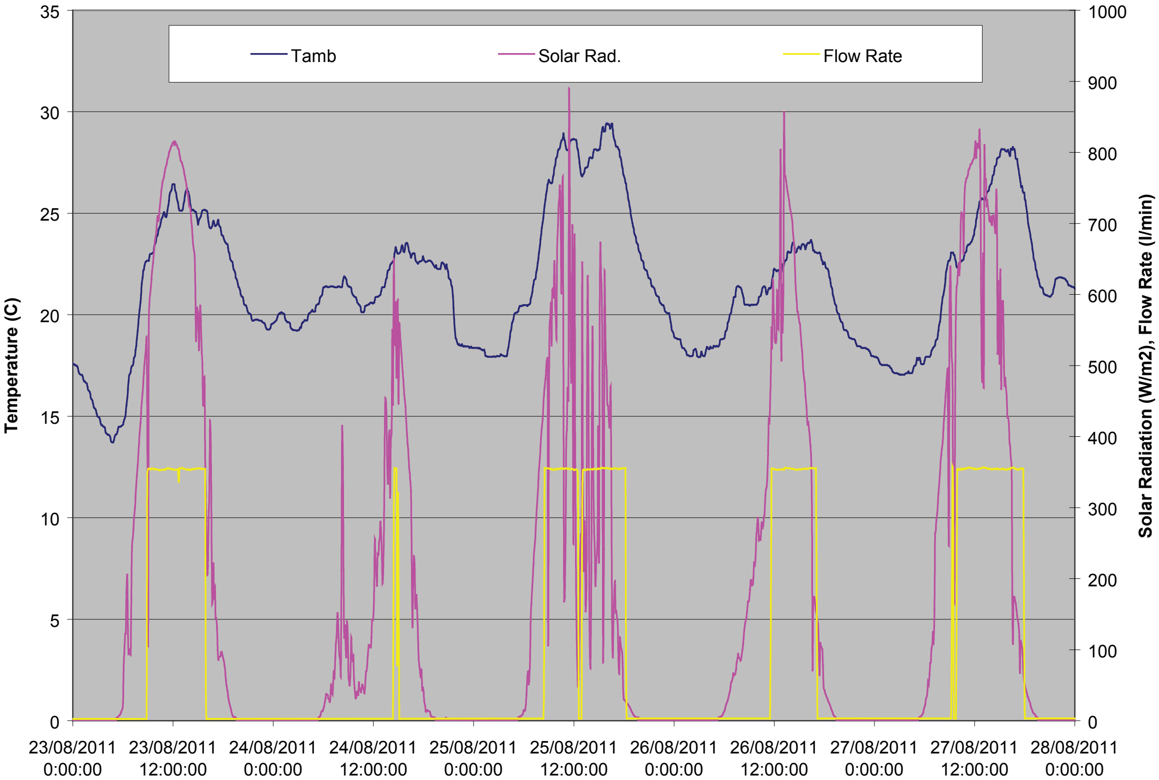


Figure 21. System operation from 23rd to 28th of August, 2011.



CONCLUSIONS AND RECOMMENDATIONS

Contributions of solar thermal systems are being counteracted by unwanted cooling effects. There is strong indication that the cooling effect is being caused by unwanted flow through the collectors during periods of no or little solar radiation. The cooling effect is significant for two of the systems, representing close to 33% of typical heat production at Rotary Park in 2010. The installation of spring-loaded check valves on the solar supply line eliminated most of the unwanted flow, but the losses are still close to 7% of typical heating. It is recommended that a motorized 2-way valve should be used to solve the problem.

Monitoring systems need to be closely reviewed to ensure proper functioning. All BTU meters installed for data monitoring purposes on outdoor City pools have the temperature sensors inverted, which caused the heating values measured to be unreliable. Therefore, the sensors position should be corrected as soon as possible. It is strongly advisable that, once the BTU meters are corrected, the City of Toronto establishes a process for the continued evaluation of the data available. It is also advisable that any installed system should have energy (BTU) meters and a protocol for continuous system evaluation. Preference should be given for suppliers with local or North American support. Basic questions regarding the Actaris BTU meters could not be answered since the company had no North American support for this type of meters and communication with European support was difficult.

Sensor settings can significantly affect system performance. The system at Rotary Park operated as expected during the monitoring period, although there are some indications that immersed controller sensors would improve energy performance.

On-site staff needs to be educated for minor trouble-shooting. During two visits to the Rotary Park system, the system was not operational. At the beginning of the season, the system had been re-commissioned, but a shut-off valve at the return piping from the collectors was left closed. Later in the season, the system was found turned off. Apparently one of the operators had shut down the system during filter back washing, and then forgot to re-start the solar heating system. With such a short season, the system can easily be disabled for a couple of weeks or even the whole season before someone realizes the problem. It is recommended that the operators collect data from the BTU meter daily, as is already done with fresh water flow. Therefore, with basic training the operator could identify a problem with the system.

APPENDIX – SCHEMATICS AND ADDITIONAL PICTURES

A.1) ROTARY PARK

Figure A.1. Rotary Park collector loop lay-out. Source: Rotary Park Solar Pool Heating System Commissioning Report, Solar Ontario, Oct 2008.

