Final Report:

Experimental Study of Portable Electric Spa Stand-by Power

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Introduction

The purpose of this report is to present the results of power tests of portable electric spas, performed at the National Pool Industry Research Center (NPIRC) at Cal Poly State University. This work was funded by the Association of Pool and Spa Professionals (APSP), and includes power tests of 27 portable residential spas. Test reports for these spas are attached to this report (Appendix A).

Testing was performed using three environmentally-controlled test chambers and instrumentation provided by APSP, and follows a test protocol finalized June 13, 2008 (Appendix B). The test protocol is based on the Codes and Standards Enhancement Initiative (CASE) Report, "Analysis of Standards Options for Portable Electric Spas" (Appendix C).

Scope of Testing

As per the test protocol, testing focused solely on stand-by operation of the spas. The spas were operated at a fixed temperature set point, with a water temperature of 102 °F or above[1], and the ambient (chamber) temperature maintained at or below 60 °F. Power and temperature data were recorded after the spas warmed up, and at least four hours after conditions stabilized. Data collection began at the end of a filter cycle, purge cycle, or heat cycle, and the

[1] Due to uncertainty in temperature measurement (±1°F), a slightly higher temperature was sought so that the water temperature did not drop below 102 °F. A similar approach was taken for the ambient (chamber) temperature.

end of a test record was the end of a corresponding filter cycle, purge cycle, or heat cycle occurring 72 or more hours after the test recording began.

Results

Spa Test Reports for each of the 27 spa models are attached to this report (Appendix A). The make and model of the spas are not included; instead each spa was given a letter designation. The tested spas ranged in volume from 142 to 470 gallons, and the measured stand-by power ranged from 81 to 479 Watts (712 to 4,192 kWh/year).

Figure 1 compares the stand-by power for the spas tested as a function of spa volume. In keeping with the CASE report, the annual stand-by energy use is also presented. The dashed line represents the allowable stand-by power, as recommended in the CASE report:

$$P_{allow} = 5V^{2/3}, \tag{1}$$

where P_{allow} is the allowable stand-by power in Watts, and V is the water volume in gallons. For Figure 1, the water volume at the recommended fill level was used. See Appendix A for the allowable stand-by power calculated at different volumes for each tested spa.

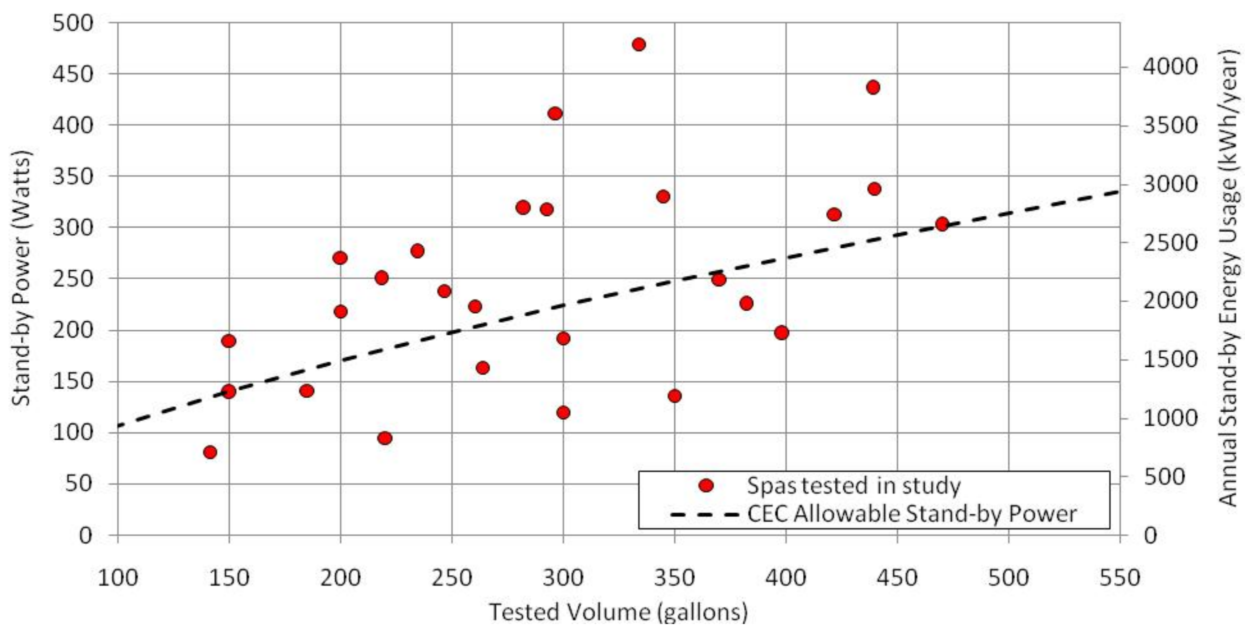

Figure 1: Measured stand-by power compared with CEC allowable stand-by power. The corresponding values of the annual stand-by energy use are also presented.

