Swimming Pool Sweep Technical Performance Assessment Offering Major Energy Savings and Program Opportunity

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ABSTRACT

Few residential appliance technologies offer the energy savings of robotic pool cleaners. Despite their high technical potential, these products have seen very low adoption due to a variety of market barriers. Nearly all of the 7.9 million residential pools in the country use automatic pool cleaners, or "sweeps." While not pervasive in all States, swimming pools have significant saturation and energy use in "sunbelt" states, such as California, where they are found in 10% of single family residences. Nationally, swimming pool energy use is estimated to be 10 billion kilowatt hours annually.

Typical robotic cleaners are directly powered by 24 VAC transformers, and draw an average of 180 Watts, while common booster-pump-powered hydraulic cleaners demand over 1 kW.

This paper summarizes an extensive technical performance evaluation of 12 individual booster pump and pool filtration pump powered hydraulic cleaners, and compares their performance to that of 6 robotic cleaners. Major cost-effective energy savings are identified and program opportunities are presented by replacing hydraulic cleaners with robotic cleaners.

Introduction

This paper, based on a study conducted by PG&E in 2010, addresses the significant energy savings that can be realized by choosing the most efficient pool cleaner operating in conjuction with either a two-speed or variable speed pump used for filtration pumping . Pools using this recommended equipment and operation are estimated to consume 1,478 to 2,792 kWh per year less than pools operating with hydraulic cleaners and single speed standard efficiency pumps.

According to EPA there are an estimated 7.9 million US households with pools[i]. These are largely located in the Northeast, Southeast, Southwest and Pacific States. Nearly all of these pools have automatic pool cleaners or sweeps of some kind to pick up debris that collects in the bottom of the pool.

Two-speed and variable speed filtration pumping technologies are becoming increasingly popular around the country. California, Florida, Arizona, Texas, Connecticut, and Washington have passed regulations requiring two-speed filtration pumping for residential new construction and retrofit applications of one total pump horsepower or more. Additionally many utilities offer incentives for pool filtration pumps which exceed state efficiency regulations. Energy Star is developing a program for pool filtration pumps, as is the Consortium for Energy Efficiency. While these pump incentives and regulations yield energy savings, significantly greater energy savings can be achieved by these programs if the hydraulic cleaner is replaced with a robotic cleaner.

Hydraulic cleaners are powered by moving water under pressure. This hydraulic power is provided by swimming pool filtration pumps or by additional booster pumps dedicated to serving the cleaners. While these cleaners do not use electricity directly, they affect the power demand and energy use of the filtration and/or booster pumps that power them. In particular, they limit the extent to which filtration pumping can be accomplished at lower flow rates over a longer period of time, using two-speed or variable speed pumps.

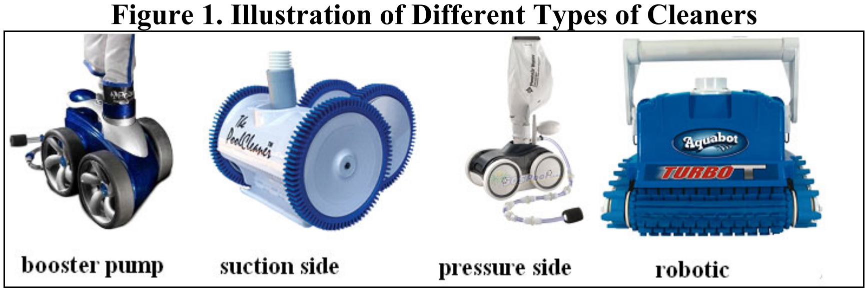
A relatively new type of cleaner, the "robotic cleaner", operates directly from an independent low-voltage power source, which eliminates the need to increase pump speed during cleaning cycles. This allows pool filtration pumping to be accomplished at the lowest flow for the longest time to achieve maximum energy savings.

Executive Summary

The pool cleaner study was developed to determine the difference in the demand and energy requirements of different types of pool cleaners. The project team expected there would be a range in energy efficiency within each type of cleaner as well as between types of cleaners. To conduct the evaluation, a test method was developed. The measured power demand and energy use was converted into common units, as hydraulic cleaners are water powered and robotic cleaners are powered directly by electricity.

Pool cleaners are made in four different designs: 1-Powered by dedicated booster pumps (booster pump cleaners), 2-Powered by pool filtration pump suction (suction side cleaners), 3- Powered by filtration pump discharge (pressure side cleaners), and 4- Powered independently of the filtration pump with low-voltage electricity (robotic cleaners). While the design and operation of each cleaner type is different, they often look similar (except for robotic cleaners, which are powered through a low voltage cord serving an integral pump and motor).