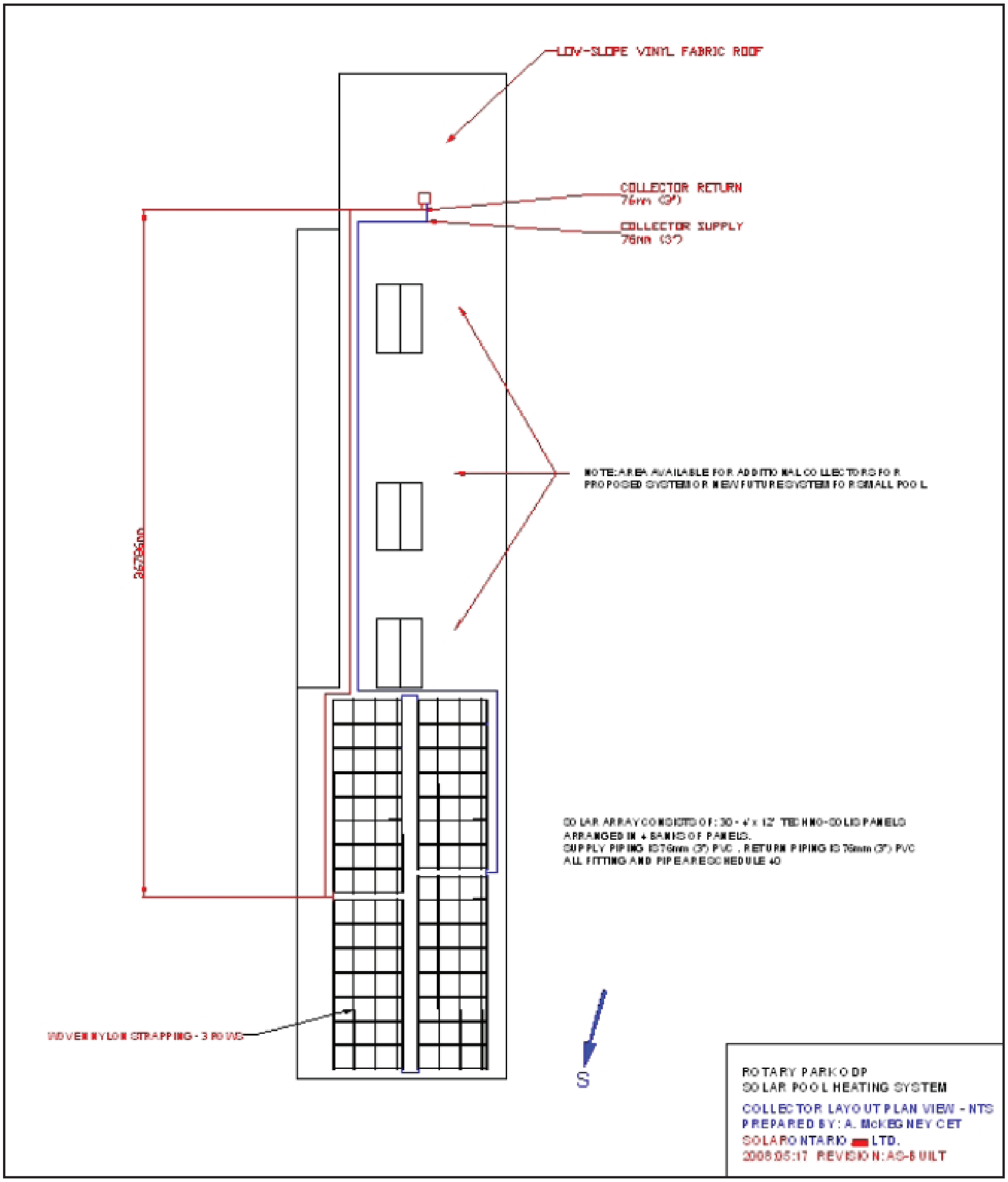


Figure A.2. Rotary Park interior plumbing schematic for solar pool heating. Source: Rotary Park Solar Pool Heating System Commissioning Report, Solar Ontario, Oct 2008.

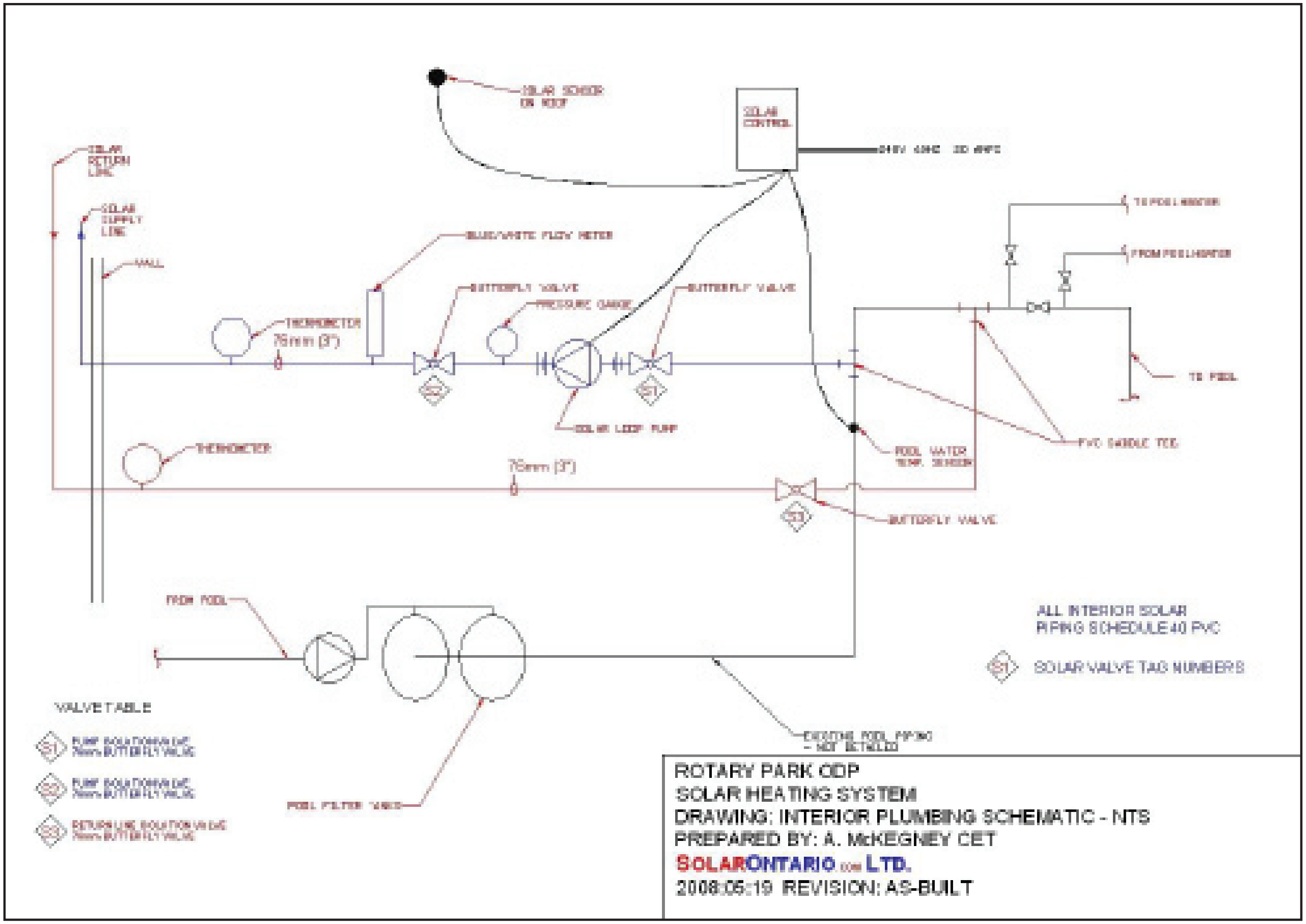


Figure A.3. Rotary Park swimming pool and building as seen from the South side.

Figure A.4. Rotary Park swimming pool.

Figure A.5. Collectors on the roof at Rotary Park.

Figure A.6. Solar pool heating "hot" sensor, this sensor was replaced by another one attached to a board in 2011.

Figure A.7. New solar pool heating "hot" sensor, installed at the beginning of the 2011 season.

Figure A.8. Solar pump and controller (white box on the wall) before the installation of spring-loaded check valve.

Figure A.9. Projected shading on the SE corner of the array of collectors. Although not compensated for magnetic declination, it is possible to observe that a fraction of the system would be shaded by the trees early in the morning.

