Engineering Measurement & Verification Study:

Multi-Family Residential Variable Speed Swimming Pool/Spa Pump Retrofit

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SDGE

A Sempra Energy utility®

PROJECT TRACKING NUMBER:
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INTRODUCTION (Executive Summary)

This report contains the results of a study on the efficacy of a specific model of variable speed swimming pool pump. This technology was evaluated to ensure that it performs as intended, and creates sufficient energy savings. To assess the performance of the variable flow pumps, Information & Energy Services, Inc. (IES) installed energy meters and data loggers to both the pre-existing and energy conserving replacement pumps at two swimming pools and one spa at two separate apartment communities. Baseline data collected before the installation and post-retrofit data collected afterward were compared to determine the average electric usage in the baseline and post-retrofit scenarios.

From the data collected for this study, we were able to conclude that variable speed pool pumps can significantly reduce average kW and total kWh, resulting in energy savings of approximately 45%. An additional benefit of the pump is the flexibility of installation; it can provide a wide range of flow-rates very efficiently to satisfy a wide range of potential applications.

This study has found the following primary results, which are summarized in Table 1 below:

- **Energy savings are gained via: Improved motor efficiency and fine tuning of flow-rate to provide exact requirement thus yielding large savings (Affinity Law)**
- **Pump has potential for additional savings by scheduling of flow-rate (potential for use of night set-back) or traditional on/off controls built in.**
- **The high performance variable speed pump tested reduces average kW and annual kWh, resulting in energy savings of 45% averaged over the two pools and one spa studied.**

Table 1: Energy Savings Summary

Swimming Pool Pump Retrofit (Both Sites)												
Summary of Savings												
Baseline kW (Avg, when enabled)				Baseline kWh/day (Adjusted)			Baseline (Adjusted) Annual kWh			Baseline (Adjusted) Annual Cost ($)		
Pool 1	*Pool 2*	*Spa 2*	*Average*	*Pool 1*	*Pool 2*	*Spa 2*	*Pool 1*	*Pool 2*	*Spa 2*	*Pool 1*	*Pool 2*	*Spa 2*
3.56	2.09	1.31	2.32	85.5	31.3	19.9	31,218	11,422	7,251	$ 5,619	$ 2,056	$ 1,305
Post-Retrofit kW (Avg, enabled)				Post-Retrofit kWh/day			Post-Retrofit Annual kWh			Post-Retrofit Annual Cost ($)		
Pool 1	*Pool 2*	*Spa 2*	*Average*	*Pool 1*	*Pool 2*	*Spa 2*	*Pool 1*	*Pool 2*	*Spa 2*	*Pool 1*	*Pool 2*	*Spa 2*
2.01	1.14	0.65	1.27	48.3	17.1	9.8	17,625	6,227	3,586	$ 3,172	$ 1,121	$ 645
Avg kW Reduction				Avg kWh/day Reduction			Avg. Annual kWh Saved			Annual Cost Savings ($)		
Pool 1	*Pool 2*	*Spa 2*	*Average*	*Pool 1*	*Pool 2*	*Spa 2*	*Pool 1*	*Pool 2*	*Spa 2*	*Pool 1*	*Pool 2*	*Spa 2*
1.55	0.95	0.66	1.05	37.2	14.2	10.0	13,593	5,195	3,665	$ 2,447	$ 935	$ 660
44%	45%	51%	45%	<<< PERCENT ENERGY SAVINGS								

Please see Table 2 and Table 3 on the following page showing simple payback estimates.

Table 2: Simple Payback Estimate – Retrofit

Simple Payback Summary Early Retirement Cost				
	Annual kWh Saved	Annual $ Saved ($0.18/kWh)	$ Retrofit Cost w/o rebate	Simple Payback (yrs)
Site #1 Pool	13,593	$ 2,447	$ 7,000	2.9
Site #2 Pool	5,195	$ 935	$ 3,500	3.7
Site #2 Spa	3,665	$ 660	$ 3,500	5.3

Table 3: Simple Payback Estimate – New Construction

Simple Payback Summary New Construction Cost				
	Annual kWh Saved	Annual $ Saved ($0.18/kWh)	$ Retrofit Cost w/o rebate	Simple Payback (yrs)
Site #1 Pool	13,593	$ 2,447	$ 5,500	2.2
Site #2 Pool	5,195	$ 935	$ 2,750	2.9
Site #2 Spa	3,665	$ 660	$ 2,750	4.2

PROJECT OBJECTIVE

The objective of this study is to evaluate the energy savings potential of variable speed drive technology integrated into a swimming pool pump. This emerging technology will be evaluated by comparing it to the pre-existing (constant speed) pump energy consumption at the test sites. The technology was tested at two swimming pools and one spa in the San Diego area. IES was contracted by the Emerging Technologies Program at San Diego Gas & Electric Company to evaluate the technology in a *"real world"* setting to determine the applicability of possible future rebate or incentive programs.

PROJECT SETTING AND METHODOLOGY

TECHNOLOGY OVERVIEW

IES tested a very popular model of variable speed pump designed specifically for the swimming pool industry from a major manufacturer. The variable speed pumps that were tested have speed capability ranging from 1100 to 3450 RPM, as well as scheduling capabilities. These features allow the pool operator to save energy in multiple ways: First, the improved motor efficiency helps to save electricity. Second, flow rates can be optimized with respect to required health code standards. Third, savings can be realized by scheduling an even further reduced flow rate at night or other un-occupied periods. Based on the Affinity Law, even a small reduction in shaft speed will result in large energy savings (electric demand is reduced theoretically by a factor of X^3). Please see Figure 1 below for a picture of the pump.

Figure 1: Variable Flow High Performance Pool Filtration Pump

The particular design tested combines the pump, strainer, motor, variable speed drive, and digital controls into a single package which can be installed in the same applications as a constant speed swimming pool filtration pump. The integrated digital controls simplify installation somewhat compared to the prevailing conditions whereby the pump is controlled via a mechanical time clock and relay. Local codes also require an emergency cur-off relay for pool and spa pumps.

HOST SITE 1 OVERVIEW

The first test site apartment complex located in the Point Loma area of San Diego is a typical 500 unit multi-building apartment complex and is referred to as Site #1. The facility features many amenities including an outdoor pool for use by residents. Recently, the pool's two older single speed pumps were replaced with new variable speed pool pumps being tested for the study. Information & Energy Services, Inc. (IES) under contract with Sempra Energy's Emerging Technologies Program was contracted to verify the electrical savings resulting from replacing the pool filtration pumps (total two pumps) with variable speed pool pump systems. Please see Figure 2 below, showing the pool at Test Site #1.

Figure 2: Test Site #1 Pool

Previously, the test pool utilized two (2) single speed pool pumps which used high service factor 1 hp motors. During the initial phase of the study these pumps were measured to have a constant flow of approximately 75 to 80 GPM each. The two pumps run in tandem at this site, meaning that the total pool water flow being filtered is the sum of the flows for Pump-A plus Pump-B. Please see Figure 3 below showing a schematic diagram of the system at Site #1.

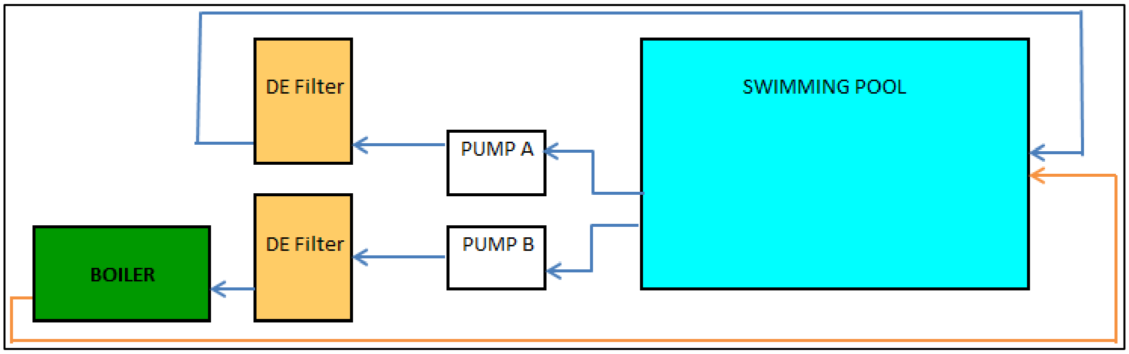

Figure 3: Test Site #1 Schematic

In October of 2011, the distributor and their contractor removed the existing pumps and installed two new variable flow pool pumps. These 3 hp pumps have variable speed capability ranging from 1100 to 3450RPM, as well as scheduling capabilities. At Site #1 the spa pump was not studied. At Site #1 the filter medium used is diatomaceous earth (DE). The two separate pool filtration pumps will be referred to as Pump A and Pump B, and were labeled as such during calculations. The flow rates from the new pumps were determined in May 2012 by installation of a temporary flow-meter used for spot measurements. For more information regarding the flow rate tests that were performed please see the Project Results Section. Figure 4 below shows the baseline pumps. Figure 5 on the following page shows the replacement pumps at Site #1.

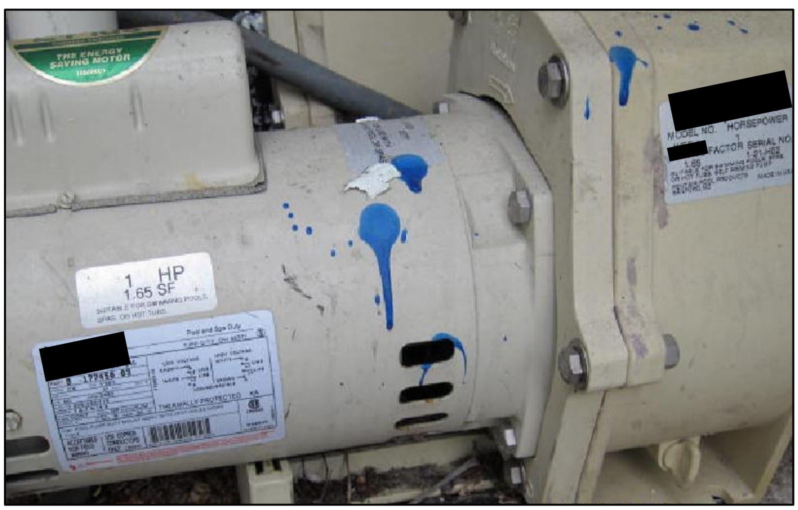

Figure 4: (BASELINE) Single Speed Pool Filtration Pump

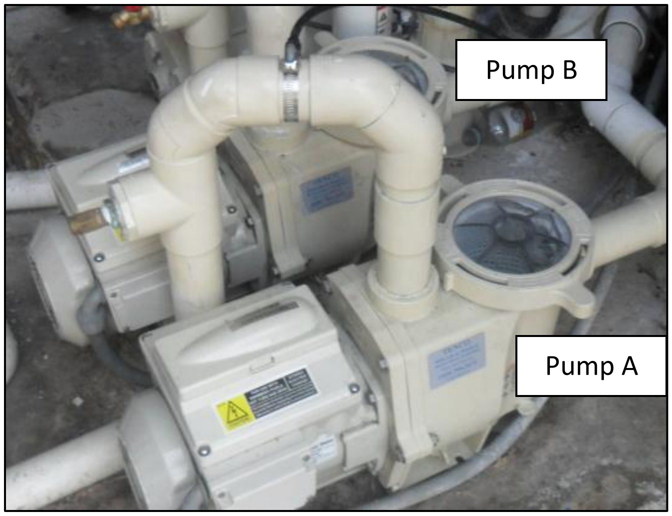

Figure 5: (RETROFIT) Variable Flow Pool Filtration Pumps

HOST SITE 2 OVERVIEW

The second test site apartment complex located in the Carmel Mountain area of San Diego is a typical 384 unit apartment complex and is referred to as Site #2. The facility features many amenities including an outdoor pool and spa for use by residents. Recently, the two older single speed pool and spa pumps were replaced with new variable speed pool pumps. As done with Site #1 IES verified the electrical savings resulting from replacing the pool and spa filtration pumps (total two pumps, one pool and one spa). Please see Figure 6 and Figure 7 below and on the following page, showing the pool and spa at Test Site #2.

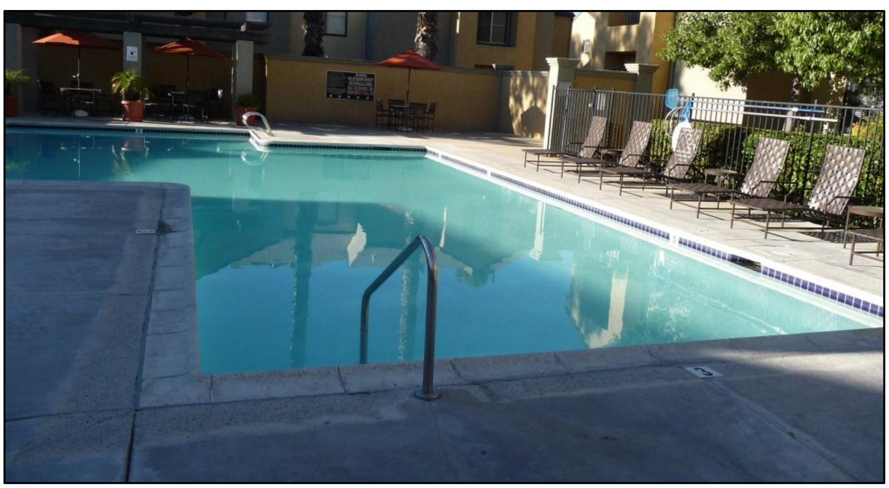

Figure 6: Test Site #2 Pool

Figure 7: Test Site #2 Spa

Simple diagrams of the pool and spa systems are shown below in Figure 8 and Figure 9 respectively.