Figure 1. Illustration of Different Types of Cleaners

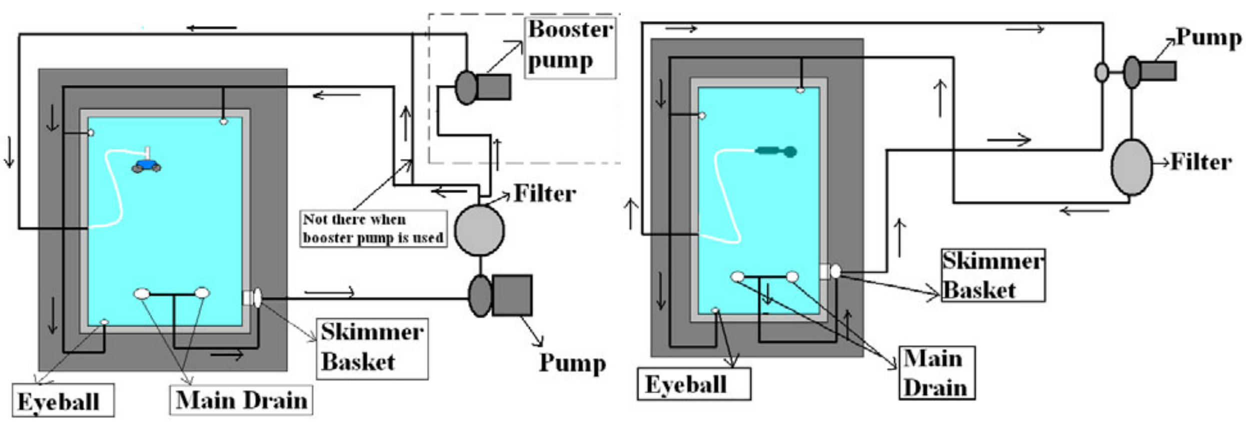


While there were differences in performance among various cleaner models of the same type, as well as differences among the three types of hydraulic cleaners, significantly greater savings may be achieved by replacing hydraulic cleaners with robotic cleaners. This is because hydraulic cleaner operation requires greater flow than filtration alone, adding to the minimum total flow rate and pump speed that could otherwise be utilized. For example, filtration, skimming, and directional inlet might be accomplished at 25 GPM of flow, while simultaneously serving cleaning might double the flow requirement to 50 GPM. This increase in flow is more significant than it seems, as pump power increases proportionally to the cube of the flow. Adding the hydraulic cleaner to the filtration often requires double the flow, which results in 8 times the power requirement for the duration of the cleaning cycle. Conversely, replacing the hydraulic cleaner with a robotic one allows the filtration pump power to be reduced dramatically during the time the cleaner is operating. The savings opportunity is even more significant for cases where the robotic cleaner replaces a hydraulic cleaner powered by a booster pump. In this case, the energy use of the booster pump can be entirely eliminated.

The different types of hydraulic pool cleaners and their plumbing are illustrated in Figure-2. The pressure side cleaners are either connected directly on the discharge side of the filtration pump (at the filter outlet) or are supplied through an additional dedicated booster pump, which is similarly connected. The suction side cleaners are connected to the suction side of the filtration pump. In all of these cases some of the water flowing into or out of the filtration pump is shared between the cleaner and other pool features such as directional inlets, skimmers, and main drains. This causes cleaner flow to be additive to the main drain and skimmer flow, or directional inlet flow unless adjustments are made to reduce other uses while cleaning is being performed. At a minimum, if the hydraulic cleaner is not replaced, adjustments should be made to direct most of the flow through the existing cleaner.

Figure 2. Illustration of Hydraulic Pool Cleaner's Plumbing

Figure 2A. Pressure-Side Cleaner Plumbing **Figure 1B. Suction-Side Cleaner Plumbing**



The findings of the test performed are shown below. In this report cleaners were assumed to operate 3 hours per day to be consistent with typical robotic cleaner operation. This allowed for a better comparison between robotic and hydraulic cleaners. The 2009 PG&E KEMA study shows a typical cleaner operation of 2.55 hours per day[ii].