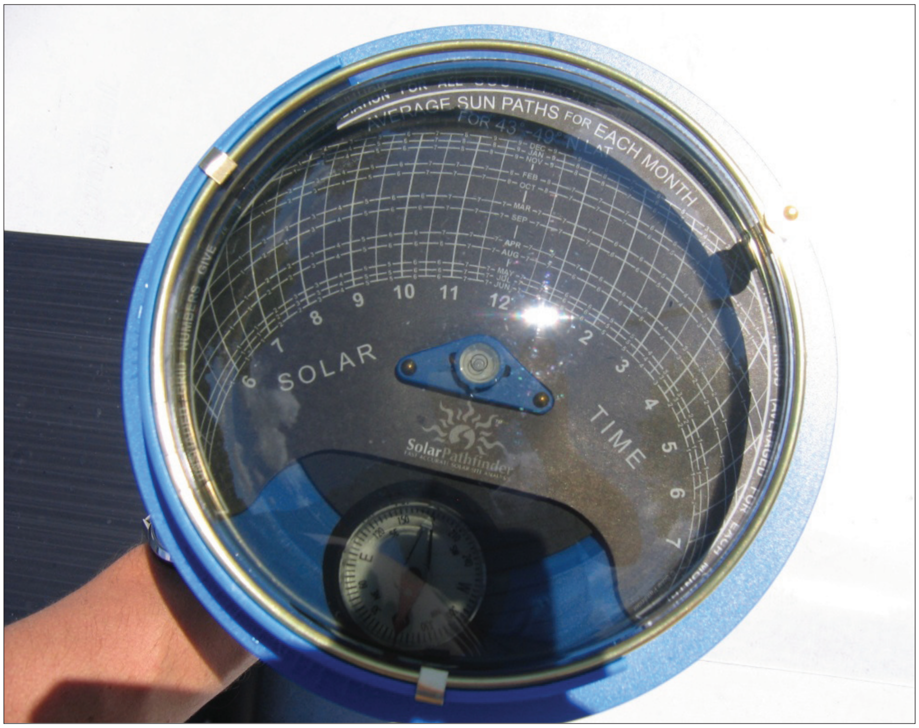
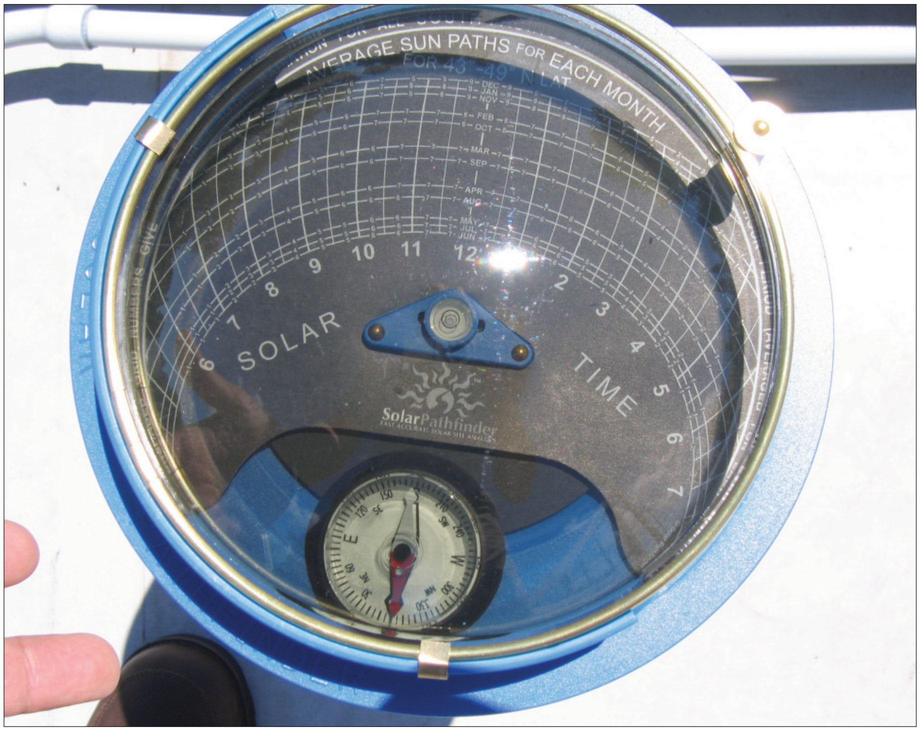


Figure A.10. Projected shading on the NW corner of the array of collectors. Although not compensated for magnetic declination, it is possible to observe that there is very little shading on this portion of the arrays.



A.2) GIHON SPRING

Figure A.11. Gihon Spring collector loop lay-out. Source: Gihon Spring Park Solar Pool Heating System Commissioning Report, Solar Ontario, Oct 2008.

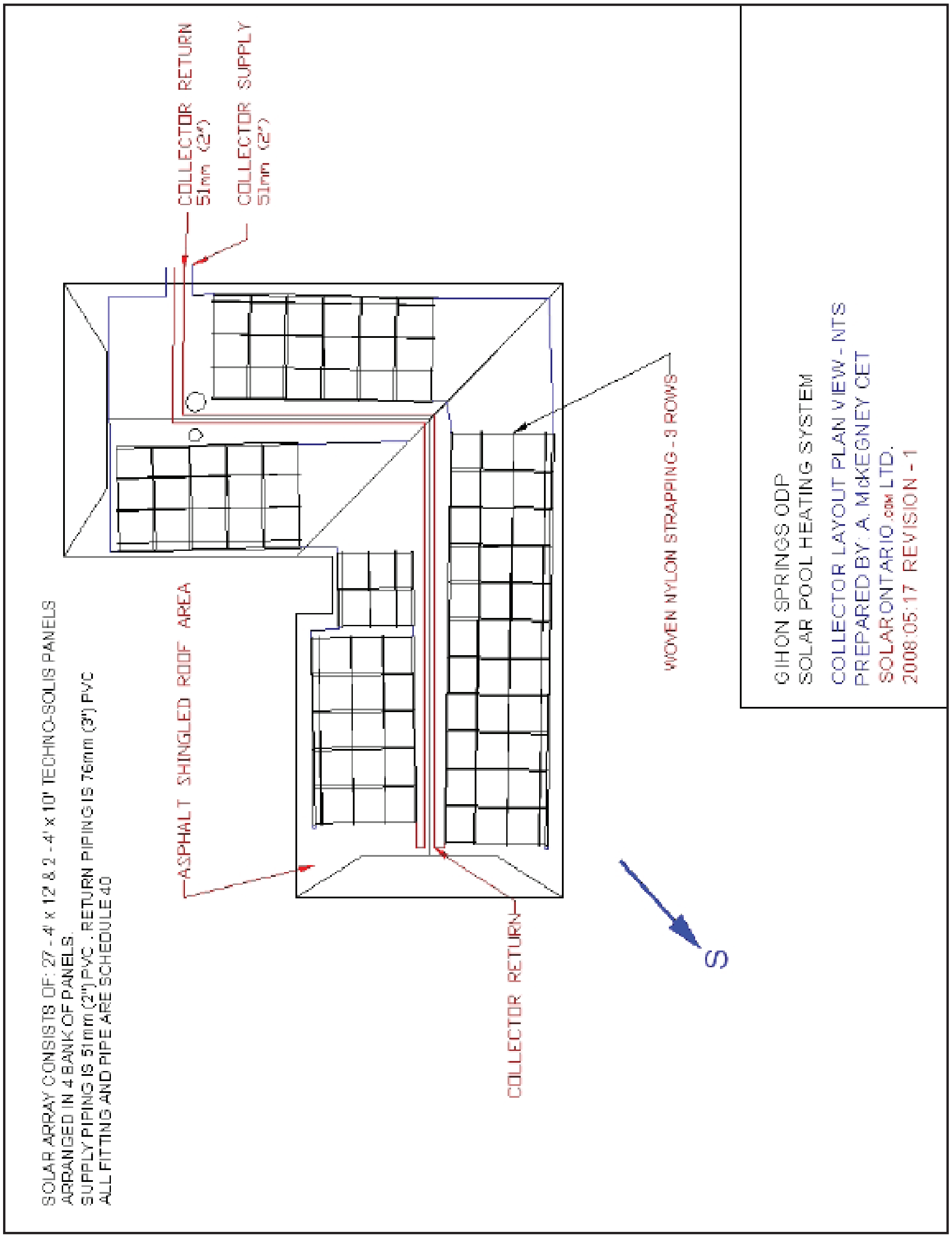


Figure A.12. Gihon Spring interior plumbing schematic for solar pool heating. Source: Gihon Spring Solar Pool Heating System Commissioning Report, Solar Ontario, Oct 2008.