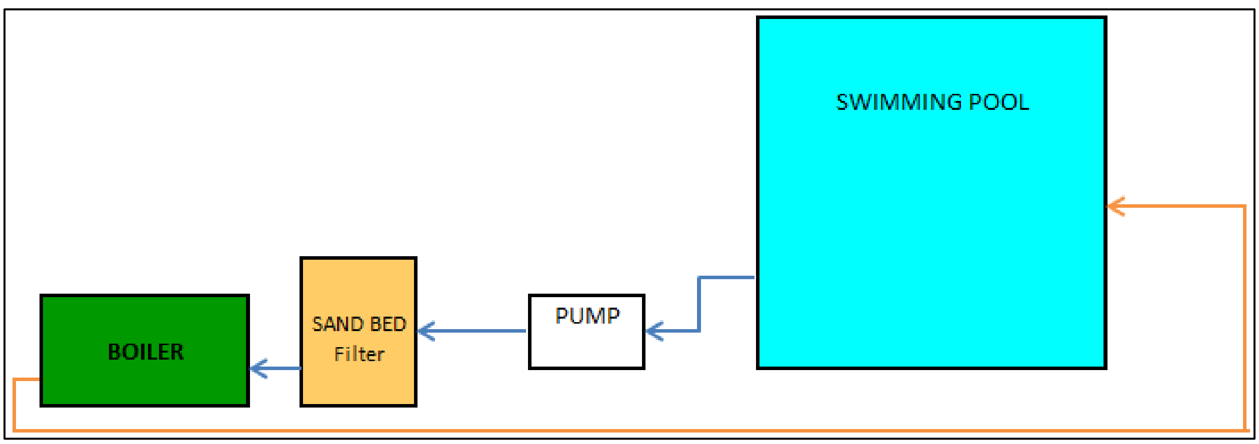

Figure 8: Test Site #2 Pool Diagram

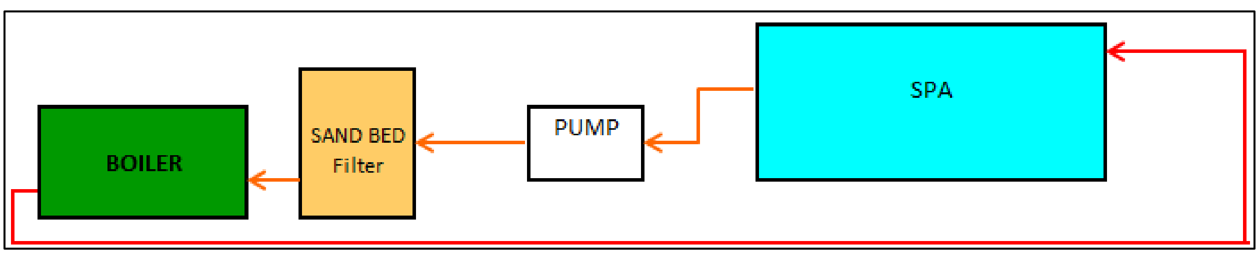

Figure 9: Test Site #2 Spa Diagram

Previously, Site #2 utilized two pumps. The pool pump had a 2 hp motor while the spa pump used a ¾ hp motor. The spa pump was determined to have a constant flow rate of approximately 48 GPM, while the pool pump had a constant 79.4 GPM flow rate. These pumps run on a consistent weekly schedule in the baseline, as shown in below.

Table 4: Site #2 Pump Schedule (Non-Adjusted Baseline)

BASELINE	Spa Pump	Pool Pump
Start Time	5:35	7:35
Stop Time	20:20	17:20
Daily Hours	**14:45**	**9:45**

In January of 2012, the distributor and their contractor removed the baseline units and installed the two variable flow pool pumps being studied. Just like at the first test site, these 3 hp pumps have multispeed capability ranging from 1100 to 3450 RPM, enabling operators to program the exact flow requirements for each pump task. In addition to the improved motor efficiency the variable flow pumps can be run at less than full speed which saved energy according to the Affinity Law. At this test site the filter medium used is sand. The units pre and post retrofit are used for the pool filtration system and the spa filtration system. Figure 10 below shows one of the baseline pumps (spa, pool similar). Figure 11 below shows one of the variable flow units.

Figure 10: (BASELINE) Single Speed Spa Filtration Pump (Pool Pump Similar)

Figure 11: (RETROFIT) Variable Speed Pool Filtration Pump Tested (Spa Pump Similar)

MEASUREMENT & VERIFICATION PLAN OVERVIEW

The M&V protocol for this emerging technology is based on the recommendations of IPMVP Option B. Option B involves directly sub-metering the system loads for the incumbent and energy saving equipment in order to verify that the measure has the potential to perform and to generate savings. Performance verification techniques include engineering calculations with short-term metered values, resulting in measured verification of performance. With the chosen method, hours of operation are measured, with any adjustments made to the baseline in the event of changes between the pre and post retrofit data sets.

Under this measurement plan, the retrofitting party assumes performance risk for the operation of the new pump and the operability of the new onboard pump controls. IES performed short term data logging of the equipment, taking 5 minute interval measurements to determine the power draw and hours of operation. Equipment was monitored for more than two weeks for each scenario.

APPLICABLE CODES & STANDARDS

Municipal health codes require minimum flow rates through the filtration system while the pool or spa is open to bathers. It is also recommended that the water is circulated through the filters two hours before and two hours after open hours. The required minimum turnover rates are shown in Table 5 on the following page. Please note that test Site #1 is built before January 1986, and Site #2 is built after.

Table 5: Minimum Turnover Rates

Type of Pool	Built before January 1, 1986	Built after January 1, 1986
Swimming	8 hours	6 hours
Spa	1 hour	1/2 hour

PROJECT RESULTS & DISCUSSION

SYSTEM COST AND COST INFLUENCING FACTORS

There are several factors that can affect the cost of this measure. Typical fully installed cost estimated by the distributor was $3,500 per pump. This cost is inclusive of several variables: installation labor, health department permit and inspector's visit, comprehensive survey, scale drawings, and in most cases a boost type transformer is required since most pool equipment rooms have 208VAC service and the variable speed drive pumps commonly require 230 VAC service. The base equipment cost of the variable speed pump is approximately 2 to 3 times as expensive as a single speed pump, but the other costs (installation) are the same for any pump. Based on readily available equipment pricing at the time of publication, the incremental equipment cost is approximately $500 to $1000 more to use a variable flow pump than a minimum code compliant pump. For calculation purposes the median value of $750 was used. In addition the Health Inspector's Visit in not required when replacing the pump like-for-like with constant speed, $250 was used as the estimated Health Inspection cost.

VERIFICATION OF SYSTEM OPERATION & DESIGN

EVALUATION OF FLOW RATE AT SITE #1

At Test Site #1, the pool holds 51,765 gallons, requiring its filtration pumps to have a minimum flow of 108 GPM to meet health code requirements[1]. The pre-retrofit pumps had a constant flow of approximately 155 GPM combined[2]. Depending on pressure loss from the filters and maintenance backwash cycles, the actual flow was believed to be in the range of 140-165 GPM.

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[1] Health code requires an 8 hour turnover.
[2] At this site both pumps A and B work in tandem to move the pool water through the filters.

The baseline GPM was determined from differential pressure readings taken before removal and the manufacturer's published pump curve chart shown in Figure 12 below. The 1 hp baseline pumps run at 3450 RPM. The readings shown in Figure 13 show the differential pressure between suction and discharge ports on each of the two baseline pumps.

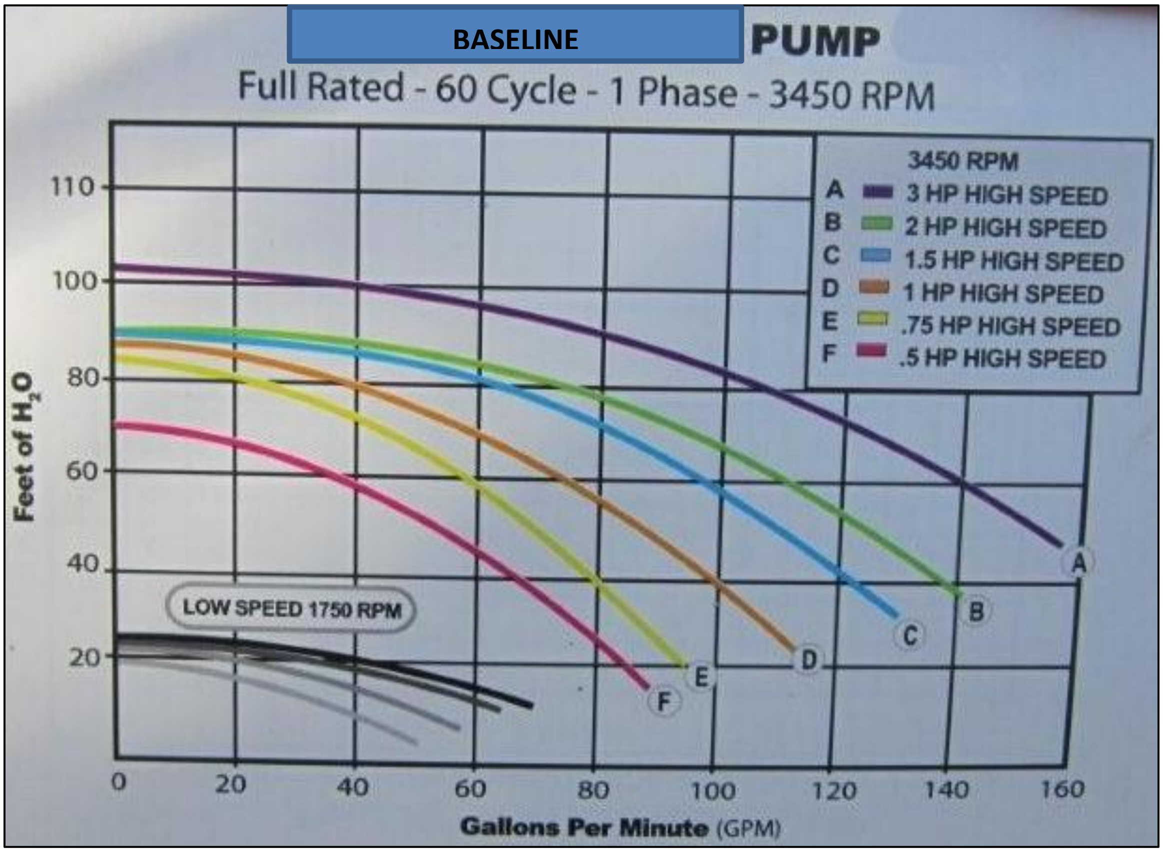


Figure 12: Baseline Pump Curve Chart

Figure 13: Differential Pressure Readings (BASELINE)

Before the retrofit the measurements shown in Figure 13 were taken and compared to the pump curve shown in Figure 12 resulting in estimated flow-rates of approximately 75 and 80 GPM (each) for the two baseline pumps, for a total of approximately 155 GPM. The filter charge state is unknown for the baseline period. The baseline pumps were determined to have a flow-rate which met the health code requirement at the time of inspection; however filtration effectiveness was not evaluated.

At Test Site #1 the post-retrofit flow rate was measured to determine if the health code requirements were being met for the pool. The County Health Inspector evaluated the post-retrofit conditions with one pump running at 2100 RPM and the other running at 2500 RPM. The relevant details from the Health Inspector's report are included in Table 6 on the following page. The health inspector passed the pool at 2100 RPM and 2500 RPM, although the pool flow-rate is illegible in Table 6. Please see Figure 14 below for a photo of the inspector's flow-meter taken while the inspector was present. Note that the Health Inspectors flow-meter is not sized properly for the water flow being measured and will therefore be rather inaccurate as the measurement is in the bottom of the range of the meter (125-500 GPM). A gauge with a range of 0-100 GPM would be more appropriate for this application.

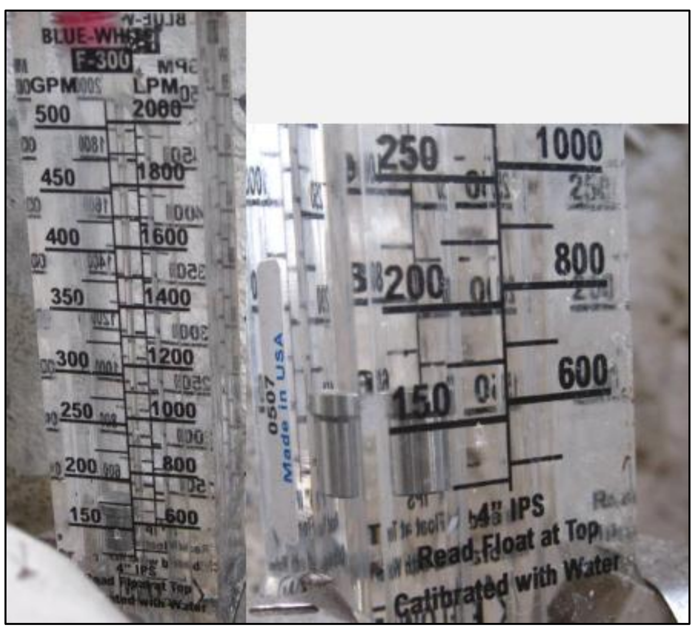
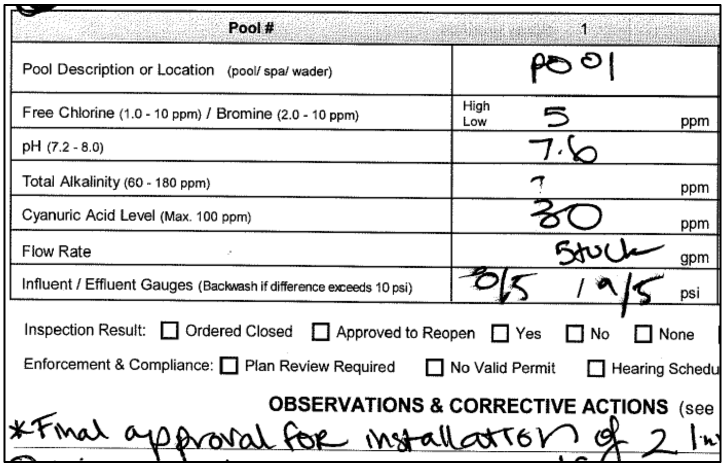


Figure 14: Inspector's Flow-Meter (Site #1, Post @ 2500 RPM & 2100 RPM)

Table 6: Site #1 – Official Health Inspector's Report



Pool #	1
Pool Description or Location (pool/ spa/ wader)	pool
Free Chlorine (1.0 - 10 ppm) / Bromine (2.0 - 10 ppm)	High / Low 5 ppm
pH (7.2 - 8.0)	7.6
Total Alkalinity (60 - 180 ppm)	? ppm
Cyanuric Acid Level (Max. 100 ppm)	30 ppm
Flow Rate	Stuck gpm
Influent / Effluent Gauges (Backwash if difference exceeds 10 psi)	8/5 1 9/5 psi

Inspection Result: ☐ Ordered Closed ☐ Approved to Reopen ☐ Yes ☐ No ☐ None

Enforcement & Compliance: ☐ Plan Review Required ☐ No Valid Permit ☐ Hearing Schedu

OBSERVATIONS & CORRECTIVE ACTIONS (see

*Final approval for installation of 2 1-

In addition to the Health Department's inspection, a flow-meter test was performed to determine if the post retrofit flow rate met the code requirement of 108 GPM within +/- 10%, or having a minimum flow rate of 97.1 GPM. This test was performed by the distributor and witnessed by Michel Rogers, P.E., C.E.M. of IES. The wattage and flow rate were measured for a series of speeds as shown in Table 7 on the following page.