Table 1. Comparative Cleaner Power Demand and Energy Use

Cleaner Type	Cleaner Hydraulic Input Power (HP)	Cleaner Hydraulic Input Power (kW)	Motor Mechanical Rated Power* (HP) / (THP)	Incremental Motor Electrical Input Power* (kW)	Hours of Cleaner Operation	Daily Energy Use (kWh)	Annual Energy Use** (kWh)
Robotic	N/A	N/A	N/A	0.180	3	0.54	197
Filtration Pump (Suction)	0.02	0.015	2.0 / 2.6	1.53	3	4.59	1675
Filtration Pump (Discharge)	0.09	0.067	2.0 / 2.6	1.53	3	4.59	1675
Booster Pump Required	0.07	0.052	0.75 / 1.125	1.53(filtration)*** + 1.2 (booster)	3	8.19	2989

* Assumes cleaner power is incremental and represents marginal values using CEC Appliance Database pump (sta-Rite-P6RA6YG-207L)
** Assumes cleaner runs 365 day per year
*** Filtration pump runs on high speed when booster pump is running

Test Objectives

The objective of the pool cleaner study was to determine the power demand and energy usage of the different types of pool cleaners; i.e. robotic self-powered, hydraulic booster pump powered, and hydraulic pressure or suction side filtration pump powered. The project specifically intended to:

- Consider eligible product categories for the development of a new rebate program
- Identify the most efficient pool cleaner types
- Determine potential energy savings of more efficient pool cleaners relative to a base case
- Discover and evaluate other related factors, such as the effect that pool cleaners have on the overall pool operation and energy use

Methodology

Testing Standards

There were no existing test procedures for determining swimming pool cleaner energy efficiency performance. Therefore, the project team needed to develop a test procedure.

Assessing cleaners on the basis of energy efficiency alone, in the absence of any measure of cleaning effectiveness, did not seem like a rational performance measure, so a test procedure was developed that attempted to measure energy use as a function of pool floor area covered. The term "energy factor" was adopted and defined as Watt-hours of energy consumed per square foot of pool floor area cleaned. The test protocol was intended to determine this figure of merit for each category of cleaner tested.

For the robotic cleaners, the electrical power and energy were measured directly. For the hydraulic cleaners, flow and pressure were measured, the water power was calculated, this value was then converted to pump brake HP and electrical power using assumed efficiencies of 0.60 for the pump head and 0.75 for the motor. This conversion was not direct, but was incremental or marginal with respect to pump motor power and energy. Since cleaner flow and power is additive to other pool needs, such as skimmer, main drain, or direct return flows, it is similarly additive to pump power. The pump affinity law finds pump power directly proportional to the cube of the flow. Where the time is the same, the energy is also proportional to the cube of the flow, so the marginal effects of adding the cleaner are not linear with respect to increased energy use.

Test Apparatus

With the performance measurement objective selected a test apparatus needed to be assembled that allowed the linear distance traveled as well as power demanded to be measured. The energy consumed over the test period could then be calculated.

A test stand was built which allowed the measurement and calculation of pool floor area covered by the cleaner per unit of time. The test table was constructed with a rotating drum protruding through the top, such that cleaners could be situated on top of the table while the cleaner wheels rotated the drum. A revolution counter was attached to the drum, such that revolutions could be measured and linear distance and area covered could be calculated. The whole apparatus, cleaner, drum, and table were submerged in a 300 gallon tank for the measurement. (See Figure-3)

This apparatus worked well for robotic cleaners with powered wheels that could turn the drum. A different approach was needed for robotic cleaners without mechanically driven wheels and for non-wheel-driven hydraulic cleaners. For these cleaners, a test set-up was constructed using a Pentair IntelliFlo VS pump equipped with suction, discharge, cleaner inlet pressure, and system flow meters. From these measurements, water power was calculated, then pump brake HP and electrical HP were calculated using assumed pump head efficiencies of 0.6 and motor efficiencies of 0.75. Calculated values were then adjusted to reflect the incremental increase in pumping power and energy. (See Figure-4)