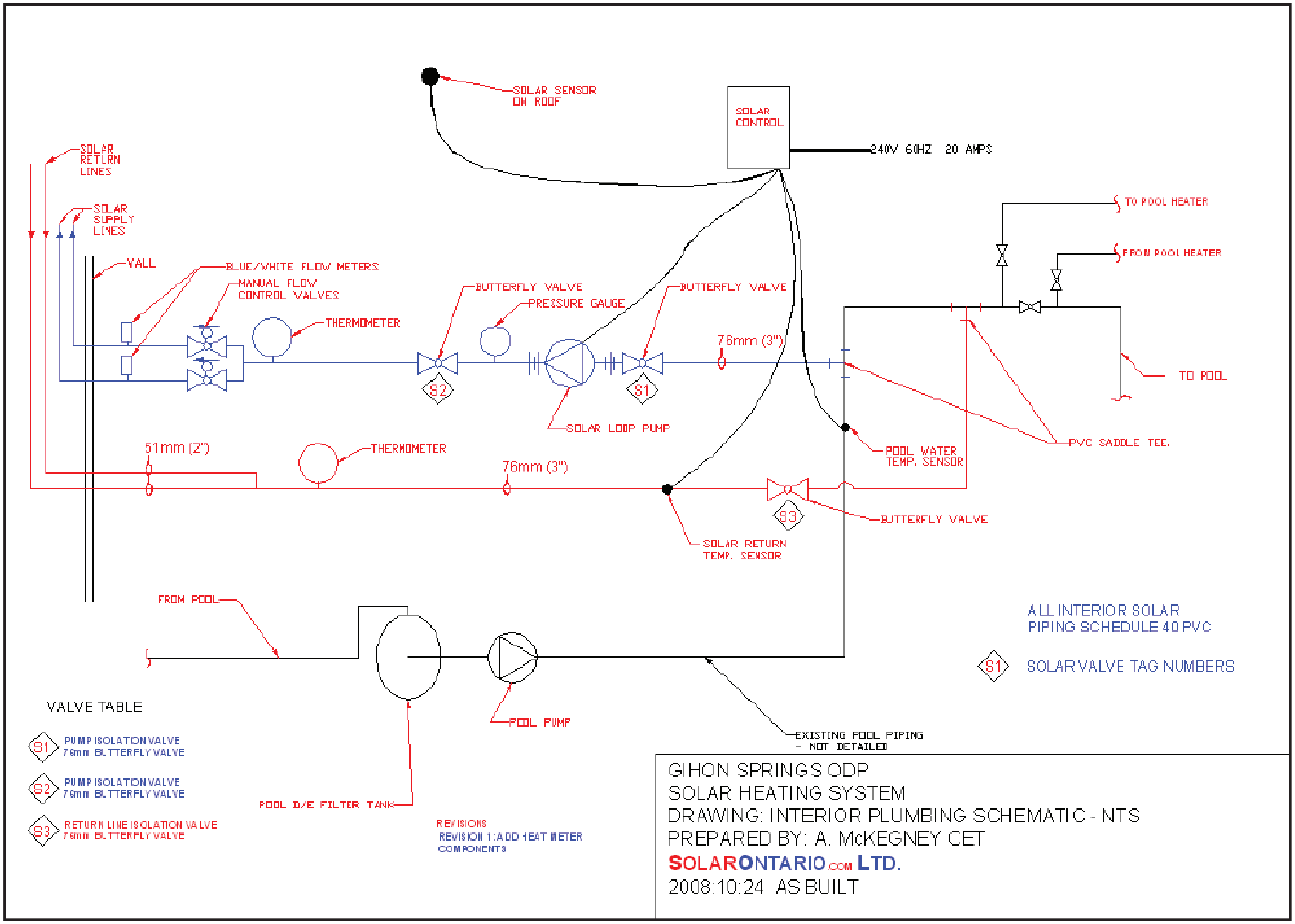


Figure A.13. Gihon Spring swimming pool and North West solar collector array.

Figure A.14. Gihon Spring East solar collector array.

Figure A.15. Gihon Spring South and West solar collector arrays.

Figure A.16. Gihon Spring energy meter.

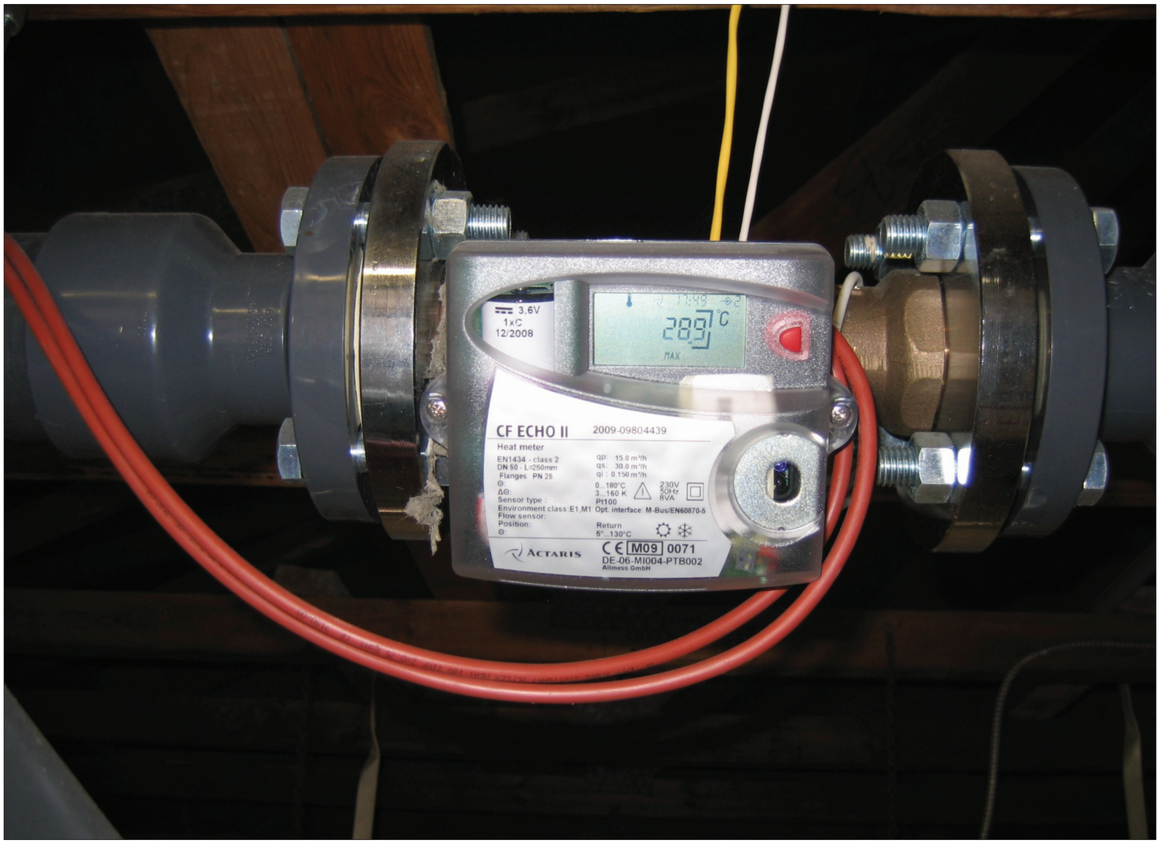


Figure A.17. Gihon Spring solar and filtering pumps. The solar pump is the black unit on the background. The white tees are the connection points for the solar heating system.