Table 7: Site #2 Flow Test Summary

Pump	RPM	GPM**	Power	Total GPM**	Compliance	Total Power
A	2100	37.2	590			
B	2500	46.5	944	83.7	NO	1534
A	2500	49.7	925		YES, after adjustment for removal of test apparatus	
B	2500	46.2	960	95.9		1885
A	2600	54.6	1086			
B	2600	49.4	1055	104.0	YES	2141
A	2650	54.8	1146			
B	2650	50.7	1110	105.5	YES	2256
A	2700	56.5	1207			
B	2700	51.7	1164	108.2	YES	2371
A	2750	58.0	1274			
B	2750	53.4	1236	111.4	YES	2510
A	2800	59.3	1346			
B	2800	54.2	1300	113.5	YES	2646

** Test required additional elbows, valve, flow meter and 15' of pipe length per system

Because adding the flow measurement apparatus changed the internal resistance experienced by the system, the flow rate is reduced slightly by the presence of the test apparatus. Additional resistance of the test apparatus is shown below in Table 8. The GPM values shown in Table 7 above are the direct measurements and have not been adjusted to compensate. The effects of the measurement apparatus can be compensated for as discussed below in the following paragraphs. It was determined that the adjusted flow rate with both pumps at running at 2500 RPM did indeed satisfy the health code within +/- 10% of an 8 hour turnover rate.

Table 8: Components of Flow Test Apparatus (Site #1)

TEST APPARATUS DIFFERENTIAL PRESSURE INCREASE
Pump A
4 elbows @ 0.06 PSIG each
1 flow meter @ 0.20 PSIG
15' of 2" pipe @ 0.30 PSIG
2 rubber connector (negligable)
Pump B
2 rubber connector (negligable)
4 elbows @ 0.06 PSIG each
1 valve @ 0.02 PSIG
1 flow meter @ 0.20 PSIG
15' of 2" pipe @ 0.30 PSIG

The apparatus was slightly different for the two pumps at Site #1 as shown in Table 8 above. The flow-meter was installed in temporary piping for the test to ensure adequate length of straight pipe for a laminar flow. The test apparatus is shown in use below in Figure 15.

Figure 15: Flow Test Apparatus

In order to determine the actual flow rate with the test apparatus removed, first the differential head pressure is determined from the measured GPM using the manufactures pump curve, as shown in Figure 16 on the following page. Please note that the manufacturer determines the pump curve charts from extensive bench testing under laboratory conditions with precise equipment, and they were independently verified by IES. The measured GPM from the flow meter is plotted as the vertical green line, which intersects the red pump curve. For Pump A, with a measured GPM of 49.7 the corresponding point on the pump curve is 46.67 ft. H2O differential pressure. The test apparatus adds 0.74 PSIG or 1.71 ft. H2O to pump A, which is subtracted from 46.67 to make 44.96 ft. H2O after the apparatus is removed. This new (adjusted) differential pressure is then graphed as shown in Figure 17 to determine the adjusted GPM. For Pump A, the adjusted differential pressure is shown by the blue line in Figure 17 where it intersects the red pump curve at a GPM of 57.3 at the vertical green line. The next step is to determine the wattage of 1014 at this GPM based upon the manufacturers pump curve, as shown in Figure 18 for Pump A. This process is repeated for Pump B as shown in Figure 19 through Figure 21.

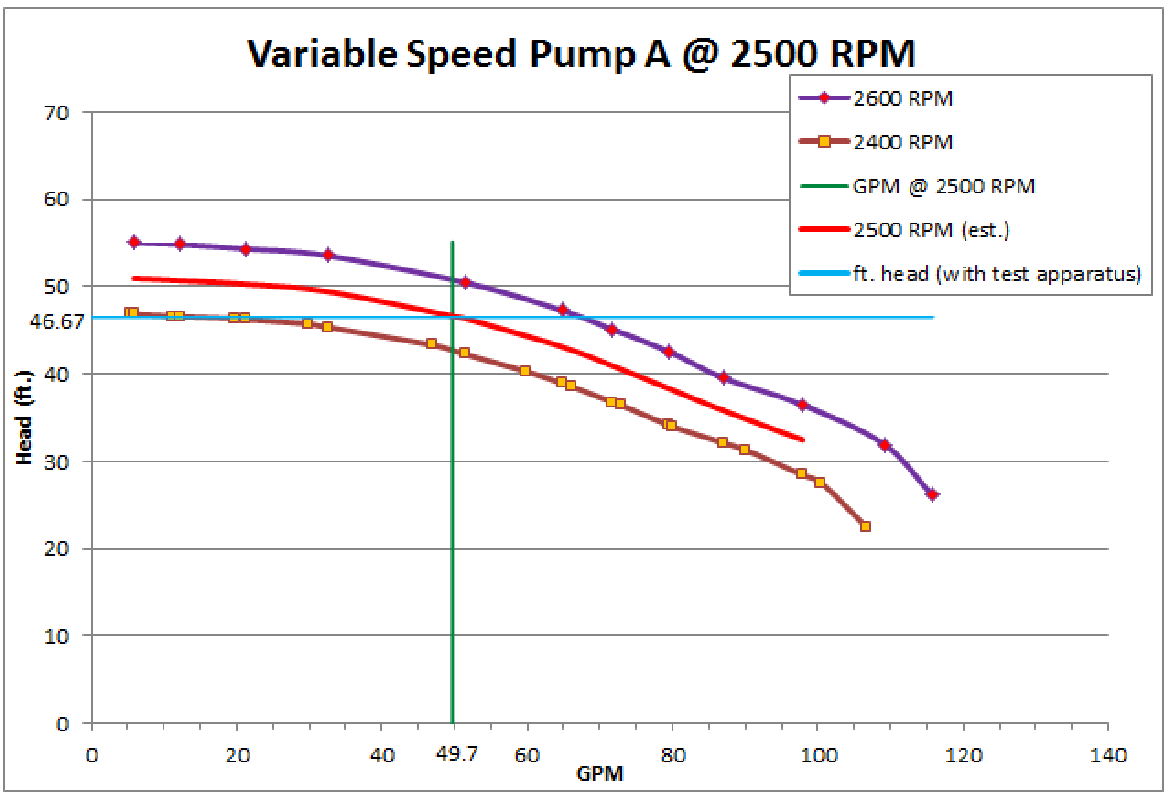


Figure 16: Pump Curve (Site #1, Pump A, Post-Retrofit, With Meter Installed)

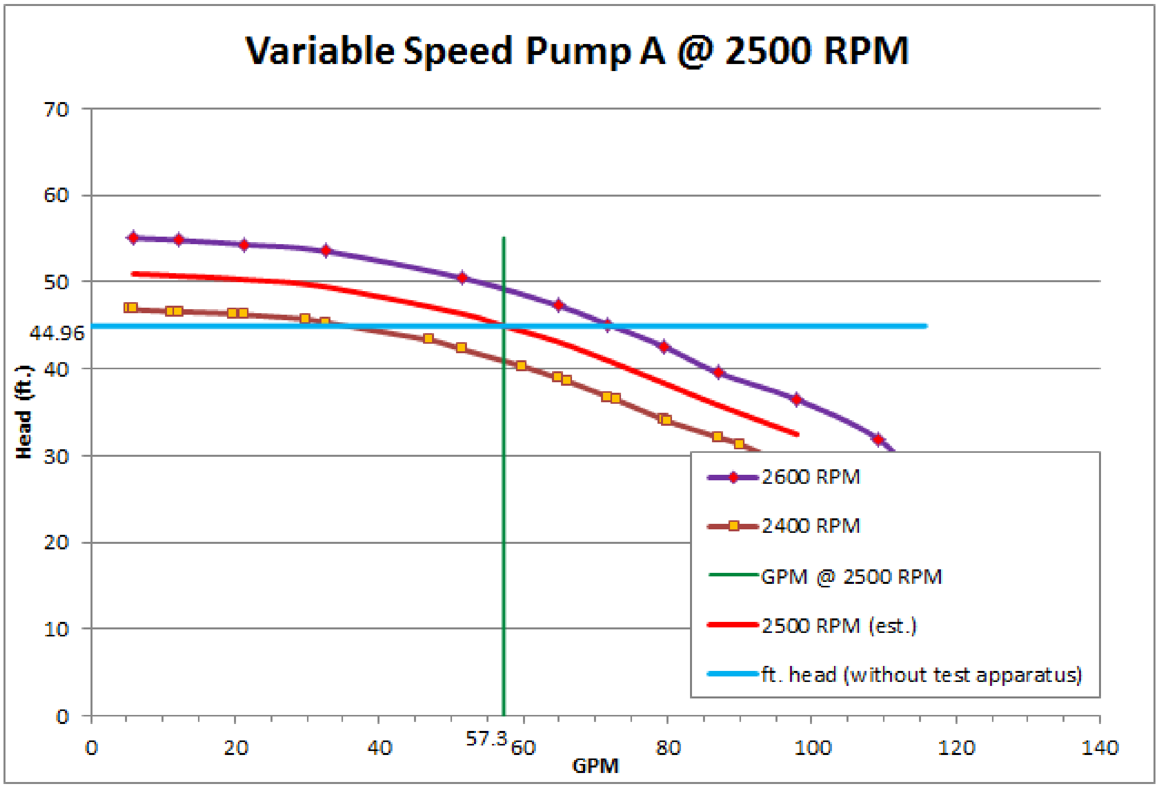


Figure 17: Pump Curve (Site #1, Pump A, Post-Retrofit, Without Meter Installed)

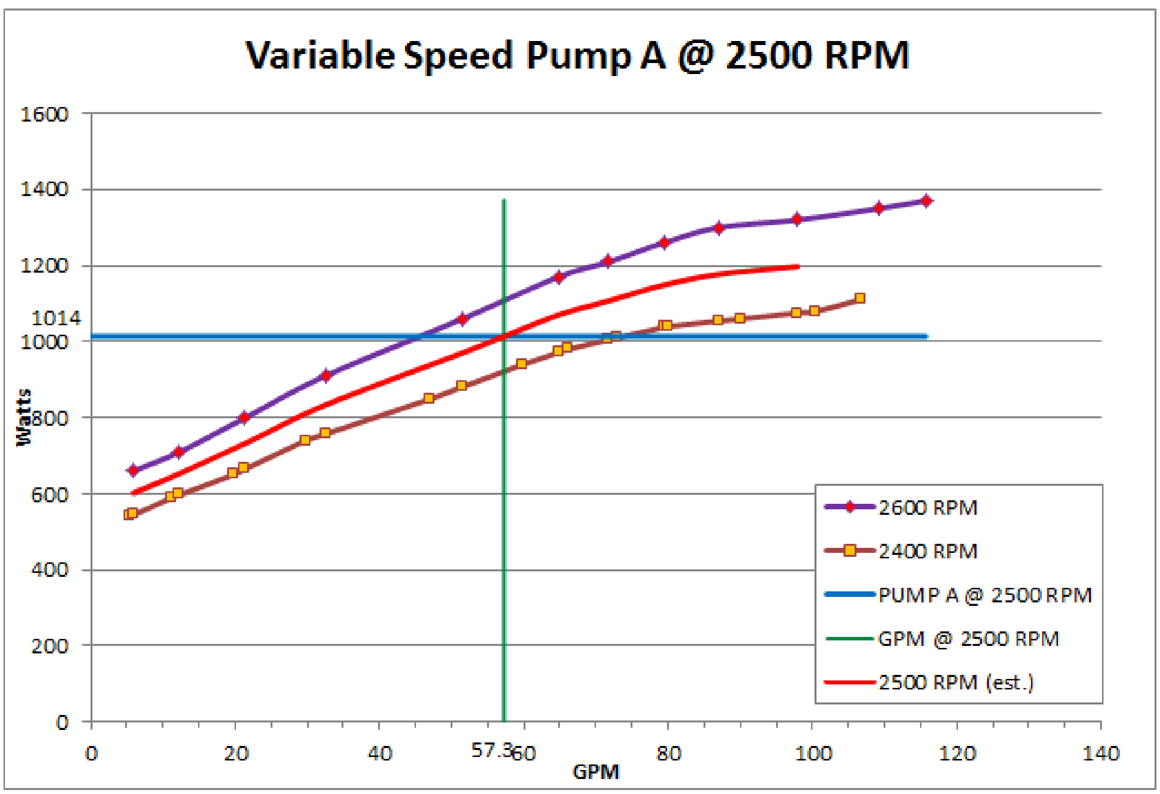


Figure 18: Wattage Pump Curve (Site #1, Pump A, Post-Retrofit, Without Meter Installed)

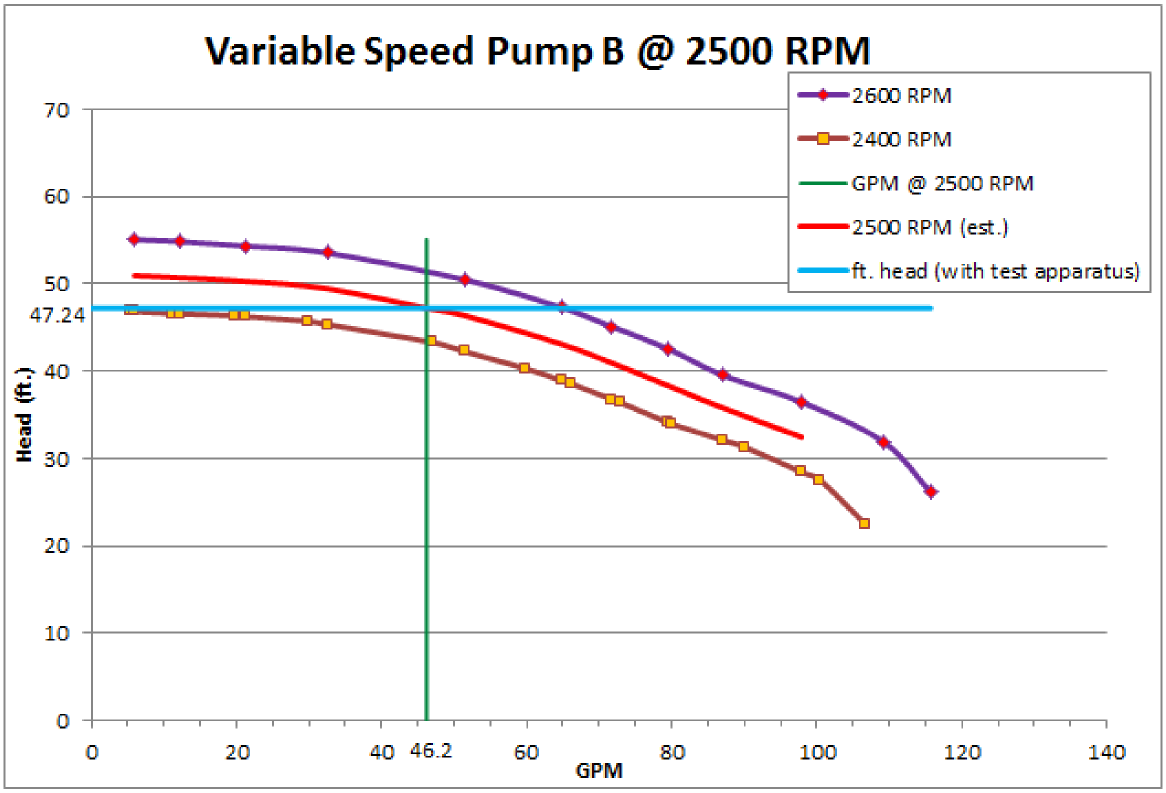


Figure 19: Pump Curve (Site #1, Pump B, Post-Retrofit, With Meter Installed)