Figure 3. Pool Trailer Test Setup

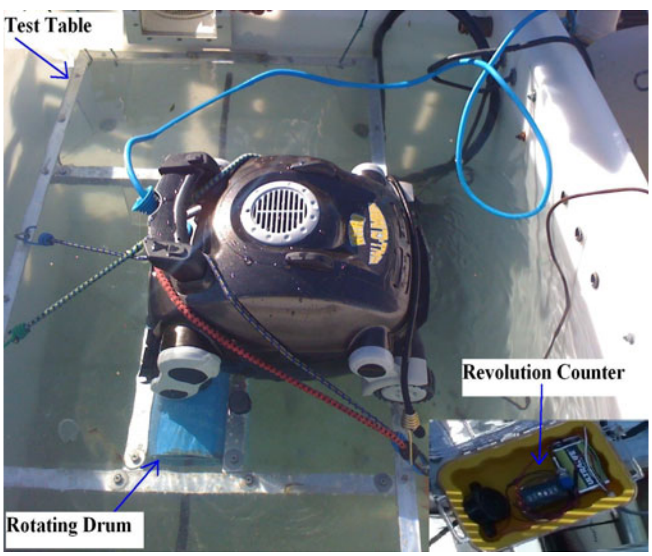
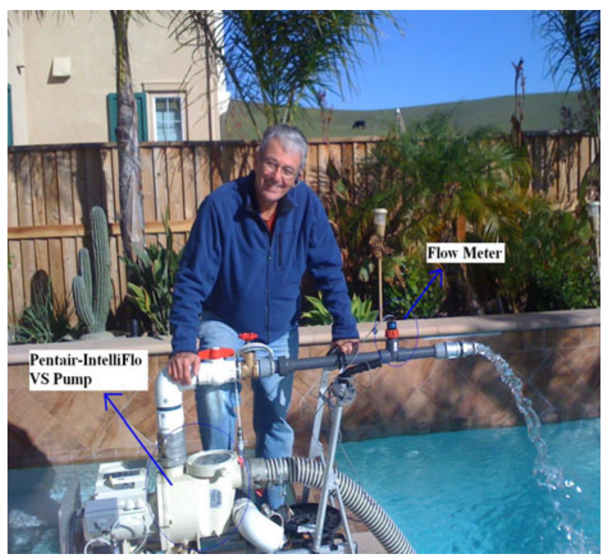


Figure 4. Hydraulic Cleaner Test Setup



As testing proceeded, it became apparent that developing an energy factor for each cleaner would be difficult, as some cleaners had unpowered wheels, making it impossible for them to turn the drum, and many cleaners had no wheels at all. Further, the cleaning performance of various cleaners in a typical pool was dependent on factors other than the pool floor area covered, such as ease of set-up for optimum performance, cleaning effectiveness, ability to deal with different sizes of debris, and propensity to get stuck in a particular place due to pool geometry or plumbing fixtures, such as drain covers and steps. While floor area covered and energy factor were determined for robotic cleaners where feasible, this approach was abandoned later as an overly simplistic measure of cleaning performance. Wide variations in cleaning performance were observed. These were highly dependent on pool pluming, geometry and debris load. In the end, the project team decided to leave performance to professional judgment and evaluate only the energy use.

Power, Measurements, and Instrumentation

System Power

Electrical power was provided by a GFCI protected Honda 4.5 kW generator, while power for the Pentair IntelliFlo VS pump was provided from the grid through a GFCI protected 120/240 VAC, 4 wire, 20 Amp outlet. (See Figure-5).

Figure 5. Generator & Robotic Test Measuring Instruments

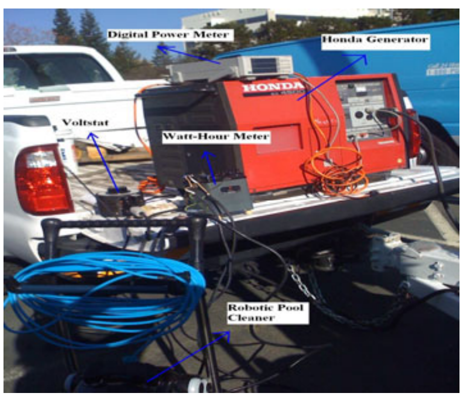
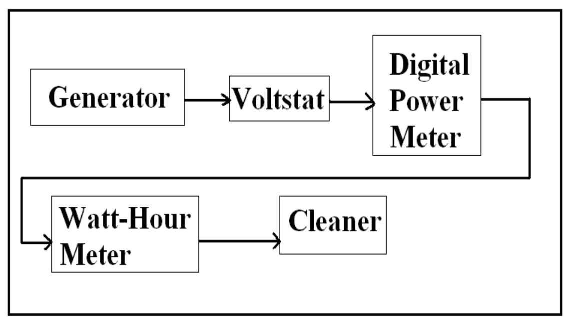


Figure 6. Block Diagram of Test Setup Connections



Electrical Measuring Instrumentation

Electrical power was supplied through a Matsushita Communications Industrial "Voltstat", Model VQ 17510 variable voltage transformer, to assure measurement at 120 VAC, ± 0.5 Volts. Voltage and power readings were taken with a Yokagawa WT-110 True RMS Digital Power Meter. Energy measurements were taken in 10 minute intervals with a General Electric Type IB-10 Portable Watt-Hour Meter Standard set to the 120 Volt, 5 Amp range. (See Figure 5) This equipment was connected in the order shown above. (See Figure 6)