A.3) PARK LAWN

Figure A.18. Park Lawn collector loop lay-out. Source: Park Lawn Solar Pool Heating System Commissioning Report, Solar Ontario, Oct 2008.

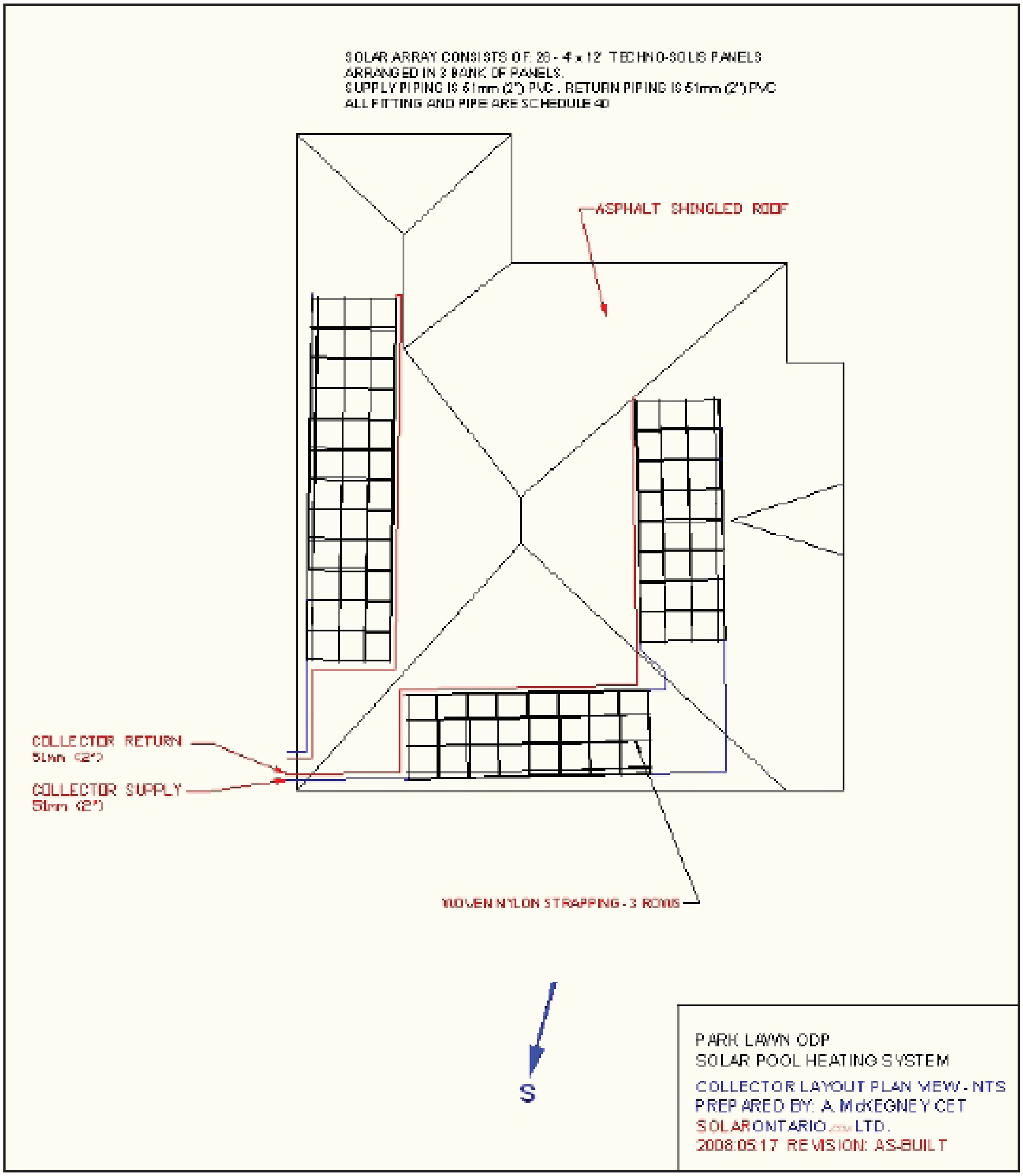


Figure A.19. Park Lawn interior plumbing schematic for solar pool heating. Source: Parl Lawn Solar Pool Heating System Commissioning Report, Solar Ontario, Oct 2008.