One concern that has been raised is the fairness of Equation (1), specifically that the equation may disadvantage lower-volume spas. Some energy use is independent of spa volume, meaning that there is some baseline power use required for any spa. It has been suggested that a constant (offset) could be applied to the equation in order to accommodate this baseline power use. However, the application of an offset may neither be prudent nor necessary for several reasons. First, a baseline power value would be difficult to establish. Mathematically, the offset value represents the power use of a spa when its volume is reduced to zero. Theoretically, as the volume is reduced to zero, the heating and pumping requirements are also reduced to zero, making an offset unnecessary. Second, the volumes of the smallest spas are far enough away from the origin in Figure 1 that a constant added to Equation (1) is not required. Finally, examining the test results in Figure 1, the smaller spas tested meet the current power standard at a similar rate to the larger spas.

Table 1 displays a summary of the results for each spa tested. The measured stand-by power was determined by dividing the total energy consumption during the test by the test duration as specified in the test protocol (Appendix B). The right-most column lists the percent difference between the measured and the allowable stand-by power.

Table 1: Summary of (non-temperature-normalized) test results

Spa	Tested Volume (gal)	Stand-by Power (Watts)		% above or below Allowable
		Measured	*Allowable*	
A	185	141	162	-13%
B	264	163	206	-21%
C	398	197	271	-27%
D	282	320	215	49%
E	440	338	289	17%
F	200	218	171	28%
G	300	192	224	-14%
H	150	190	141	34%
I	370	249	258	-3%
J	334	479	241	99%
K	142	81	136	-40%
L	220	95	182	-48%
M	300	119	224	-47%
N	235	277	190	46%
O	345	330	246	34%
P	247	238	197	21%
Q	439	437	289	51%
R	296	411	222	85%
S	293	318	220	44%
T	150	140	141	0%
U	470	304	302	1%
V	350	136	248	-45%
W	382	226	263	-14%
X	422	313	281	11%
Y	200	270	171	58%
Z	260	223	204	9%
AA	219	251	181	38%

A second concern arose due to the consistency of the water and chamber air temperatures from test to test. The average water temperature varied minimally from test to test – about 1 to 2 °F from the target value of 102 °F. However, the average chamber air temperature sometimes fell significantly below the target value of 60°F – as low as 52 °F on average during one test. This behavior was a result of limitations in the climate control equipment used in the chambers, which were commercial window air conditioners that had been modified by APSP. The importance of this issue is that the heat lost from each spa increases as the difference between the water and the chamber temperatures increases. It is therefore crucial that the measured temperature difference be taken into account, so that spas are judged consistently, and that no spa "fails" merely because the temperature difference is different than ideal conditions.

As a result of this concern, APSP and PG&E are discussing the possibility of normalizing the stand-by power using the average temperature difference. This technique is discussed in the CASE report, where some test data were normalized to an average air temperature of 60°F. APSP and PG&E have suggested this method, using the following equation:

$$P_{norm} = P_{meas} \frac{\Delta T_{ideal}}{\Delta T_{meas}} \quad , \qquad (2)$$

where ΔT_{ideal} is some idealized temperature difference between the water and ambient temperatures, ΔT_{meas} is the measured temperature difference, and P_{meas} is the measured stand-by power.

APSP and PG&E are considering 37 °F for the value of ΔT_{ideal}. This value is based on temperature tolerances being proposed for the air and water temperatures. The current test protocol does not specify tolerances on the air and water temperatures – instead, it specifies that the water temperature must be maintained at 102 °F or above, and the air temperature must be maintained at 60 °F or below. APSP and PG&E are considering specifying a tolerance of ±2°F to the water temperature and ±3°F for the air temperature. If these tolerances are adopted in a future revision of the test protocol, the minimum allowable temperature difference would be 37 °F.

This normalization is only an approximation, based on the assumption that the heat loss (and therefore, to a large extent the power demand) is linearly proportional to the temperature difference. Certainly other factors, such as spa insulation/construction and spa geometry will also affect this relationship, although the effects are not known precisely. Regardless, this technique may be useful as a first approximation, and is in fact supported in the CASE report.

Applying a 37 °F normalization to all of the spas gives the following results shown in Figure 2 and Table 2. It is important to note that applying the normalization allowed six of the tested spas (E, H, I, P, X, and Z) that initially did not comply with the CEC allowable power (Eqn. 1) to meet the stand-by power requirement.