Hydraulic Measuring Instrumentation

Water flow was provided by a Pentair Intelliflo VS, variable speed pump. Flow was measured by a GF Signet 51530-P0 paddlewheel flow sensor in a 1-1/4 inch Signet F08T012F measurement pipe section and displayed by a Red Lion Controls Model APLR digital rate display. Pressures were measured with Wika Instruments Model N-10, -30 In Hg to +30 psi pressure transmitters, and displayed by Wika tronic, Model 907.50.910 programmable meters, manufactured by Red Lion Controls. (See Figure 7 & 8) Back up measurements were made with Wika liquid filled pressure gauges plumbed in parallel with the electronic pressure transducers.

Figure 2. Hydraulic Measuring Instruments

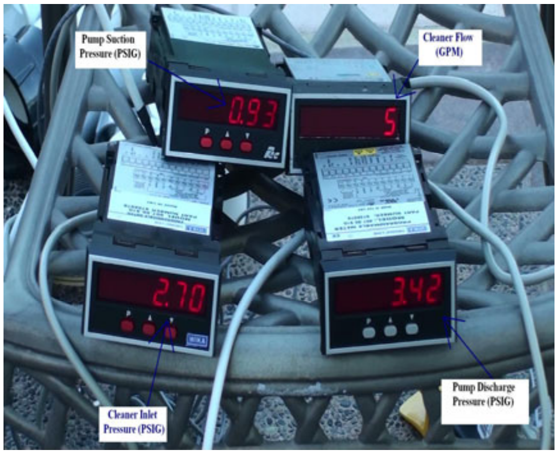
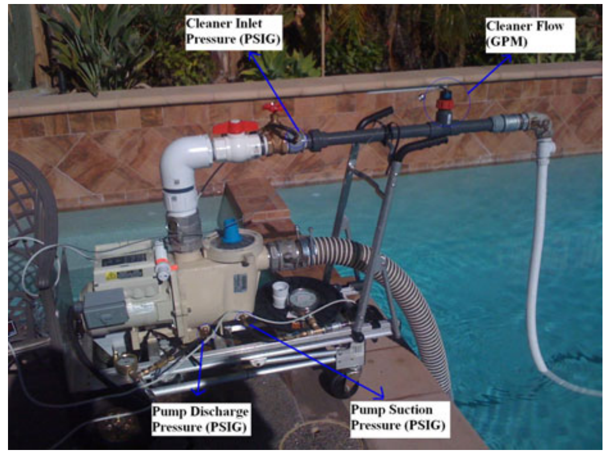


Figure 8. Illustration of Hydraulic Sensors



Test Conditions

During robotic cleaner testing, voltage was adjusted and maintained at 120 VAC, ± 0.5 VAC, while voltage, power, and energy use were measured. During hydraulic cleaner testing, flows were set and maintained at values appropriate for minimum, typical, and maximum cleaner operation, while pressures were measured.

Test Procedure

Robotic cleaners were located on the test stand such that the wheels rotated the drum, but cleared the stationary portion of the table. The test stand and cleaner were then submerged in the 300 gallon tank. Electrical voltage, power, and energy measurements were taken over a 10 minute interval, along with cleaner suction port width and a count of drum rotations.

Hydraulic cleaners were connected to the Pentair IntelliFlo VS pump with approximately 25 feet of hose and were submerged in a 14,000 gallon swimming pool. Pump speed was adjusted while flow and pressure measurements were taken and cleaner operation was observed.

Results

Discussion

As expected, robotic cleaners as a class were found to demand the least electrical power and use the least energy of any of the products tested, as well as provide excellent cleaning performance. Average power demand for the class tested was 0.18 kW. Daily operating hours were assumed to be 3, for an average daily energy use of 0.54 kWh.

Filtration pump powered hydraulic cleaners worked at a lower flow and demanded less hydraulic power and energy than expected. Their direct hydraulic efficiency performance was similar to the robotic cleaner's direct electrical energy efficiency performance. The large energy savings opportunity stems from the fact that hydraulic cleaners need to be powered by a pump, which is pretty inefficient, particularly when the additional flow to power the cleaner is added incrementally to the minimum filtration flow. When these cleaners are compared in terms of their electric energy requirements, robotic cleaners can be an order of magnitude more efficient.

Since water flow through the cleaner is shared in these systems with skimmers and main drains in the case of filtration pump powered suction cleaners, or with pool returns and other features (such as: laminars, etc.) in filtration pump powered pressure cleaners, actual pump flow, power, and energy use is incrementally additive to the minimum filtration flow needs.