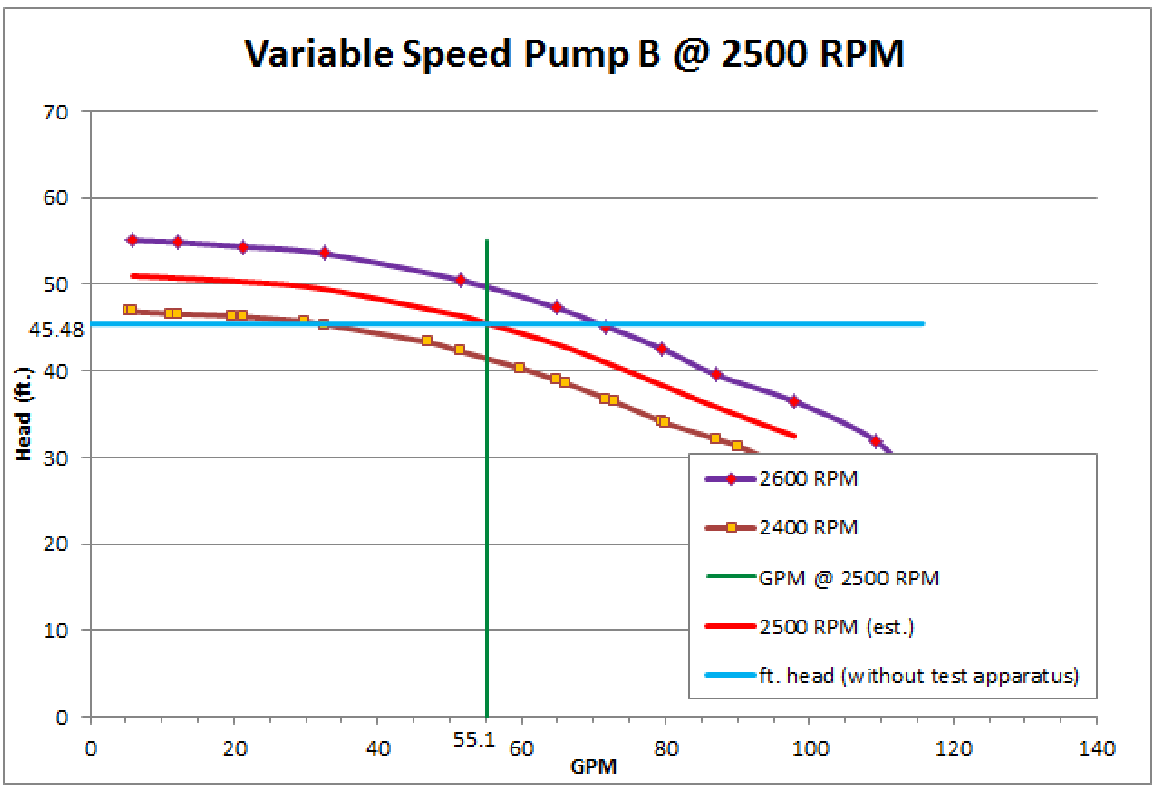


Figure 20: Pump Curve (Site #1, Pump B, Post-Retrofit, Without Meter Installed)

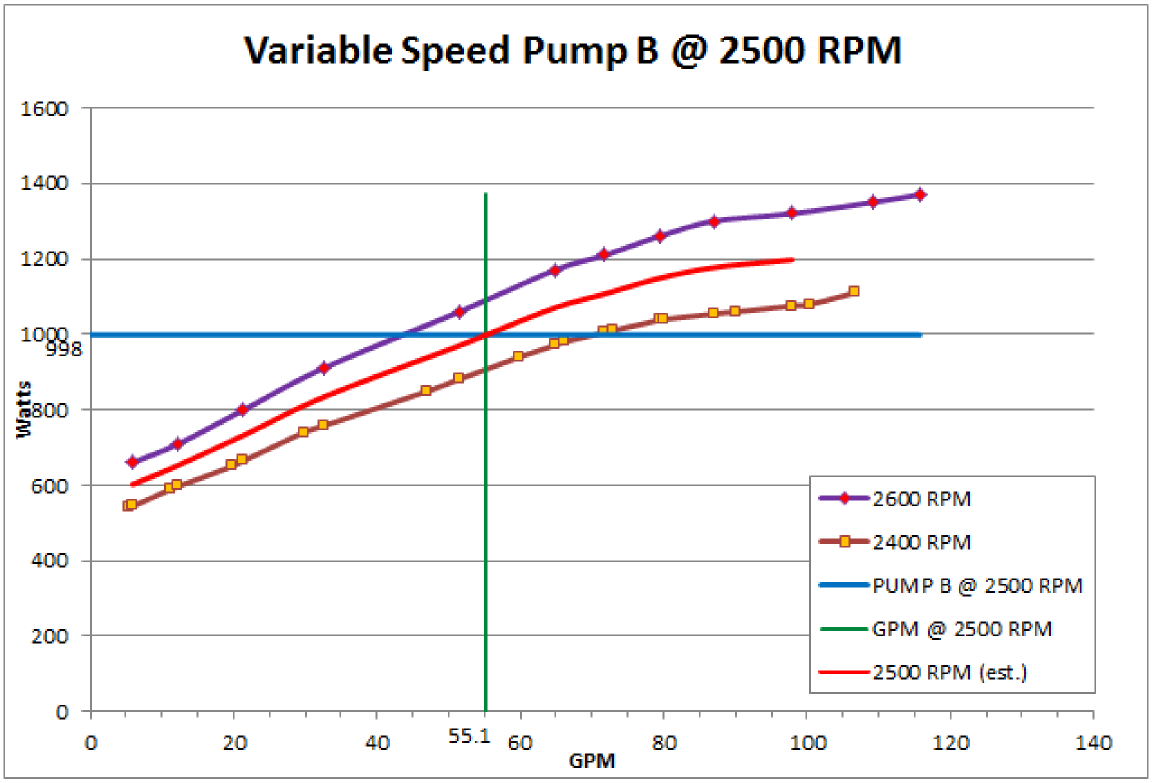


Figure 21: Wattage Pump Curve (Site #1, Pump B, Post-Retrofit, Without Meter Installed)

Based on a measured GPM of 46.2 (with measurement apparatus installed) Pump B was determined to have a flow rate of 55.1 GPM with the measurement apparatus removed, reducing the differential pressure by 0.76 PSIG or 1.75 ft. H2O to 45.48 ft. H2O. At a GPM of 55.1 Pump B was determined to draw 998 watts as shown in Figure 21 on the previous page.

EVALUATION OF FLOW RATE AT SITE #2

The water volume of the spa is 1,395 gallons, and local health code requires that its pump keep a minimum flow of 46.5 GPM[3]. At baseline the pump worked at a constant 48 GPM. The pool holds 28,000 gallons of water and requires a minimum flow of 77.8 GPM so satisfy the health code requirements[4]. At baseline the pool pump worked at a constant 79 GPM. Depending on the pressure loss of the filters and the maintenance back wash cycles, the actual baseline flow is believed to have been in the range of 46-49 GPM for the spa and 76-79 GPM for the pool.

At Test Site #2, a pump head test was performed the distributor and witnessed by Michel Rogers P.E., C.E.M. of Information & Energy Services, Inc. and Joe Shiau, P.E. of Sempra Energy. The pump head test was performed to compare pump GPM calculated using the

[3] Spa minimum turn-over time is 30 minutes.
[4] Pool minimum turn-over time is 6 hours.

manufacturer's published pump curve to the GPM measured using a flow-meter installed temporarily for the test. The result of the test was successful, meaning that the calculations made using the published pump curve were verified according to the flow-meter, and the head pressure readings were in agreement. Please see Figure 22 and Figure 23 below, showing the flow-meter readings of 49.3 GPM for the spa and 69.2 GPM for the pool, respectively. Please note that while this pool GPM was spot checked to be slightly below code (77.8 – 10% = 70 GPM > 69.2 GPM) it is expected to meet code if the resistance of the temporary flow meter were removed the flow rate would be slightly higher and easily meet code within 10%. The spot checked flow meter values are shown below and on the following page.

Figure 22: Spa Flow Meter

Figure 23: Pool Flow Meter

The pump head test was performed on the post-retrofit pumps. The procedures taken to perform the test were as follows:

A differential pressure gauge was installed temporarily to the suction and discharge ports on the pump body.

The flow-meter was installed temporarily.

Differential pressure was read from the gauge and pump speed was read from pump controller display. The Spa pump head pressure reading at 2150 RPM was determined to be faulty but the indicated wattage of 690 was used to correlate to approximately 45-50 GPM. Please see Figure

24 below, showing the manufacturers published pump curve at 2200 RPM for the particular 3 hp variable speed pump being tested.

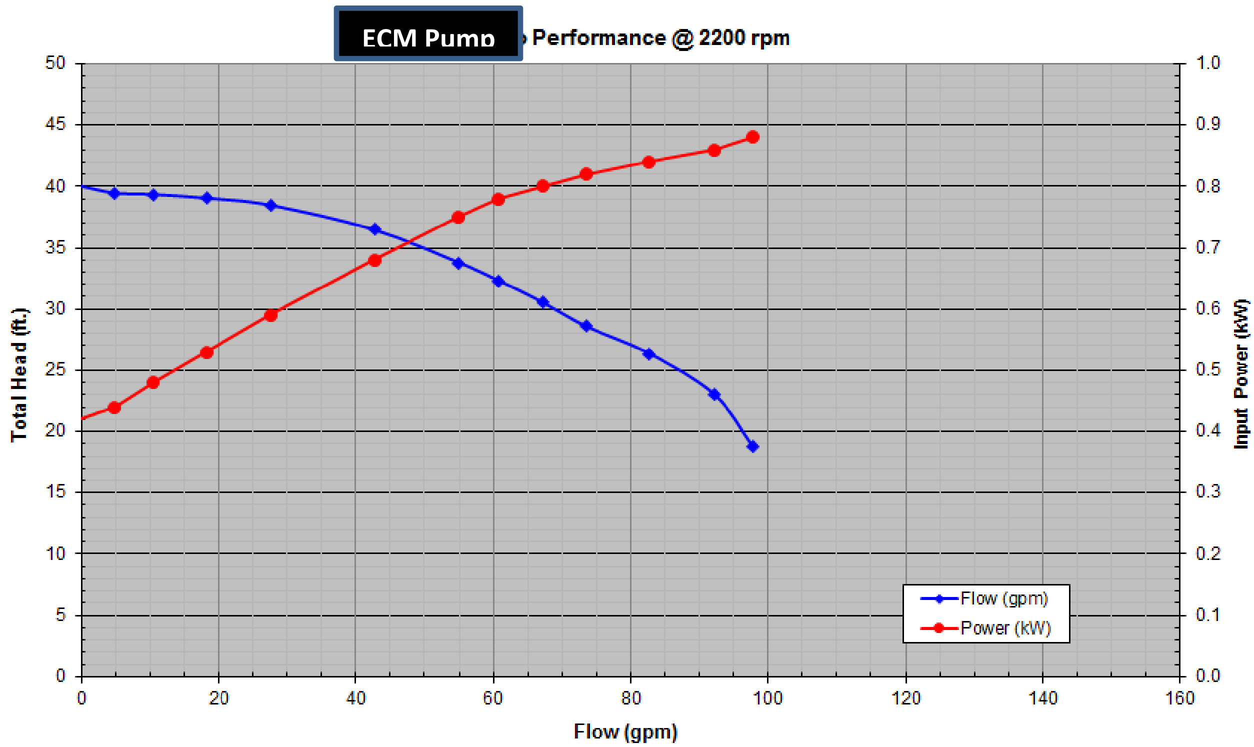


Figure 24: Variable Speed Pump Curve (@ 2200 RPM)

The pool pump read 51 feet of head at 2900 RPM. This information was then used with the manufacturer's published pump curve to determine flow-rate in GPM. Figure 25 below shows the estimated pump curve at 2900 RPM and can be used to estimate GPM. The 2900 RPM curve (in red line) is estimated from the manufacturer's published curves at 2800 RPM and 3000 RPM.