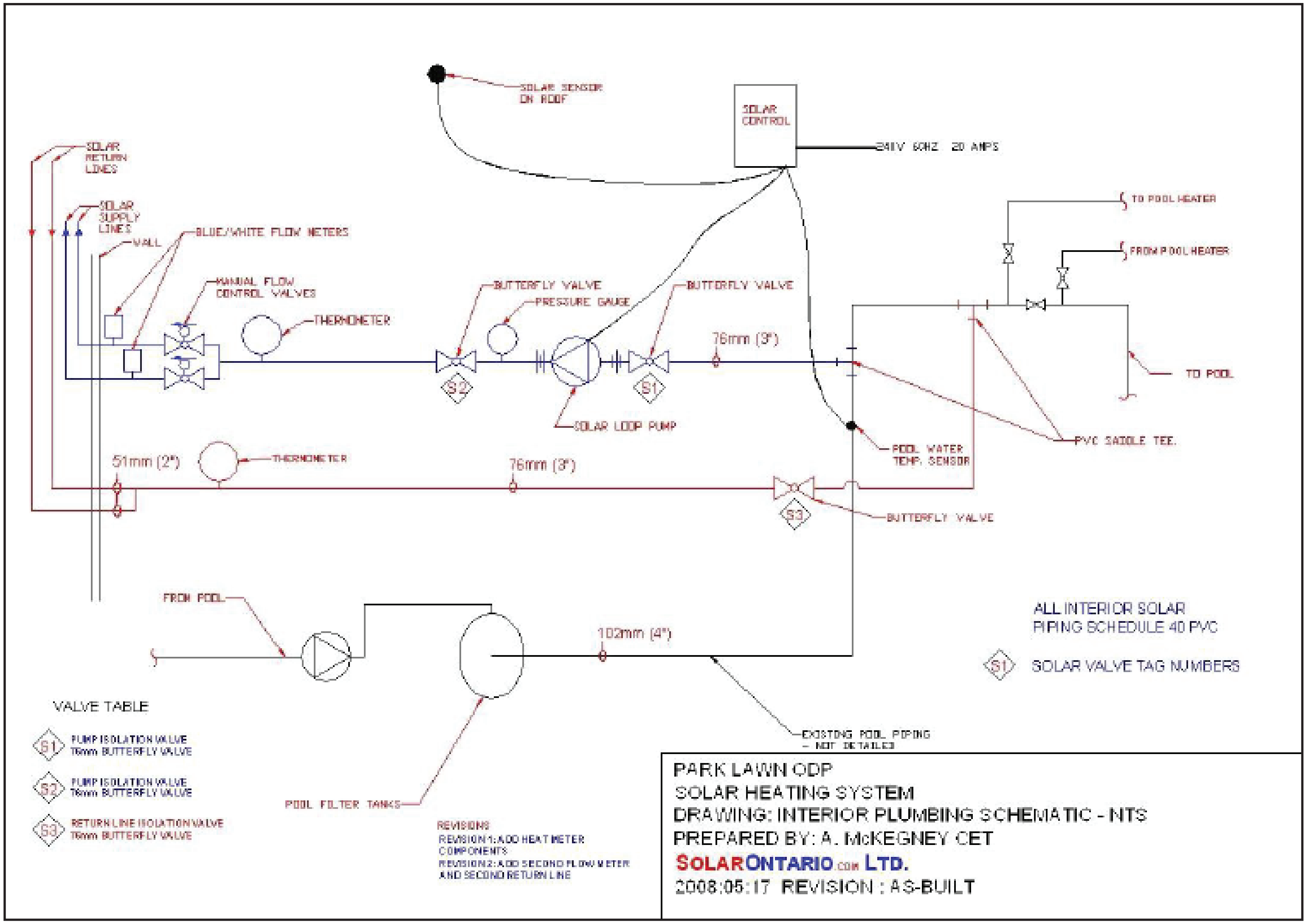


Figure A.20. Park Lawn South and West solar collector arrays.

Figure A.21. Park Lawn South and East solar collector arrays.

Figure A.22. Perforated collector with detail of the perforation on the insert.

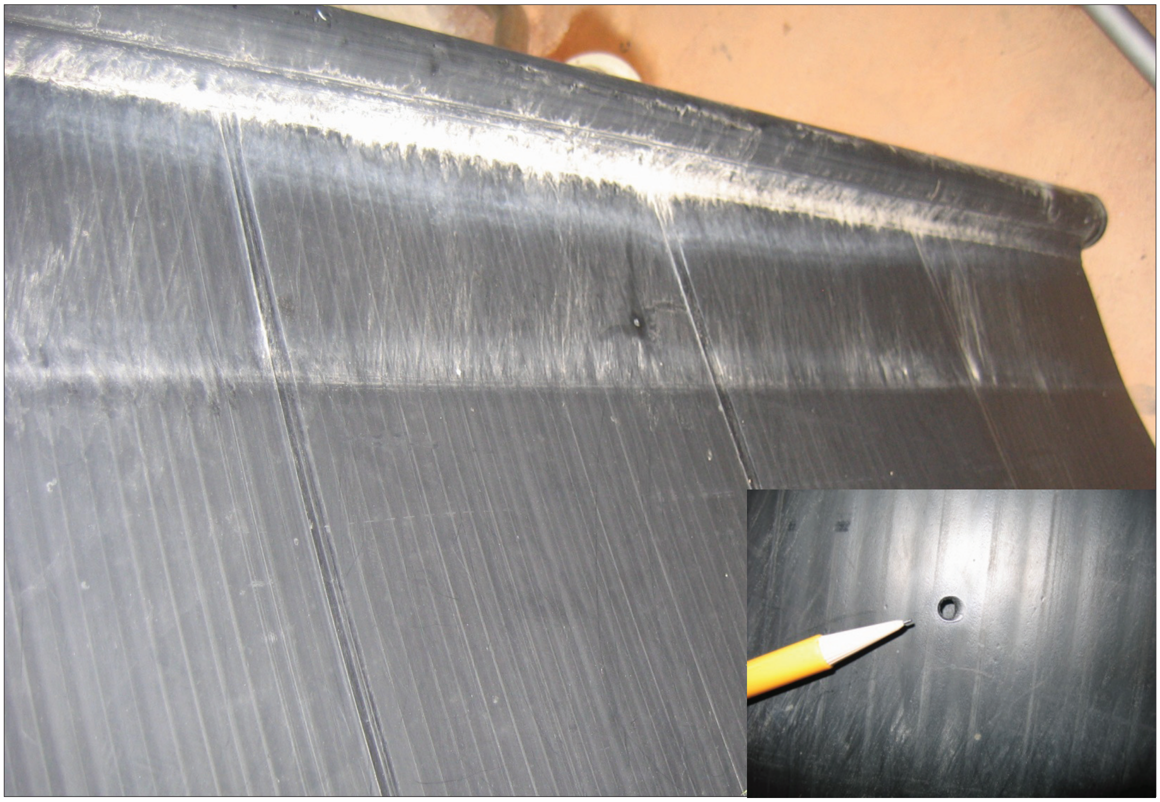


Figure A.23. Solar pump (black unit on left) and solar system piping tie-in (white tees).