The booster pump required cleaners similarly demanded less hydraulic power and energy than expected. Their hydraulic performance was similar to the other classes of cleaners. This was not expected, as these cleaners are typically powered by a separate ¾ HP - nameplate, 1.5 - Service Factor, 1.125 - Total Horse Power, standard efficiency booster pumps, demanding 1.2 kW. The implication is that these cleaners could be designed and operated with much smaller booster pumps than are normally used. Further, these cleaners typically operate at 4 to 8 GPM of flow, suggesting that filtration pumps serving these booster pumps do not need to operate a full speed and flow to prevent booster pumps from being "starved" for water.

The testing and determination of pool cleaner hydraulic power and energy requirements indicates that there is not a significant difference in the energy efficiency performance of the different classes of cleaners; however, in practice and due to the application, there are very significant differences in the pool cleaner system power and energy use requirements. Simply stated:

- Filtration pump powered and booster pump powered hydraulic cleaners, as well as robotic cleaners, have wide variations in cleaning performance depending on their ability to deal with pool pluming, geometry, in-pool plumbing fixtures, sizes and types of debris.
- All cleaner categories tested in this project have similar direct power requirements, where the power comparison is made between robotic cleaners' electrical input power and hydraulic cleaners' hydraulic input power. Differences in power demand, and savings, result indirectly from the hydraulic system effect, where two speed filtration pump motor power increases exponentially when operating at high speed to power the added load of a hydraulic cleaner.
- Filtration pump powered hydraulic cleaners have lower system energy efficiency because they are powered by pool pumps where their water supply is shared with other pool functions, making it more challenging to optimize filtration pumping speed and flow for maximum efficiency, and requiring that cleaner flow be supplied incrementally at exponential cost in power and energy.
- Booster pump powered cleaners are generally utilized with massively oversized, ¾ HP nameplate, 1.5 Service Factor standard efficiency pumps. Since booster pumps are typically connected to filtration pump's discharge, filtration pumps operate at full speed whenever booster pumps are running, reducing the likelihood that filtration pumps will run a larger percentage of the time on low speed.

In conclusion, the test result show that pool cleaner power demand and energy use can be reduced using a robotic cleaner while operating the pool pump at low flow and speed, for optimum filtration efficiency. Alternatively, improvements for hydraulic cleaners can be made by installing motor operated valves to separate the cleaning function from the pool filtration function, allowing each to be operated sequentially by variable speed pumps for optimum efficiency. Where it is impractical to add automated valves, manual valves can be adjusted such that most of the flow is diverted to the cleaner to achieve the best system efficiency. Lastly, booster pump cleaner performance can be improved by better sizing of the pump relative to the cleaner hydraulic power demand and by utilizing high efficiency booster pump motors.

Given the complexity and cost of setting up hydraulic cleaners to operate at maximum efficiency, and the relative simplicity of adding a robotic cleaner while operating the pool pump for maximum filtration efficiency, robotic cleaners are recommended, with selection for maximum cleaning performance in individual pools left to pool professionals.

Table 2, shows the following data for booster pump required cleaners: Typical flows, inlet pressures, hydraulic horse power, pump brake horse power, and required motor electrical power and energy. Pressure requirements are higher than those normally produced by pool filtration pumps, indicating the need for dedicated booster pumps. Required flows however, are low, indicating that it may not be necessary to follow the common practice of running filtration pumps at full speed to supply booster pumps. Also, the actual booster pump power requirement is much smaller than the ¾ HP, 1.5 SF pump normally used.

Table 2. Summary of Test Units- Booster pump Required Hydraulic Cleaner-Typical Operation

Cleaner Model	Flow (GPM)	Cleaner Inlet Pressure (PSIG)	Hydraulic Horse Power (HP)	Pump Brake Horse Power (HP)	Required Motor Electrical Power (kW)	Required Motor Electrical Energy (kWh/Day)
A	**7.33**	**22.15**	**0.11**	**0.18**	**0.18**	**0.41**
B	**7.75**	**13.92**	**0.07**	**0.12**	**0.12**	**0.35**
C	**4.00**	**16.51**	**0.04**	**0.07**	**0.07**	**0.21**

Table 3, shows the following data for filtration pump powered pressure side cleaners: Typical flows, inlet pressures, hydraulic horse power, pump brake horse power, and required motor electrical power and energy. While the flows and pressures vary for the different cleaners in this class the hydraulic horse power required by these cleaners is similar. If operated independently, the pump motor power requirement would be low, but these cleaners are normally operated in parallel with pool returns, such as directional "eyeballs", laminars, and other water features. Adding the cleaner and other features to minimum filtration flows moves the operating point of the pump up the pool hydraulic system curve. This typically requires full speed, in lieu of low-speed, operation in two-speed filtration pumping systems. Pump affinity laws show that doubling the flow and speed of the filtration pump to serve cleaners, requires 8 times the filtration flow power for the 3 hour typical cleaner operating time.