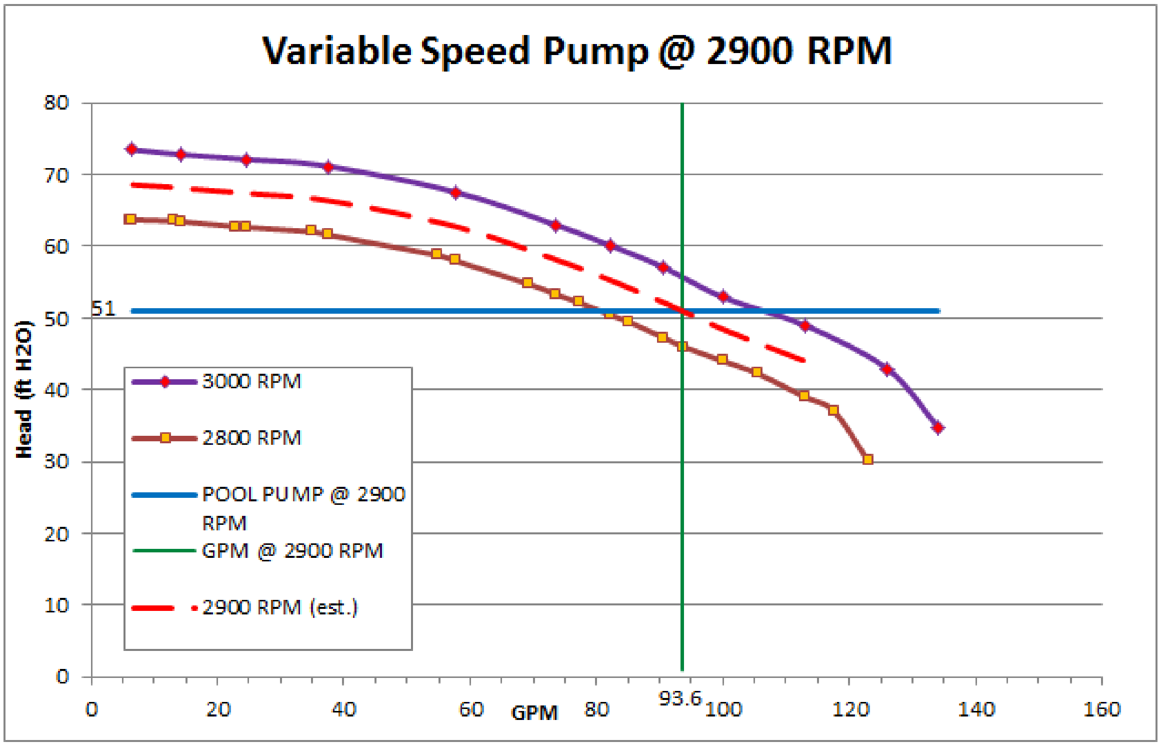


Figure 25: Variable Speed Pump Curve (@ 2900 RPM)

The result from the pump curve chart is then compared to the GPM reading from the flow-meter shown in Figure 22 and Figure 23. The Spa and Pool flow meter readings were 49.3 and 69.2 GPM respectively. The spa flow meter reading was confirmed within the precision of the test method and equipment. Using the differential head pressure reading method produced a higher flow-rate result at the pool, compared to the flow-meter result. Since the lower of the two was determined to be adequate, the pool flow rate was determined to meet code. Calculations used the flow-meter result (69.2 GPM) because it was determined to be more reliable (first hand measurement, rather than interpolated value).

CUSTOMER FEEDBACK

For the most part the customers (management) at both test sites have been pleased with the performance of the retrofit pumps. The only specific comment relating to the equipment has been that the retrofit pumps are quieter than the baseline pumps.

ENERGY SAVINGS

At both test pools and the test spa the resulting energy savings were substantial. The pool at Test Site #1 was found to use 44% less electricity. The pool at Test Site #2 was found to use 45% less energy. The spa at test site #2 was found to use 51% less electricity. The remainder of the section will be used to discuss the details of these finding on a site by site basis.

ENERGY SAVINGS – Site #1

At Test Site #1, the two swimming pool pumps are referred to as Pump A and Pump B. Pump B circulates through the filters and the heater, Pump A does not feed the heater. Pump A had a baseline average power draw of 1.63 kW, while Pump B had a baseline average power of 1.93 kW, combining for a total average power draw of 3.56 kW. On average Pump A consumed 39.2 kWh/day, while Pump B consumed 46.3 kWh/day, combining for 85.5 kWh/day. Annually, this amounts to an average electric consumption of 31,218 kWh/yr. At the calculated blended utility rate of $0.18/kWh, the estimated annual electric cost to operate the two baseline pumps would be $5,619.

The total power draw by the post-retrofit pumps was much lower than that of the baseline pumps. Figure 26 on the following page shows the average post retrofit daily load profile (blue line) and the average baseline demand (red line) overlaid to show the energy saved.

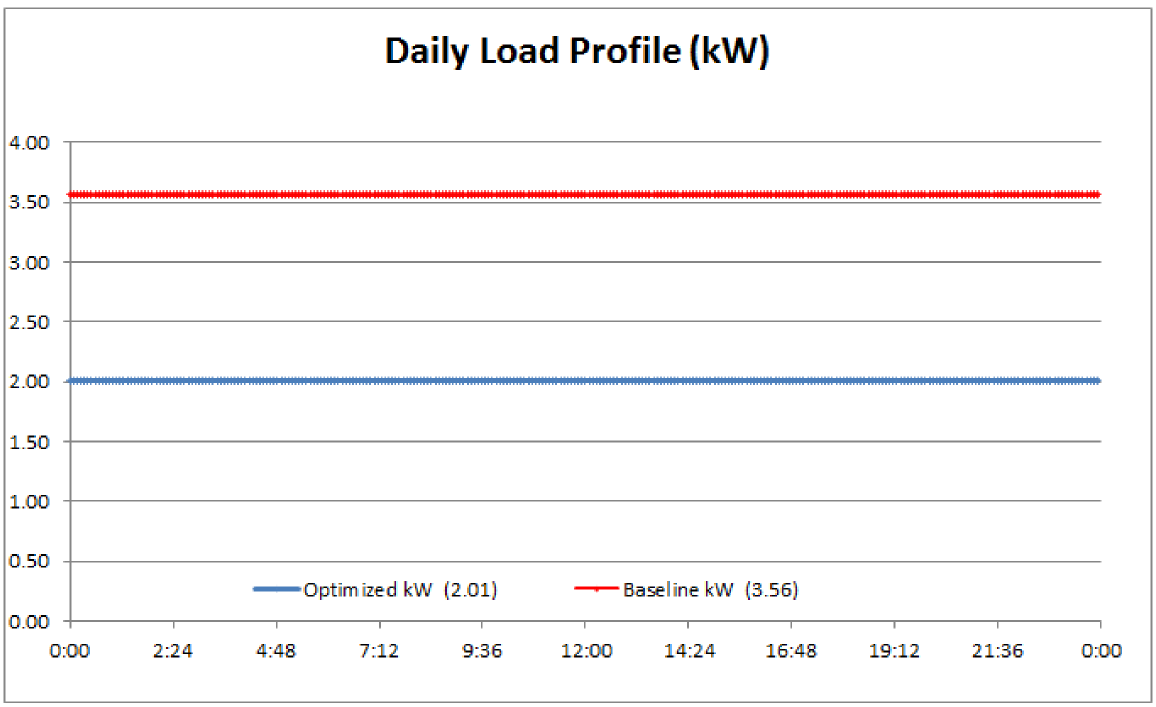


Figure 26: Combined Load Profile

For the post-retrofit time period, the pumps were determined to have an average power draw of 2.01 kW at 2500 RPM (both pumps). Due to the lowered power draw the daily energy consumption is reduced from 85.5 kWh/day to 48.3 kWh/day. Annually, this amounts to an average consumption of 17,625 kWh/year after the retrofit. At the 12 month blended utility rate of $0.18/kWh, the estimated annual electric cost to operate the two new pumps is $3,172. The retrofit is estimated to save **13,593 kWh** or **44%** which is **$2,447** in electric charges per year. Using this data, we can verify that installing the particular variable flow being tested in this study has resulted in significant energy savings. Please see Table 9 below, summarizing the Site #1 results.

Table 9: Site #1 Average Energy Savings

Swimming Pool Pump Retrofit (Site #1)							
Summary of Savings							
Baseline kW (Avg)			**Baseline kWh/day**			**Baseline**	**Baseline**
Pump A	*Pump B*	*Combined*	*Pump A*	*Pump B*	*Combined*	*Annual kWh*	*$/yr*
1.63	1.93	3.56	39.2	46.3	85.5	31,218	$ 5,619
Post-Retrofit kW (Avg)			**Post-Retrofit kWh/day**			**Post-Retrofit**	**Post-Retrofit**
Pump A	*Pump B*	*Combined*	*Pump A*	*Pump B*	*Combined*	*Annual kWh*	*$/yr*
1.01	1.00	2.01	24.3	23.9	48.3	17,625	$ 3,172
Avg kW Reduction			**Avg kWh/day Reduction**			**kWh Saved**	**$ Saved**
Pump A	*Pump B*	*Combined*	*Pump A*	*Pump B*	*Combined*	*Annual kWh*	*$/yr*
0.62	0.93	1.55	14.9	22.4	37.2	13,593	$ 2,447
						Percent Energy Savings	**44%**

ENERGY SAVINGS – Site #2

At Test Site #2 the energy consumption by the pool pump and spa pump were measured separately. The Spa Filtration Pump had a baseline average power draw of 1.31 kW when energized. The baseline spa pump runs between 5:35 AM and 8:20 PM seven days a week, which amounts to 14.75 hours per day or 5,383.75 hours per year in the non-adjusted baseline. Therefore, the spa pump consumed 19.3 kWh/day or 7,052 kWh/year in the non-adjusted baseline.

The baseline had to be adjusted at Site #2 because at the time of retrofit it was discovered that the pool was open to bathers for more hours per day than the pumps were enabled, which violated health code guidelines stating the filtration system must be enabled whenever the pool is open to bathers. Post-retrofit, the hours of operation were adjusted to match the pool schedule. Accordingly, the baseline must be adjusted to account for this schedule change, in effect compensating such that the baseline load is what it would have been if the baseline pumps were meeting health code requirements.

The power draw by both the post-retrofit pool and spa pumps was much lower than that of the baseline pumps. The average (non-adjusted) daily load profile is shown for the baseline and post-retrofit spa pumps below in Figure 27, and for the pool in Figure 28 on the following page.

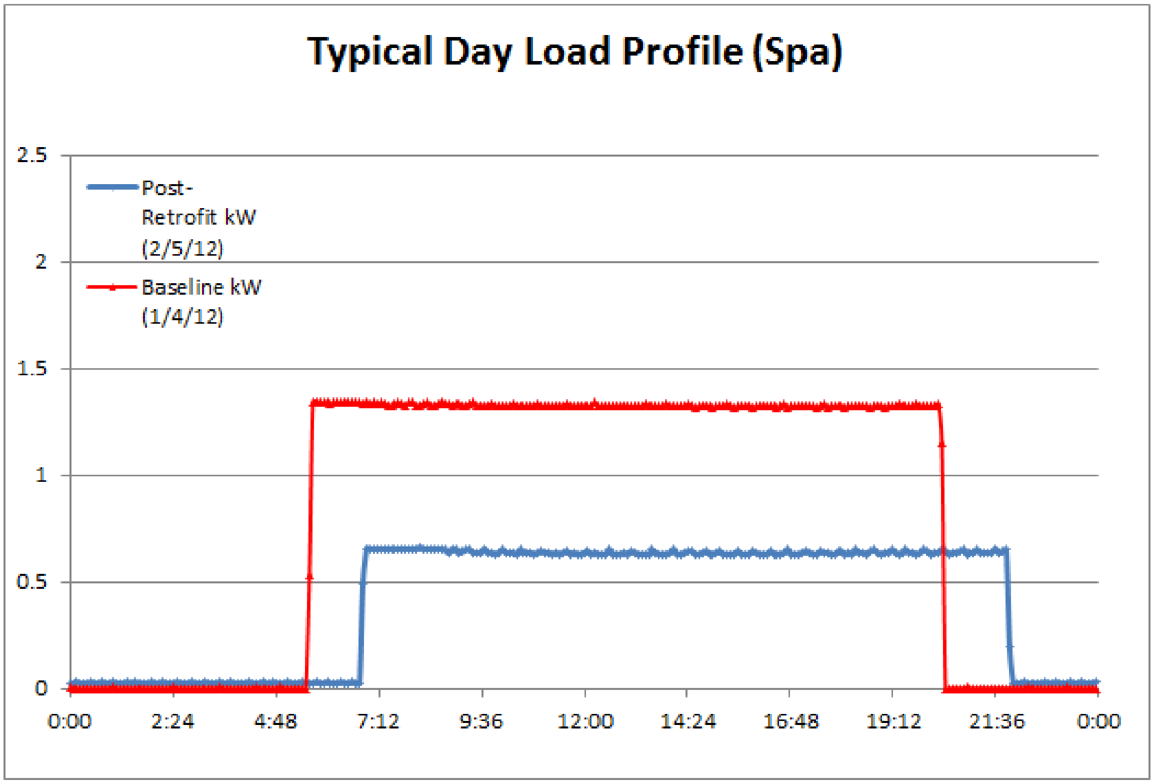


Figure 27: Site #2 - Typical Daily Spa Pump Load Profile (Non-Adjusted Baseline)

The Pool Filtration Pump had a baseline average power of 2.09 kW while energized. The baseline pool pump ran between 7:35 AM and 5:20 PM seven days a week, which amounts to 9.75 hours per day or 3,558.75 hours per year in the non-adjusted baseline. Therefore the pool pump consumed 20.3 kWh/day or 7,424 kWh/year in the non-adjusted baseline.

The average daily load profile is shown for the baseline and post-retrofit pool pumps on the following page in Figure 28.

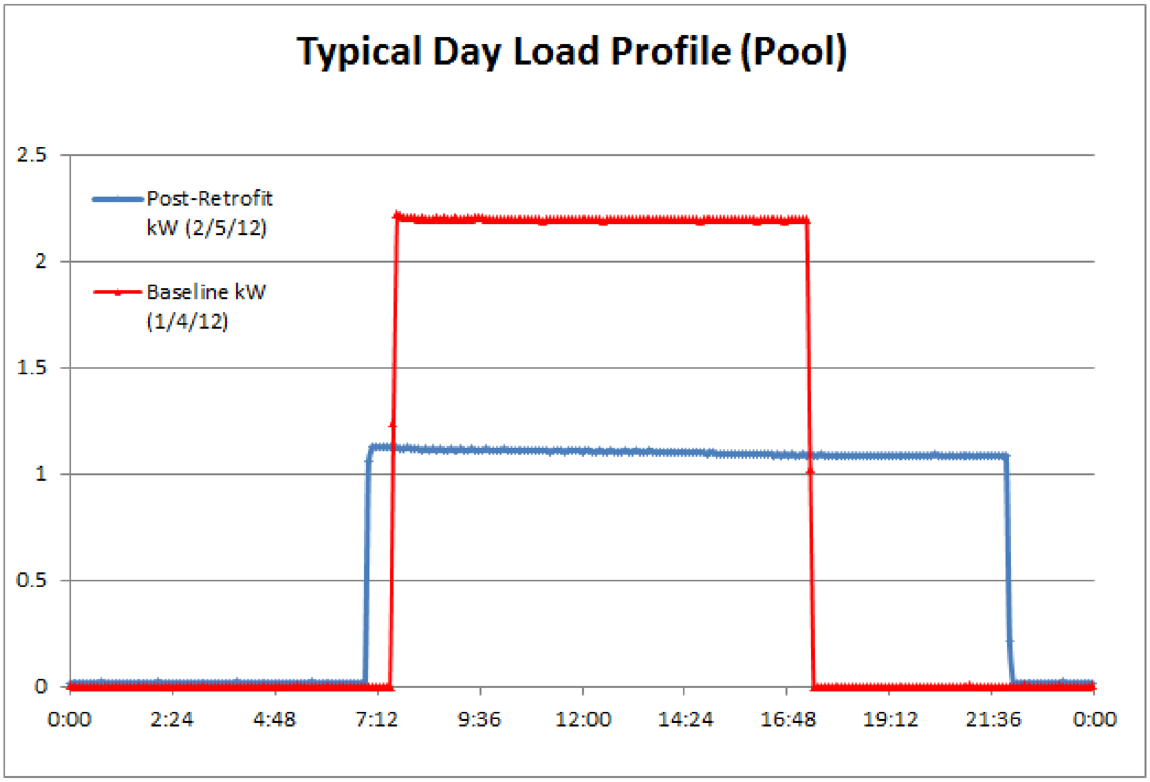


Figure 28: Site #2 - Typical Daily Pool Pump Load Profile (Non-Adjusted Baseline)

At the blended utility rate of $0.18/kWh, the estimated annual electric cost to operate the two baseline pumps (pool + spa) was $3,361, however this was not meeting health code requirements based on schedule of pool operation. To meet requirements the hours of operation were extended to match the schedule of actual pool use at the time of retrofit. Table 10Table 9 along with the figures below shows the difference between the pre- and post-retrofit schedule.