A.3) WESTON LIONS

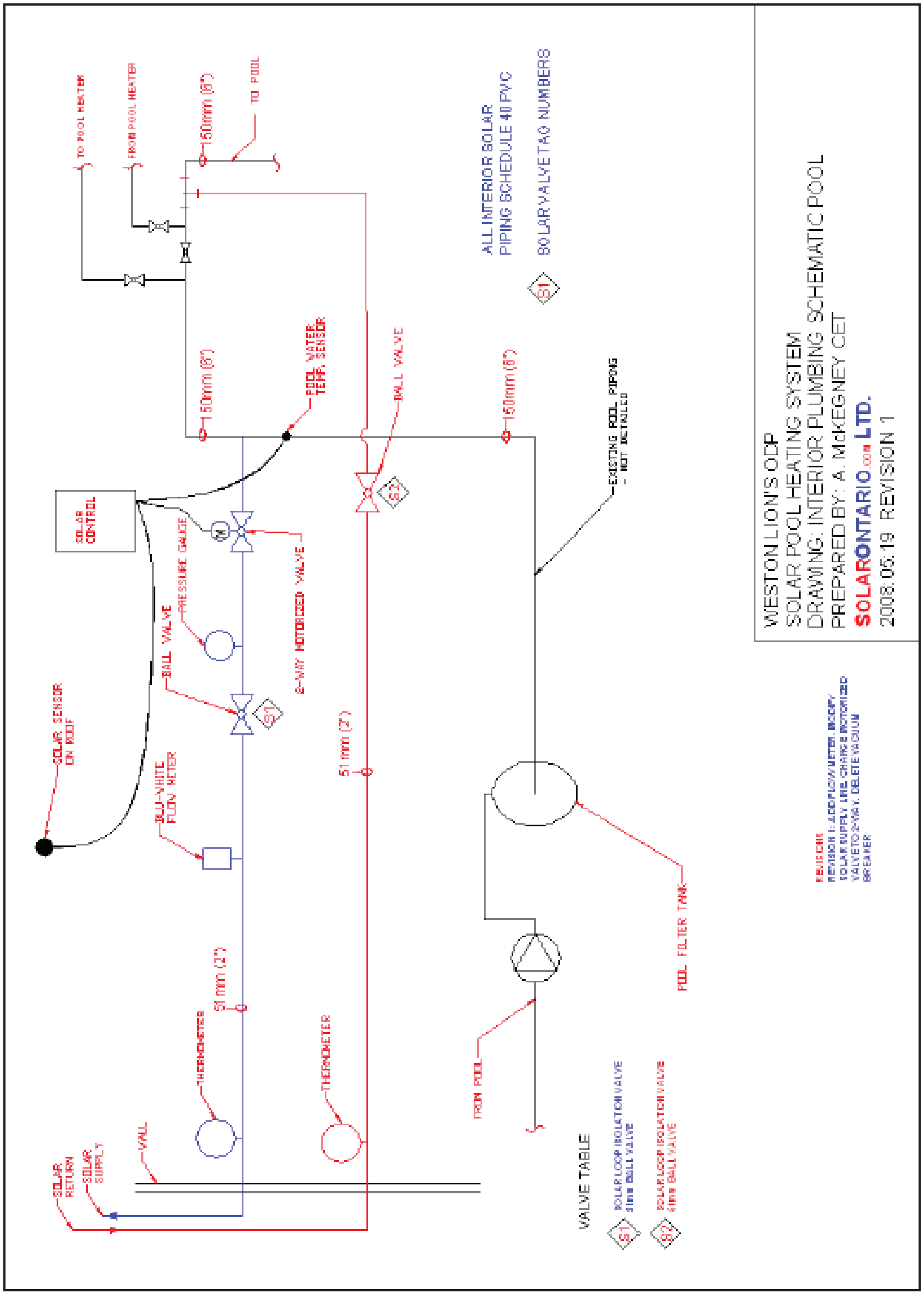


Figure A.24. Weston Lions interior plumbing schematic for solar pool heating. Source: Weston Lions Solar Pool Heating System Commissioning Report, Solar Ontario, Oct 2008.

Figure A.25. Weston Lions collector loop lay-out. Source: Weston Lions Solar Pool Heating System Commissioning Report, Solar Ontario, Oct 2008.

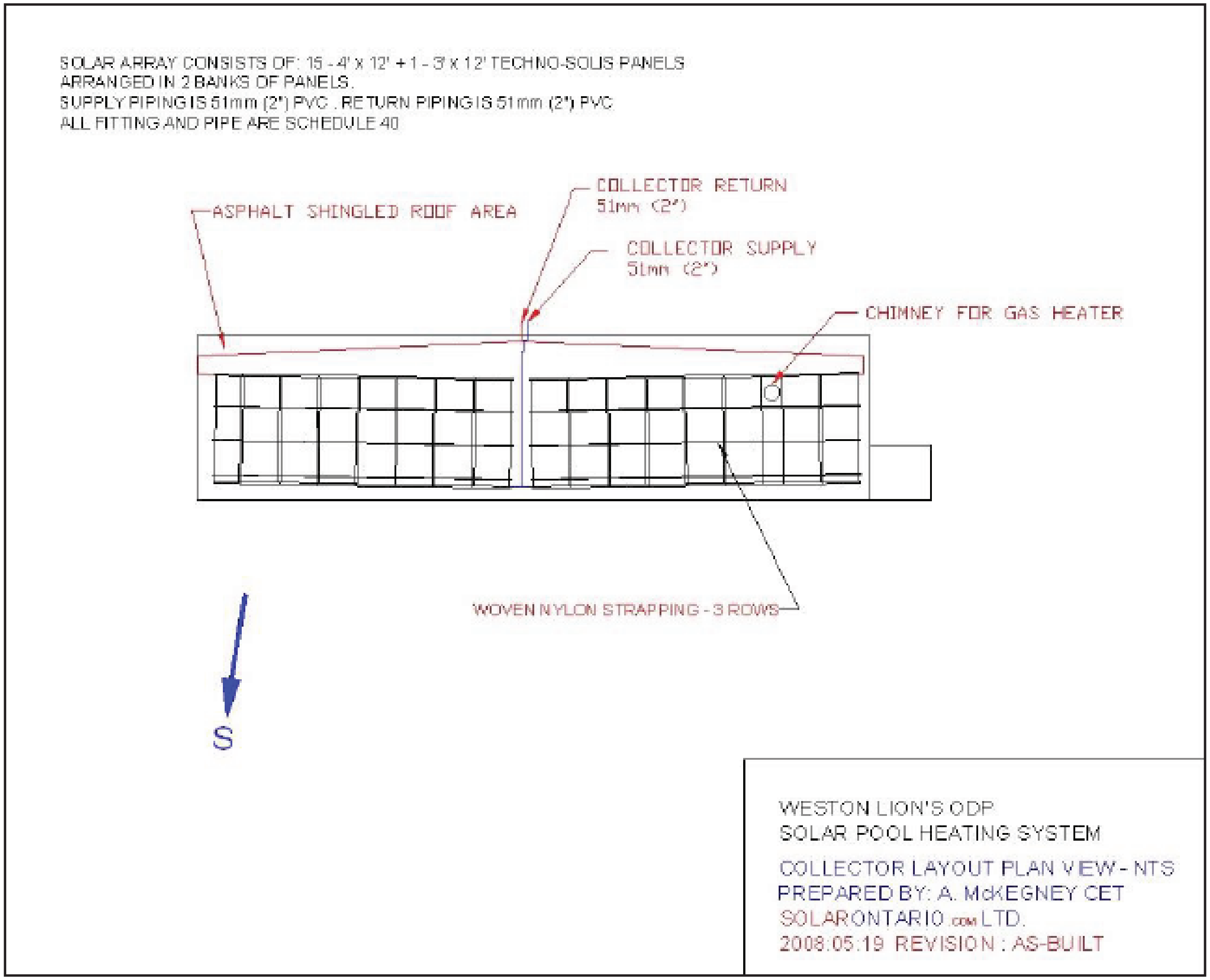


Figure A.26. Weston Lions solar collector array and main swimming pool.

Figure A.27. Weston Lions solar array flow control valve.

Figure A.28. Weston Lions solar array (hot) temperature sensor on the roof.

Figure A.29. Weston Lions pool water (cold) temperature sensor attached to plastic piping.

Figure A.30. Weston Lions solar array flow meter (rotameter) with system in operation.