Table 3. Summary of Test Units- Filtration pump required-Pressure Side Cleaners-Typical Operation

Cleaner Model	Flow (GPM)	Cleaner Inlet Pressure (PSIG)	Hydraulic Horse Power (HP)	Pump Brake Horse Power (HP)	Required Motor Electrical Power (kW)	Required Motor Electrical Energy (kWh/Day)
D	15.00	8.00	0.08	0.13	0.13	0.40
E	27.50	4.88	0.10	0.16	0.16	0.48
F	12.50	9.72	0.09	0.15	0.15	0.45

Table 4, shows the following data for typical filtration pump powered suction side cleaners: Typical flows, inlet pressures, hydraulic horse power, pump brake horse power, and required motor electrical power and energy. As in the case of filtration pump powered pressure side cleaners, the cleaner hydraulic and motor power requirements are small. However when added incrementally to main drain, and skimmer flow requirements, two-speed filtration pumps are forced to high speed operation, doubling the flow and speed of the filtration pump, requiring 8 times the filtration flow power and 4 times the energy for the 3 hour typical cleaner operating time.

Table 4. Summary of Test Units- Filtration pump required-Suction Side Cleaners-Typical Operation

Cleaner Model	Flow (GPM)	Pump Suction Pressure (PSIG)	Hydraulic Horse Power (HP)	Pump Brake Horse Power (HP)	Required Motor Electrical Power (kW)	Required Motor Electrical Energy (kWh/Day)
G	22.50	1.46	0.02	0.03	0.03	0.10
H	20.00	1.87	0.02	0.04	0.04	0.12
I	17.50	0.77	0.01	0.02	0.02	0.05
J	18.29	1.59	0.02	0.03	0.03	0.10
K	22.50	0.90	0.01	0.02	0.02	0.06
L	32.50	1.84	0.04	0.06	0.06	0.19

Table 5, shows the following data for typical robotic cleaners: Cleaner suction width, number of revolutions of the test table drum per 10 minutes, linear distance traveled, average power demand, linear velocity, and the energy factor. Among these cleaners, the energy factor varies by a ratio of more than 3 to 1, indicating that some robotic cleaners cover significantly more pool bottom surface area per unit of energy consumed than others, but as noted elsewhere in this report, energy factor was not considered an adequate measure of overall cleaning performance.

Robotic cleaners are the most energy efficient automatic cleaning option, as they draw an average of 0.180 kW, do not require a separate booster pump drawing 1.2 kW, and do not add incrementally to filtration pump power demand and energy use in any non-linear, exponential way.

Table 5. Summary of Test Units- Robotic Cleaners-Test Duration 10min

Cleaner Model	Cleaner Suction Width (in)	Number of Revolutions per 10 Minutes	Linear Distance Traveled (feet)	Average Power Demand (kW)	Required Motor Electrical Energy (kWh/Day)	Linear Velocity (ft/min)	Energy Factor (sf/watt-hr)
M	12.75	305	479	0.19	0.57	47.91	15.96
N	12.50	253	397	0.20	0.60	39.74	12.67
O	12	170	267	0.18	0.54	26.70	8.96
P	12.75	544	855	0.15	0.45	85.45	35.79
Q	12	278	437	0.06	0.18	43.67	41.51
R	NA	0	0	0.30	0.90	0.00	0.00

Energy Factor

While a good concept, energy factor was eventually abandoned due to difficulty in fairly characterizing pool cleaner cleaning performance, and normalizing the results for this performance. Cleaning performance is pool specific and best left to the judgment of pool professionals.

Energy Savings

Energy savings and demand reduction calculations are based on the field observation that for the 3 hours of typical operation, hydraulic cleaners add to the filtration system flow requirements. While filtration could proceed at 30 GPM, satisfactory cleaner operation necessitates that this flow be increased by an additional 30 GPM for the duration of cleaning.

In the case of filtration pump powered hydraulic suction and discharge side cleaners; the pump affinity law defines the additional, incremental power needed to supply this additional cleaner flow. As the flow doubles to accommodate the cleaner needs, the power demand increases by a factor of 8.