During the 25 day post-retrofit time period, the Spa Filtration Pump had an average power draw of 0.65 kW when energized, while the Pool Filtration Pump had an average power draw of 1.14 kW when energized. Due to the lowered power draw, the daily combined energy consumption fell from 51.2 kWh/day in the baseline to 26.9 kWh/day post retrofit. Annually, this amounts to an average total consumption of 9,813 kWh/year after the retrofit. Interestingly, the flow rate for the Site #2 pool was determined to be lower in the baseline, actually 21 more GPM were being moved by the post-retrofit pumps. This increase is warranted because the baseline pumps were barely satisfying the health code requirements for flow rate when they were running, and were not running enough hours as mentioned above. The post-retrofit pumps definitely satisfy the health code, and still use much less electricity. At the blended utility rate of $0.18/kWh, the estimated annual electric cost to operate the two post-retrofit pumps is $1,766. The retrofit is estimated to save the pool operator 8,860 kWh or

$1,595 on electric charges per year after correcting for the operating hours change that was implemented at the time of installation.

As shown in the load profiles of Figure 27 and Figure 28, the hours of operation were changed at the time of installation. Therefore the baseline hours of operation must be adjusted to match the post-retrofit data in order for a true comparison to be made.

At this site the run schedule of the spa and pool pumps were changed at the time of retrofit. The runtime change was necessary because it was found that the baseline pumping was not meeting health code requirements for turnover rate. Accordingly, the baseline must be adjusted to account for this schedule change, in effect compensating such that the baseline load is what it would have been if the baseline pumps were meeting health code requirements. The schedule of the non-compliant baseline pumps is shown in Table 4 on Page 13. For calculation purposes the baseline schedule was adjusted to match the corrected post-retrofit schedule as shown in Table 10 below.

Table 10: Post-Retrofit Hours at Site #2

	Non-Compliant		After Adjustment	
	Spa Pump	Pool Pump	Spa Pump	Pool Pump
Start Time	5:35	7:35	6:50	7:00
Stop Time	20:20	17:20	22:00	22:00
Daily Hours	**14:45**	**9:45**	**15:10**	**15:00**

Figure 29 and Figure 30 on the following page show a typical day load profile for the spa and pool pumps respectively. The adjusted baseline is shown, in contrast to the non-adjusted baseline in Figure 27 and Figure 28. After the adjustment, the schedule is matching (compensated) but the load is less in the post-retrofit data set (blue line). The savings represented are attributed to the increased electrical efficiency of the post-retrofit pump compared to the incumbent pump, as well as the fact that the post-retrofit pump was running at less than its full speed. Because of the Affinity Law the savings from this speed reduction compared to the evaluated pumps full speed of 3450 RPM is proportional to the cube of the shaft speed reduction. The difference in maximum horsepower rating between the incumbent and post-retrofit pumps is canceled by the variable speed factors.

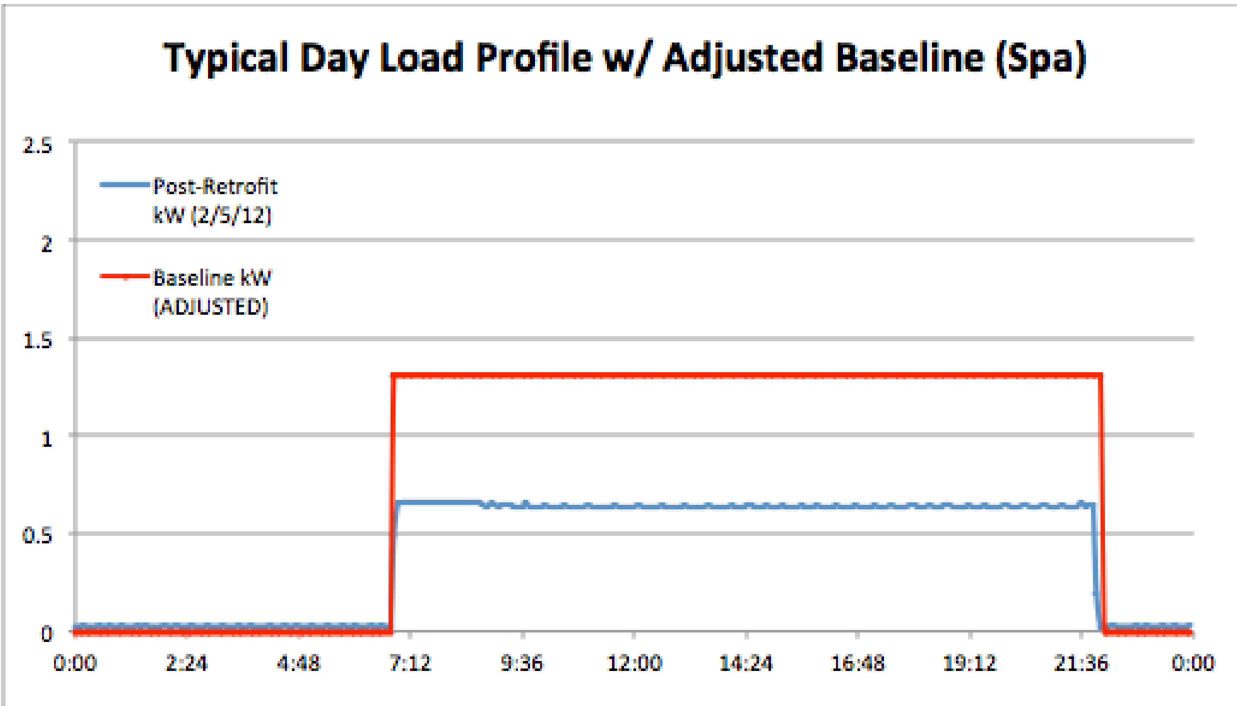


Figure 29: Site #2 - Typical Daily Spa Pump Load Profile (Adjusted Baseline[5])

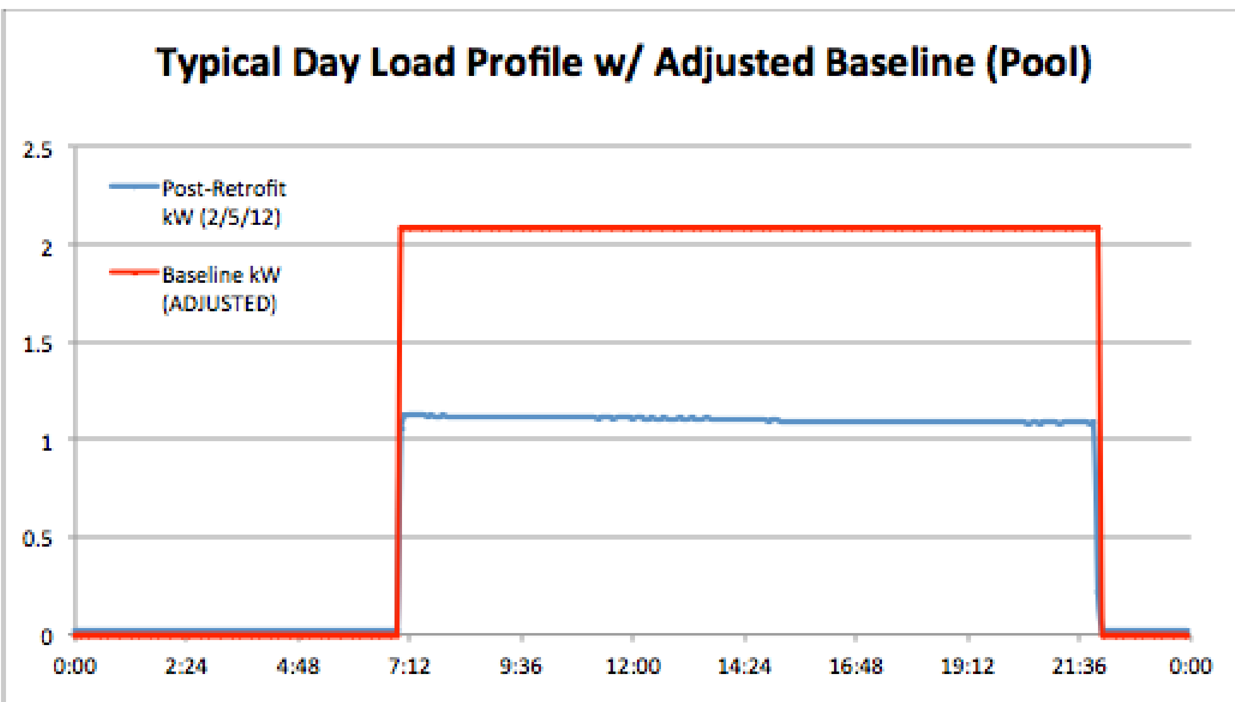


Figure 30: Site #2 - Typical Daily Pool Pump Load Profile (Adjusted Baseline[6])

[5] Adjusted for runtime, to bring spa filtration system in compliance with local health code.
[6] Adjusted for runtime, to bring pool filtration system in compliance with local health code.

Table 11 below summarizes the results for Test Site #2, both the swimming pool and the spa.

Table 11: Site #2 Average Energy Savings

Swimming Pool Pump Retrofit (Site #2)							
Summary of Savings							
Baseline kW (Avg, when enabled)			**Baseline kWh/day (Adjusted)**			**Baseline (Adjusted)**	**Baseline (Adjusted)**
Pool Pump	*Spa Pump*	*Combined*	*Pool Pump*	*Spa Pump*	*Combined*	*Annual kWh*	*$/yr*
2.09	1.31	3.40	31.3	19.9	51.2	18,673	$ 3,361
Post-Retrofit kW (Avg, enabled)			**Post-Retrofit kWh/day**			**Post-Retrofit**	**Post-Retrofit**
Pool Pump	*Spa Pump*	*Combined*	*Pool Pump*	*Spa Pump*	*Combined*	*Annual kWh*	*$/yr*
1.14	0.65	1.79	17.1	9.8	26.9	9,813	$ 1,766
Avg kW Reduction			**Avg kWh/day Reduction**			**kWh Saved**	**$ Saved**
Pool Pump	*Spa Pump*	*Combined*	*Pool Pump*	*Spa Pump*	*Combined*	*Annual kWh*	*$/yr*
0.95	0.66	1.61	14.2	10.0	24.3	8,860	$ 1,595
45%	51%	47%	<<< PERCENT ENERGY SAVINGS				

The average annual energy savings for retrofitting the pool and spa filtration pumps are estimated to be **8,860 kWh** or **$1,595** after correction for the change in schedule**.** This is a **51%** reduction for the spa and a **45%** reduction for the pool, compared to the previous pumping configuration if the code required hours of operation were used with both systems. Using this data, we can verify that installing the particular pumps being tested for this study has resulted in significant energy savings. In general these results should be typical of any similar technology in which a VFD is used to reduce the speed of a swimming pool or spa filtration pump.

ENERGY INTENSITY & SIMPLE PAYBACK

In order to better compare and extrapolate the results of this study to other situations the energy intensity is calculated in units of Watts per GPM. For a given flow-rate the power required by the pumps can be measured and compared to other pools. At Test Site #1 the baseline flow rate was 155 GPM, which required the pumps to draw 3.56 kW, therefore the energy intensity was 23.0 Watts/GPM. After the retrofit the flow rate was determined to be 112 GPM, at which point the pumps required 2.01 kW, thus the energy intensity was 17.9 Watts/GPM.

At Test Site #2 the baseline flow rate of the pool was 69 GPM, which required the pump to draw 2.09 kW; therefore, the energy intensity was 30.1 Watts/GPM. After the retrofit the flow rate was determined to be 90 GPM, at which point the pump required 1.14 kW, therefore the energy intensity was 12.6 Watts/GPM.

The results from the spa at Site #2 were similar to the pool. The baseline flow rate was 48 GPM, which required 1.31 kW for the pump; therefore, the energy intensity was 27.3 Watts/GPM. After the retrofit the flow rate was determined to be 50 GPM which required 0.65 kW at the pump, making the energy intensity only 13.0 kW for the spa after the retrofit. Please see

Table 14 for the Energy Intensity Findings.

Simple payback is shown below in Table 12. Estimated cost is shown for both a retrofit application as well as incremental cost for a new construction application.

Table 12: Simple Payback Summary

Simple Payback Summary Early Retirement Cost				
	Annual kWh Saved	Annual $ Saved ($0.18/kWh)	$ Retrofit Cost w/o rebate	Simple Payback (yrs)
Site #1 Pool	13,593	$ 2,447	$ 7,000	2.9
Site #2 Pool	5,195	$ 935	$ 3,500	3.7
Site #2 Spa	3,665	$ 660	$ 3,500	5.3

Simple Payback Summary New Construction Cost				
	Annual kWh Saved	Annual $ Saved ($0.18/kWh)	$ Retrofit Cost w/o rebate	Simple Payback (yrs)
Site #1 Pool	13,593	$ 2,447	$ 5,500	2.2
Site #2 Pool	5,195	$ 935	$ 2,750	2.9
Site #2 Spa	3,665	$ 660	$ 2,750	4.2

SAVINGS INFLUENCING FACTORS

The primary factor influencing potential savings is the internal hydraulic resistance of the particular system. Resistance to the flow of water is affected by the length and diameter of pipe between the pool and the pump, the number of turns in the pipe run, number of valves or gauges, and the type of filter.