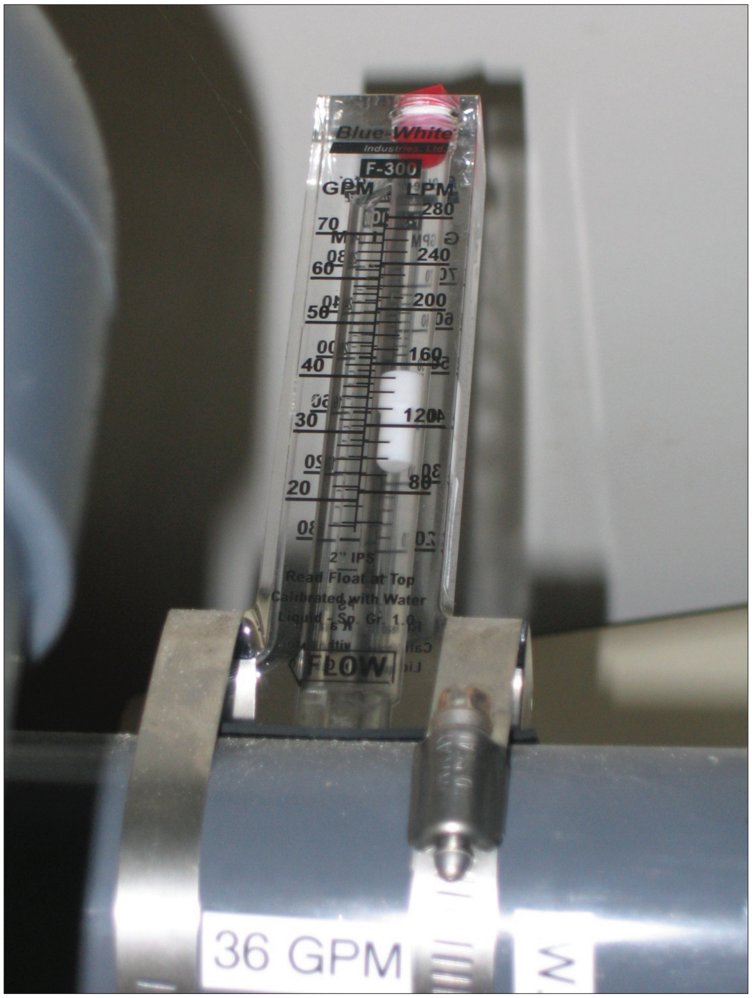


Figure A.31. Projected shading on the SE corner of the array of collectors. Although not compensated for magnetic declination, it is possible to observe that a fraction of the system would be shaded by the trees in the morning.

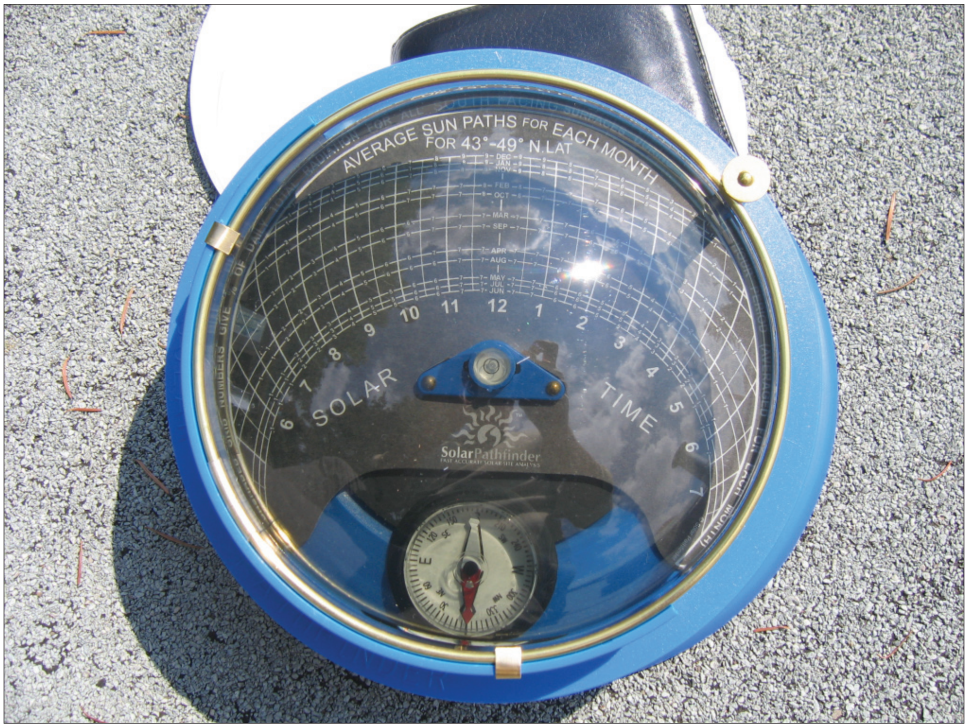
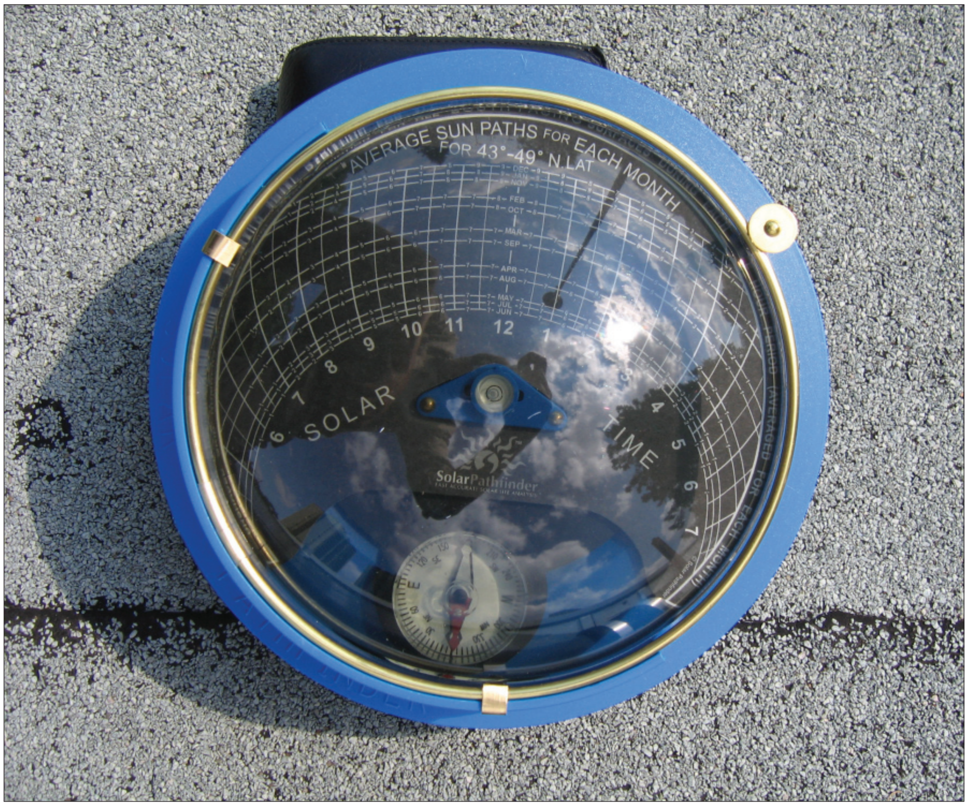


Figure A.32. Projected shading on the NW corner of the array of collectors. Although not compensated for magnetic declination, it is possible to observe that a fraction of the system would be shaded by the trees in the afternoon.



About the SolarCity Partnership

The SolarCity Partnership is a joint initiative of the Toronto Atmospheric Fund, Toronto and Region Conservation Authority and the City of Toronto designed to promote best practices and careful monitoring of large solar installations. SolarCity Partnership is an information-sharing hub for both public and private organizations involved in deploying solar power. Our **SolarCityPartnership.ca** website provides case studies, research, and solar weather data to help with the effective use of zero emissions energy from the sun.

We want to hear from you!

If you have further best practices recommendations, insights into system design, deployment or maintenance or a project to profile, please get involved with the SolarCity Partnership! Contact us at:

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