This additional use minus the energy use of the robotic cleaner represents the savings that could be realized if filtration pumps are run at optimal speeds for filtration, and robotic cleaners are used to accommodate pool cleaning needs.

For booster pump powered cleaners, the additional energy use is calculated by multiplying the power demanded by the booster pump by the amount of time it operates. The energy savings that could be realized is this value minus the energy use of the robotic cleaner. It is common practice to run the filtration pump at full speed while the booster pump is operating, compounding the savings opportunity. The increased power needed to run the filtration pump at full speed was 1.53kW. (See Table 6)

Table 6. Demand and Energy Savings

Cleaner Type	Base Case Demand (kW)	Measure Case Demand (kW)	Net Demand Savings (kW)	Typical Hrs of Operation	Annual Energy Savings (kWh)
Robotic	N/A	0.18	0	3	Base Case – N/A
Filtration Pump Suction	1.53	0.18	1.35	3	1478
Filtration Pump Pressure	1.53	0.18	1.35	3	1478
Booster Pump	1.2 (booster) +1.53 (filtration)	0.18	2.55	3	2792

Demand reduction and energy savings calculations are done using data reported by manufacturers to the California Energy Commission's Appliance Database. These calculations are made with a Sta-Rite 2-speed pump with a motor nameplate of 2HP. Also, the data is shown for a more typical Pentair 2-speed pump using a permanent split capacitor motor. Its motor nameplate horsepower is 2, with a Service Factor of 1.3, for a Total motor Horsepower of 2.6. Please note that the power draw is higher especially at the high speed. (See Table 7)

Table 7. Example of CEC Appliance Database Report of Pump Performance

Brand Name	Motor Efficiency %	Nameplate HP	Curve-A gpm Flow	Curve-A Power Watts	Curve-A Energy Factor
Sta-Rite	76	2	63	1941	1.95
Sta-Rite	48	2	35	415	5.06
Pentair	78.6	2	68	2160	1.89
Pentair	54	2	36	449	4.81

Annual Cost of Operation

The annual cost of operation is shown in Table 8 below. The assumptions are listed below the table. This report assumes that filtration is done on the low speed of a Title 20 compliant 2-speed pump, but adding the additional flow needs of the cleaner requires that the pump operate on high speed.

Table 8. Annual Cost of Operation of Cleaning and Filtration with Different Cleaner Options

	Cleaning Energy/year	Cleaning Cost/year	Filtering/skimming energy/year	Filtering/skimming Cost/year
Robotic with filtration and skimmer	0.18kW*3hrs*365= 197 kWh/yr	197kWh*$0.30/kWh = $59/yr	0.415kW*6hrs*365= 909 kWh/yr	909kWh*$0.30/kWh = 273$/yr
Hydraulic with filtration and skimmer	(1.94-0.415=1.53kW) *3hrs*365= 1670 kWh/yr	1675kWh*$0.30/kWh= $501/yr	0.415kW*3hrs*365= 454 kWh/yr	454kWh*$0.30/kWh =136$/yr
Hydraulic with booster pump with filtration and skimmer	(1.2+1.53)kW*3hrs*365 = 2989 kWh/yr	2989kWh*$0.30/kWh= $897/yr	0.415kW*3hrs*365= 454 kWh/yr	454kWh*$0.30/kWh =136$/yr

1 Assumes cleaner power is incremental and represents marginal values using CEC Appliance Database pump (sta-Rite-P6RA6YG-207L)
2 Assumes cleaner runs for 3hrs and filtration/skimming takes another 3hrs and both run 365 day per year
3 Filtration pump runs on high speed when booster pump is running
4 Assumes a rate of $ 0.30/kWh, since this is typical for residential pool owners

Conclusion

Robotic cleaners should be encouraged, as they demand less power and use less energy than the pumps and motors that supply hydraulic cleaner needs in addition to basic filtration needs.

As shown in Table 6, estimated power demand reduction and annual energy savings by replacing the following cleaners with a robotic cleaner are:

- 1.35 kW and 1,478 kWh for filtration pump powered discharge (pressure) side and suction side cleaners as a baseline
- 2.55 kW and 2,792 kWh for booster pump powered cleaners as a baseline

References

[i] US EPA, Office of air and radiation letter, Nov 29 2011 to Residential pool pump manufacturers or other interested parties, announcing launch of a process to develop an Energy Star specification for residential pool pumps

http://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/res_pool_pumps/Pool_Pump_Launch_Cover_Memo.pdf

[ii] KEMA-PG&E process and Evaluation of 2006-2008 PG&E Mass Market Portfolio