In general more savings can be attained in a hydraulically efficient system by switching to a variable speed pump. This is because of the behavior of the single speed baseline pump: in a system with more hydraulic restrictions a given pump will produce less flow and therefore use less energy than in a system with fewer hydraulic restrictions. In other words a given pump will actually turn slower and use less energy in a system which seriously resists its flow than if the same pump were placed in a system with less resistance. The savings come when the single speed pump is replaced with a variable speed pump. With the variable speed pump the flow-rate can be tuned to still provide a required minimum flow-rate, but the pump must still overcome the hydraulic resistance, which limits the potential savings. In the case of the system with less hydraulic resistance the variable speed pump is able to be tuned to an even lower level because there is less resistance to overcome thus the potential for savings is higher. Although a variable speed pump is an effective energy saving measure for all types of filter systems, further significant savings can be attained by maximizing the hydraulic efficiency of the system, and should be considered as part of any energy reduction efforts for systems that include variable frequency drives.

APPLICIBILITY OF FUTURE REBATE/INCENTIVE PROGRAMS

Currently there are rebate programs for this technology in the single family residential sector only. This study finds that rebate or incentive programs designed to increase proliferation of this technology in the commercial and multi-family residential market segments would be appropriate. The EEBI program could potentially offer incentives for this measure under the "other measures" rate. The EEBR program could potentially implement rebates specifically targeted for this retrofit, and that would be a way to way to streamline the rebate process to encourage acceptance of the retrofit. Alternately the variable speed pool pump could be combined with the existing VFD rebate measure already on the books.

STATEWIDE MARKET POTENTIAL

Based on the number of swimming pools and spas estimated to be in use in California, we can make certain market potential estimates. These estimates are shown to provide an ***example*** of how one might perform market potential calculations, several assumptions are made as shown below:

- 17,000 county regulated swimming pools and spas in Los Angeles County.
- 4,000 county regulated swimming pools and spas in San Diego County.
- 25% of all swimming pools and spas in California are located in LA and SD counties. Making the total estimate for CA 84,000 bodies of water.
- Market Penetration rate of 5% assumed, this excludes all non-eligible systems.
- Average energy savings results of 45% from this study assumed to be valid at other sites.
- Average baseline energy consumption estimated from pools in this study, 80% weighted for the smaller single pump pool, or 15,381 kWh per pool per year.

$$\begin{aligned}\boldsymbol{Statewide\ Electricity\ Savings} \\ &= \boldsymbol{Total\ Pools\ in\ CA} \times \boldsymbol{Per\ Pool\ Baseline\ kWh} \\ &\times \boldsymbol{Energy\ Savings}\ \% \times \boldsymbol{Market\ Penetration\ Rate}\end{aligned}$$

Table 13: MARKET PENETRATION EXAMPLE CALCULATION

CALIFORNIA MARKET POTENTIAL (EXAMPLE CALCULATION)	
17,000	Total Number of LA County Pools (per Dist.)
4,000	Total Number of SD County Pools (per Dist.)
25%	% of CA Accounted for
84,000	Total Estimated Pools in CA
5%	Example Market Penetration Rate
15,381	Average Annual Per Pool Baseline kWh
45%	Average % Energy Savings
29,070,090	Example Calculation - Statewide Annual kWh Savings

PROJECT ERROR ANALYSIS

PROJECT PLAN DEVIATION

It was necessary to deviate from the project plan in order to handle the anomalous data discussed in the following section. In addition to the anomalous data, the project plan was deviated from in order to compensate for below code flow rate experienced at Site #1 post retrofit, as detailed in the section "Evaluation of Flow Rate at Site #1."

ANAMOLUS DATA AND TREATMENT

SITE #1 BASELINE DATA

The baseline data at Site #1 did contain anomalies. These anomalies were due to outdoor nighttime lighting being fed from the same circuit as the pool pumps being studied. IES had to work within the constraints presented by the existing wiring of the facility. With the constant speed baseline pumping we were able to easily separate any non-pumping loads from the data set. The outdoor lighting followed a schedule that could easily be compensated for. All data collected when the lighting was enabled was culled from the data set.

SITE #1 POST-RETROFIT DATA

The first post-retrofit data set at Site #1 did contain anomalies. These anomalies were due to a different circuit being used to supply the buck boost transformer (and new pumping). IES was told that the same circuit was being used. This discrepancy was only discovered by IES after the data set was collected and analysis was started. This data set was completely removed from the study. The data logging equipment was moved to the single circuit serving the transformer (which in turn supplies the pumps) to collect the second data set.

The second post-retrofit data set at Site #1 did contain anomalies. These anomalies were due to the filter medium not being re-charged on time which in turn reduces the resistance to the pump and does not provide representative data. After a quick look at this data set it was evident that there was an issue with the equipment. Site maintenance staff determined that the filter medium was not properly charged. The data set was completely removed from the study. The DE filter was recharged prior to collection of the third data set.

The third post-retrofit data set at Site #1 did not contain anomalies, and was used in this study.

Wattage was determined from readings taken on 5/23/12 when the flow rate was measured at various speeds.

SITE #2 BASELINE DATA

The baseline data at Site #1 did contain anomalies. Adjustments to the hours of operation were required because the hours were increased at the time of retrofit to meet health inspector requirements. The baseline was adjusted to meet the corrected hours of operation only.

SITE #2 POST-RETROFIT DATA

The post-retrofit data set as Site #2 did not contain anomalies, and was used in calculations for this study.

CONCLUSIONS

BENEFITS OF EVALUATED TECHNOLOGY

The particular type of pool pump that was evaluated has numerous benefits aside from the aforementioned savings. The pumps run relatively quiet compared to standard pumps, reducing noise pollution for residents. The pumps are highly customizable, and when used under optimum settings can have a much longer lifespan than the standard pumps due to the reduced number of starts. In general, variable flow pumps are very versatile, allowing for installation in a wide variety of swimming pools while making the required flow-rate.

POSSIBLE DRAWBACKS & RISKS OF EVALUATED TECHNOLOGY

Pump operators do need very basic training to get the best use of the pump. Pump room doors should always remain locked so that unauthorized personnel cannot accidently change system settings or access the systems and potentially dangerous chemicals contained within the pool room. Any control panels should remain locked with a password so that unauthorized personnel cannot change system settings. Finally, the variable speed units are moderately more expensive than constant speed pumps, but this incremental cost is easily offset by the energy savings to be gained, with incremental simple payback of under a year expected in most cases.

APPLICIBALITY OF FINDINGS TO OTHER LOAD TYPES AND SECTORS

The findings of this study (and the equipment evaluated) could be applicable in any process whereby water is being moved at a specific target flow-rate. Furthermore the results could be used to estimate savings from not only the particular make and model of pump evaluated in this study, but of any variable speed drive swimming pool pump with similar control capabilities. In order to compare and extrapolate the results of this study to other situations the energy intensity was calculated in units of Watts per GPM. This unit can also be converted to kWh/Gallon. For a given flow-rate the power required by the pumps can be measured and compared to other pools. Please see

Table 14 below for the energy intensity findings at the test pools and spa

Table 14: Pumping Energy Intensity Findings

Watts per GPM Findings (BASELINE)	
3.56	Pool #1 Baseline kW
155	Pool #1 Baseline GPM
23.0	**Pool #1 Baseline Watts/GPM**
2.09	Pool #2 Baseline kW
69.2	Pool #2 Baseline GPM
30.1	**Pool #2 Baseline Watts/GPM**
5.65	Pool Baseline kW (Pool 1 + Pool 2)
234	Pool Baseline GPM (Pool 1 + Pool 2)
24.1	**Avg. Pool Baseline Watts/GPM**
1.31	Spa Baseline kW
48	Spa Baseline GPM
27.3	**Spa Baseline Watts/GPM**

Watts per GPM Findings (POST-RETROFIT)	
2.01	Pool #1 Post-Retrofit kW
112	Pool #1 Post-Retrofit GPM
17.9	**Pool #1 Post-Retrofit Watts/GPM**
1.14	Pool #2 Post-Retrofit kW
90	Pool #2 Post-Retrofit GPM
12.6	**Pool #2 Post-Retrofit Watts/GPM**
3.15	Pool Post-Retrofit kW (Pool 1 + Pool 2)
202	Pool Post-Retrofit GPM (Pool 1 + Pool 2)
15.6	**Avg. Pool Post-Retrofit Watts/GPM**
0.65	Spa Post-Retrofit kW
50	Spa Post-Retrofit GPM
13.0	**Spa Post-Retrofit Watts/GPM**

These energy intensity levels can be applied to other projects. For rebate and incentive considerations, it is recommended that other commercial and multi-family residential pools be encouraged to implement the technology evaluated in this study.

CONSIDERATIONS FOR LARGE SCALE PERSISTANT MARKET IMPLIMENTATION

Large scale implementation would save energy over the constant speed pumps that are commonly used today.

POSSIBLE FUTURE STUDY

The authors recommend a large scale field placement study based on the encouraging results of this study.

ENERGY STAR BENCHMARKING

The Energy Star Benchmarking process is not applicable for this emerging technology measure.

GLOSSARY AND ACRONYMS

Affinity Law- Fluid flow is proportional to shaft speed. Head pressure is proportional to the square of shaft speed. Power is proportional to the cube of shaft speed.

Laminar Flow- when a fluid flows in parallel layers, with no disruption between the layers

GPM- Gallons per Minute

RPM- Revolutions per Minute

ECM- Energy Conservation Measure

VS- Variable Speed

VFD- Variable Frequency Drive

EEBR- Energy Efficiency Business Rebate program

EEBI- Energy Efficiency Business Incentive program

APPENDIX A: PROJECT PLAN

TECHNOLOGY UNDER INVESTIGATION: Variable flow pool pump.

INCUMBENT TECHNOLOGY BEING REPLACED: Constant speed swimming pool filtration pumps.

GOALS OF ASSESMENT PROJECT: The objective of this study is to evaluate the energy savings potential of the variable speed pool pump model being tested. This emerging technology will be evaluated by comparing it to the pre-existing pump energy consumption at the test sites. The technology was tested at two swimming pools and one spa in the San Diego area. Results will be applicable to other similar retrofit applications. The results of this study will be presented in terms of kWh saved and % electricity saved, as well as in terms of the difference in kWh/gallon between the baseline and post-retrofit data in order for the results to be applied to other applications.

M&V PLAN: Please see APPENDIX B – M&V PLAN

TEST SITE INFORMATION: Two test sites were used. Test Site #1 is a typical 500 unit multi-family residential apartment complex in the Point Loma area of San Diego, CA. Site #1 uses two pumps to filter the swimming pool. Test Site #2 is a typical 384 unit apartment multi-family residential apartment complex in the Carmel Mountain area of San Diego, CA. Site #2 uses one pump to filter the swimming pool. At site #2 the spa is also being studied, a single pump filters the spa. In all cases the single speed pumps were replaced with the same model of variable speed pump being evaluated.

PROJECT TRACKING NUMBER: ET11SDGE0017

APENDIX B: M&V PLAN

The long-term success of any comprehensive energy efficiency program depends on the development of an accurate, successful Measurement & Verification (M&V) plan. The main objective is to develop a cost effective plan that quantifies and verifies the performance results of the emerging technology. IES subscribes to using industry standard M&V protocols that have been developed in response to the need for reliable and consistent measurement practices.

The following reference is used for the development of M&V procedures for this project:

- U.S. Department of Energy. 2002. *International Performance Measurement & Verification Protocol (IPMVP)*.

MEASUREMENT AND VERIFICATION OPTIONS

The IPMVP protocols have defined four M&V options (Options A through D) that meet the needs of a wide range of performance contracts and provide suggested procedures for baseline development and post-retrofit verification. These M&V options are flexible and reflect the considerations previously mentioned. The options are summarized in the following table.

Table 15: Measurement and Verification Options

M&V Option	How Savings Are Calculated	Typical Applications
Option A: Partially Measured Retrofit Isolation		
Option B: Retrofit Isolation		
Savings are determined by field measurement of the energy use of the systems to which the ECM was applied, separate from the energy use of the rest of the facility. Short-term or continuous measurements are taken throughout the post-retrofit period.	Engineering calculations using short term or continuous measurements	Application of controls to vary the load on a constant speed pump using a variable speed drive. Electricity use is measured by a kWh meter installed on the electrical supply to the pump motor. In the base year this meter is in place for a week to verify constant loading. The meter is in place throughout the post-retrofit period to track variations in energy use.

M&V Option	How Savings Are Calculated	Typical Applications
Option C: ***Whole Facility (Bill Comparison)***		
Option D: ***Calibrated Simulation (Calibrated Building Modeling)***		

IES selected Option B in order to most accurately quantify the energy load from both the incumbent and retrofit equipment. Short term continuous measurements will be taken at 5 minute intervals for both the incumbent and retrofit equipment. Duration will be such that the load can be accurately extrapolated. The following table summarizes the methods IES recommends for the project based on past experience and the scope of the M&V being requested.

Table 16: M&V Option Selected

#	ECM Description	Option A	Option B	Option C	Option D
1	Install variable speed swimming pool or spa pumping		X		

M&V PLAN- INSTALL VARIABLE SPEED POOL PUMPING

MEASUREMENT AND VERIFICATION REVIEW

The M&V protocol for this emerging technology is based on the recommendations of IPMVP Option-B. Option-B involves directly sub-metering the system loads for the baseline and energy saving equipment in order to verify that the measure has the potential to perform and to generate savings. Performance verification techniques include engineering calculations with short-term metered values, resulting in measured verification of performance. With the chosen method, hours of operation are measured, with any adjustments made to the baseline in the event of changes between the pre and post retrofit data sets.

Under this measurement plan, the retrofitting party assumes performance risk for the operation of the new pump and the operability of the new onboard pump controls. IES will perform short term data logging of the equipment, taking 5 minute interval measurements to determine the power draw and hours of operation. This will be established by trending the average load on the pump circuit in the baseline and then again after installation of the measure. Data collection is planned to persist for two weeks or as needed in each scenario.

TEST LOCATIONS

Test Site #1 is a typical 500 unit apartment complex in the Point Loma area of San Diego. At Site #1, a single swimming pool using two pumps was selected. Site #2 is a typical 384 unit apartment complex in the Carmel Mountain area of San Diego. At Test Site #2 a single swimming pool and a single spa were selected, using one pump each for filtration.

Testing Sites were selected by the distributor based on their willingness to participate and then approved by IES. The sites are qualified based on their locations and the fact that the swimming pools used to test are typical of what is found at most multi-family residential apartment complexes.

ENERGY SAVINGS CALCULATION METHODOLOGY

Savings Algorithm:

$$Annual\ kWh\ Saved = Annual\ kWh_{\ pre} - Annual\ kWh_{post}$$

$$Annual\ kWh = 365 \times Avg\ kW \times run\ hours\ per\ day$$

$$Avg\ kW = Average\ of\ load\ when\ motor\ running$$

$$run\ hours\ per\ day = amount\ of\ time\ that\ the\ pump\ motor\ runs\ each\ day$$

$$energy\ intensity = \frac{Watts}{GPM} = \frac{Avg\ kW \times 1000}{GPM}$$

$$GPM = gallons\ per\ minute, determined\ for\ each\ scenario$$

MEETERING PLAN

All data collection will be performed at 5-minute intervals using two (2) C.C.S. WattNode WMB-3D-240-P pulse input kWh meters, one for each pump, which logged power readings into a single HOBO UX-120 data logger. The kWh meters will use 20 amp CTs manufactured by Magnelab for use with the WattNode kWh meters.

The following data points will be collected on a 5 minute interval basis:

- Time/Date (of each data point)
- Instantaneous kW load (Site #1 Baseline, Pump A)
- Instantaneous kW load (Site #1 Baseline, Pump B)
- Instantaneous kW load (Site #1 Post-Retrofit, both pumps combined)
- Instantaneous kW load (Site #2 Baseline, Pool Pump)

- Instantaneous kW load (Site #2 Baseline, Spa Pump)
- Instantaneous kW load (Site #2 Post-Retrofit, Pool Pump)
- Instantaneous kW load (Site #2 Post-Retrofit, Spa Pump)
- kWh consumed in each 5 minute interval (Site #1 Baseline, Pump A)
- kWh consumed in each 5 minute interval (Site #1 Baseline, Pump B)
- kWh consumed in each 5 minute interval (Site #1 Post-Retrofit, both pumps combined)
- kWh consumed in each 5 minute interval (Site #2 Baseline, Pool Pump)
- kWh consumed in each 5 minute interval (Site #2 Baseline, Spa Pump)
- kWh consumed in each 5 minute interval (Site #2 Post-Retrofit, Pool Pump)
- kWh consumed in each 5 minute interval (Site #2 Post-Retrofit, Spa Pump)

In addition, the following parameters will be determined one time each:

- *baseline GPM: pool #1*
- *post retrofit GPM: pool #1*
- *baseline GPM: pool #2*
- *post retrofit GPM: pool #2*
- *baseline GPM: spa*
- *post retrofit GPM: spa*

EXPECTED ACCURACY

The M&V plan for this study allows for a high level of confidence in the calculation of savings, while limiting the length of time involved and the costs of verification. The stated accuracy of the CCS WattNode kWh meters used is 0.5% of the reading. All equipment will be new and factory calibrated.

The Blue-White F-1000 flow meter used in the direct flow measurement tests has a manufacturer’s stated accuracy of +/- 2% of the full scale flow rate range. The range of the meter used was 0.4 to 300 GPM, making the accuracy of the measurements +/- 6.0 GPM.

APPENDIX C: SAVINGS CALCULATION DETAILS

All data collection was performed at 5-minute intervals using two (2) C.C.S. WMB-3D-240-P pulse input kWh meters, one for each pump, which logged power readings into a single HOBO UX-120 data logger. Please see Figure 31 and Figure 32 below for views of the kWh meter and data logger. The current sensing device used with the kWh meter was manufactured by Magnelab (model # SCT-0400-020) for use with the meter.

Figure 31: Continental Control Systems WMB-3D-240-P (kWh Meter)

Figure 32: Onset HOBO UX120-017 (Data Logger)

Using the baseline data collected from the metering equipment and subtracting the readings after retrofit, IES determined the energy savings in terms of reduced power consumption. Please see Equations 1 and 2 below.

Equation 1 $$Annual\ kWh\ Saved = Annual\ kWh_{\ pre} - Annual\ kWh_{post}$$

Equation 2 $$Annual\ kWh = 365 \times Avg\ kW \times run\ hours\ per\ day$$

Equation 3 $$Watts/GPM = \frac{Avg\ kW \times 1000}{GPM}$$

Please note that the "Avg kW" comes from the 5 minute logged data, and is the average of all instantaneous power readings when the pump is energized. "Run hours per day" is the length of time that the pump is enabled each day. All seven days a week are the same in all cases. Annual kWh pre and Annual kWh post are both calculated in the same method shown in Equation 2. GPM is measured using the methods discussed in the Project Results and Discussion section. Watts per GPM is calculated in order to compare the energy intensity results among different pools. Watts per GPM could be converted to kWh per Gallon as needed.

Weather will not affect the runtime of the pool and spa filtration pumps. Load increased slightly as filters become clogged. Cleaning occurs on a regular schedule. In the baseline pump, motor speed is the same for all tasks, i.e. *"constant speed"*. After retrofit, although the new pumps allow the operator to program the exact speed needed for each task, the pumps were programed to a specific speed for a specific 7 day a week schedule. For this study the variable speed capabilities of the post-retrofit pumps were only utilized to reduce the speed from the maximum down to the necessary level to satisfy the health code requirements.

The average cost of electricity is derived from actual historical billing data in the period, ranging from $0.17 to $0.21 per kWh. Please see Appendix D for these rates. The 12 month average blended rate of $0.18/kWh was used in all calculations.

APPENDIX D: UTILITY DATA

TEST SITE #1

Blended utility rates are used in all calculations. At Test Site #1 the pump is scheduled to run 24 hours a day, seven days a week, making a blended rate approach appropriate.

Table 17: Site #1 Electric Utility Summary

Site #1 Utility Data: November 2010-October 2011													
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
kWh	9,605	9,679	8,791	9,646	8,454	9,005	9,365	9,267	11,585	12,074	11,509	9,913	118,893
Cost ($)	$1,619.78	$1,632.09	$1,462.55	$1,592.09	$1,396.69	$1,484.63	$1,817.20	$1,904.26	$2,368.59	$2,478.53	$2,352.27	$1,780.23	$21,888.91
Blended Rate ($/kWh)	$0.17	$0.17	$0.17	$0.17	$0.17	$0.17	$0.19	$0.21	$0.21	$0.21	$0.21	$0.18	$0.18

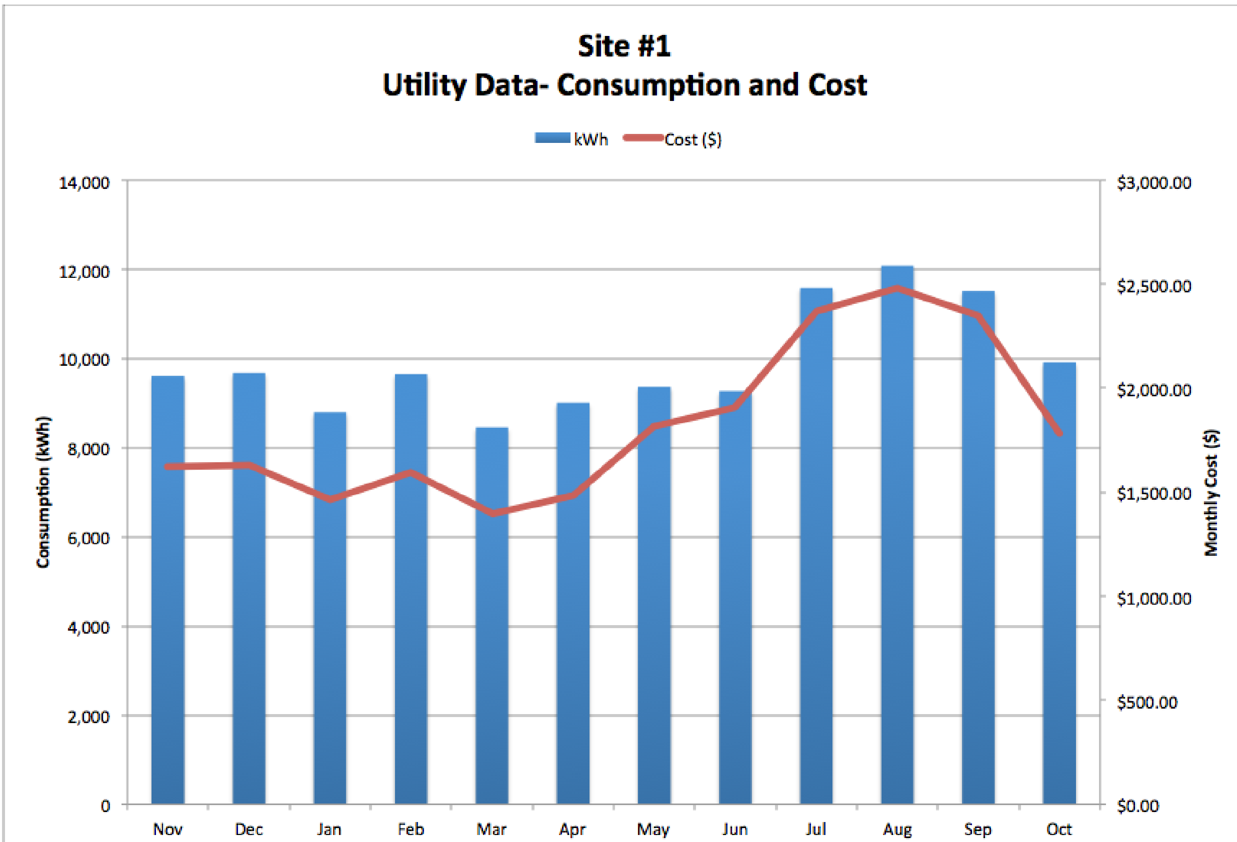


Figure 33: Site #1 Electric Utility Chart

TEST SITE #2

Blended utility rates are used in all calculations. At Test Site #2 the pump is scheduled to run during the day, and was off at night. Therefore no energy savings was obtained at night when rates are lowest, and all savings were obtained during the day. In this case the most conservative way to estimate the electric cost was determined to be the blended electric rate, which will slightly under-estimate the potential for financial savings. This slight under-statement of performance was acceptable since the amounts are small compared to other sources of error such as rounding (results reported to the nearest dollar).

Table 18: Site #2 Electric Utility Summary

Site #2 Utility Data: January- December 2011													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
kWh	5,485	5,207	4,775	5,051	5,609	5,837	5,808	5,410	6,141	5,083	5,489	5,427	65,322
Cost ($)	$922.00	$864.00	$793.00	$837.00	$1,014.00	$1,203.00	$1,197.00	$1,116.00	$1,268.00	$979.00	$930.00	$919.00	$12,042.00
Blended Rate ($/kWh)	$0.17	$0.17	$0.17	$0.17	$0.18	$0.21	$0.21	$0.21	$0.21	$0.19	$0.17	$0.17	$0.18

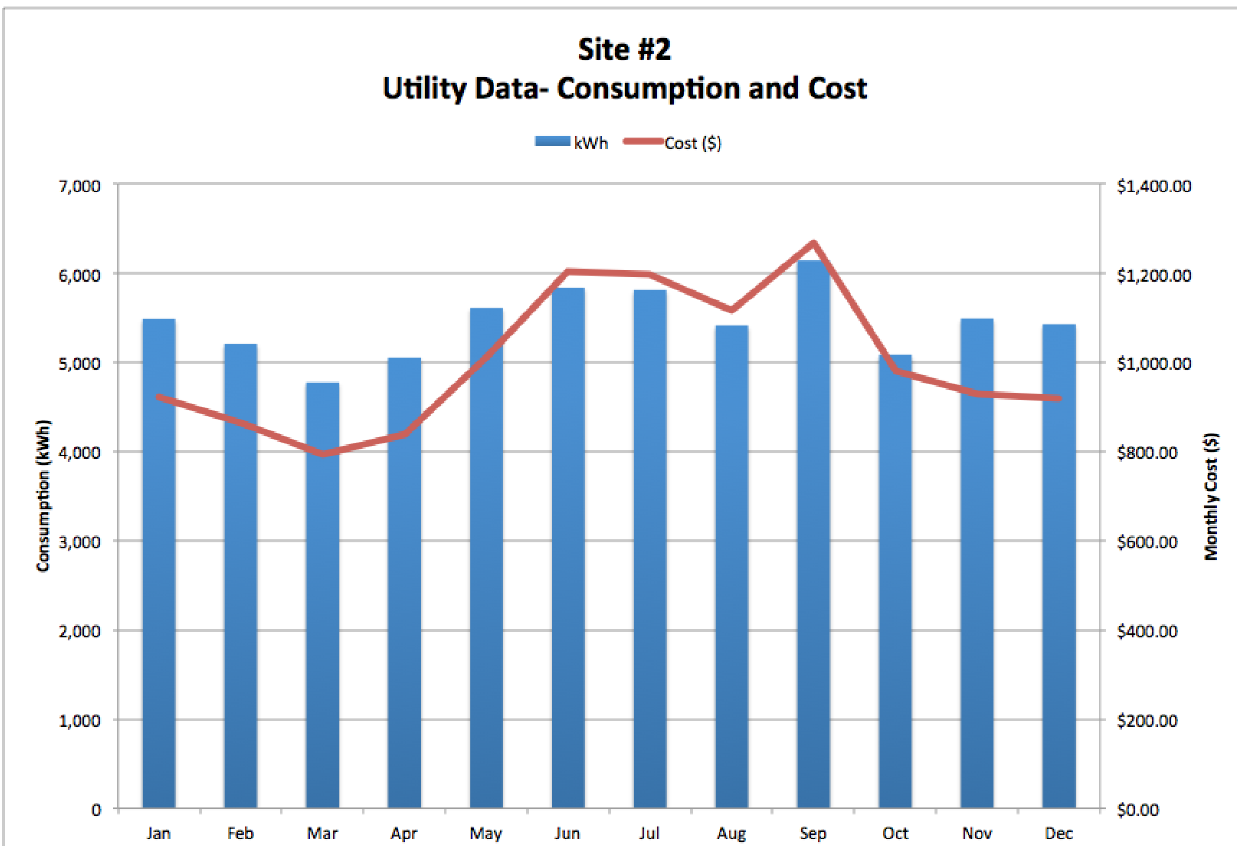


Figure 34: Site #2 Electric Utility Chart

APPENDIX E: PEER REVIEW CERTIFICATE

NegaWatt Consulting, Inc.

www.negawattconsult.com
(619) 309-4191

San Diego, 8/6/2012

This report file, named
"VFD Pump MFR Swim Pool & Spa M&V Report FINAL rev28.pdf",
and titled
"Variable Speed Swimming Pool Pump Retrofit"
has been peer reviewed by us, and our suggestions for improvement have been incorporated. Based on the information available, we believe that the research was conducted in a sound and rigorous manner, and that the results are accurate and complete as presented.

Marc Esser
President of NegaWatt Consulting, Inc.