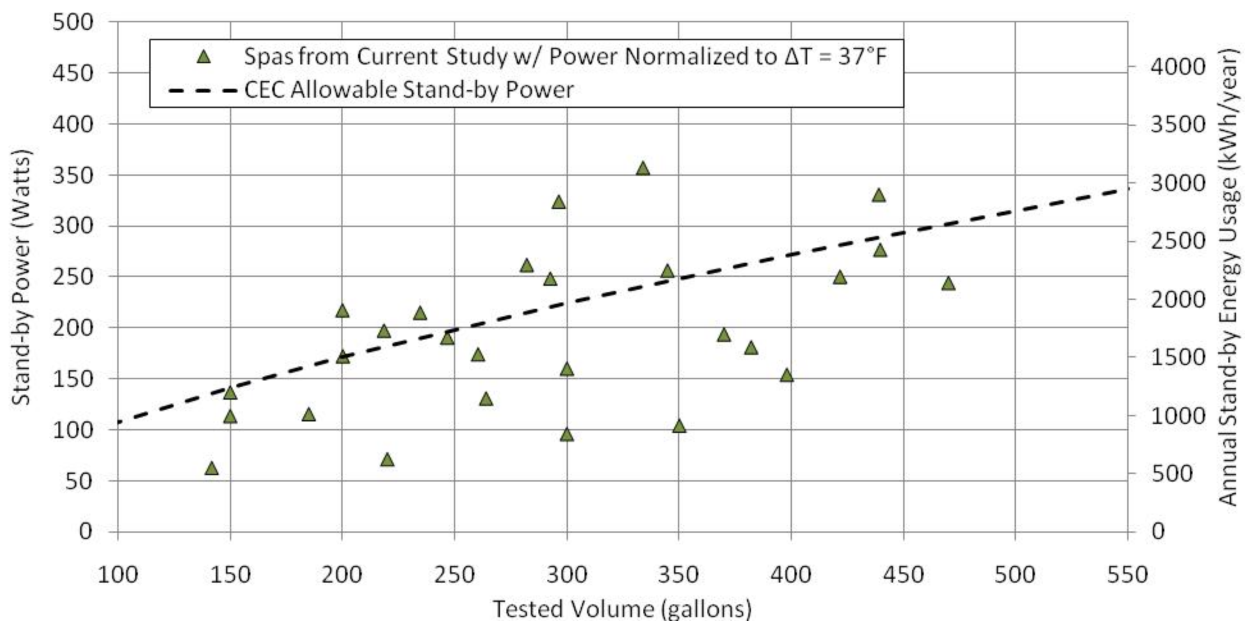

Figure 2: Plot of the stand-by power for the tested spas. The power was normalized using equation (2) with ΔT_{ideal} equal to 37 ºF.

NIST Traceability

As required by the test protocol, the accuracies of the temperature and power measurement equipment were verified against NIST (National Institute of Standards and Technology) certified equipment. We verified the accuracy of the test equipment by comparing temperature, voltage, current, and power factor data with those recorded with the NIST-traceable equipment during the tests of six spas. It should be noted that a verification of accuracy was performed, not a calibration. A calibration would have involved the test equipment and NIST-traceable equipment being compared across the range of the voltage, current, and power factor values. The equipment necessary to vary the load, and particularly the power factor, was not available. Further, the project schedule and the limited time we had the NIST-traceable equipment did not allow a full calibration.

The temperature measurements for all three test chambers were found to fall within ±1 °F of the NIST-traceable measurements. Therefore, no adjustments to the temperature measurements were required.

The instantaneous power for all three test chambers was found to be within ±2% of full-scale when compared with the NIST-traceable equipment (the data acquisition, or DAQ, systems supplied by APSP have a listed accuracy of ± 0.5% of full scale). One issue that arose was that at zero power demand, the DAQ system read a small non-zero reading (approximately 5-10 W), while the NIST-traceable equipment read zero power. In addition, the same non-zero power reading was present even when no spa was electrically connected to the DAQ system. To correct this error, all power readings below 20 W were set to zero for all of the spas in the study.

Table 2: Spa test results with the power normalized using ΔT_{ideal} equal to 37 ºF.

Spa	Stand-by Power (Watts)		Normalized Power (Watts)	% above or below Allowable
	Measured	*Allowable*		
A	141	162	116	-29%
B	163	206	131	-36%
C	197	271	154	-43%
D	320	215	262	22%
E	338	289	277	-4%
F	218	171	173	1%
G	192	224	160	-28%
H	190	141	137	-3%
I	249	258	194	-25%
J	479	241	357	48%
K	81	136	63	-53%
L	95	182	72	-61%
M	119	224	97	-57%
N	277	190	215	13%
O	330	246	256	4%
P	238	197	191	-3%
Q	437	289	330	14%
R	411	222	324	46%
S	318	220	248	13%
T	140	141	114	-19%
U	304	302	244	-19%
V	136	248	105	-58%
W	226	263	181	-31%
X	313	281	250	-11%
Y	270	171	218	27%
Z	223	204	174	-14%
AA	251	181	198	9%

Table 3 compares the energy consumption (kWh) measured by the DAQ system with that recorded by the NIST-traceable equipment. For five of the six spas, the measured energy consumption was within ± 2% of the value measured with NIST-traceable equipment. Notably, for one spa, Spa R, the DAQ system read an energy consumption that was 3.3% higher than the NIST-traceable standard. The larger error can be explained by the fact that the accuracy of the DAQ system is based on the full-scale range of the device. The full-scale power measured by the DAQ system is 12,000 W. Even at the claimed accuracy of ± 0.5% of full scale, the uncertainty in any particular power reading is ±60 W. This uncertainty has a larger relative effect when the measured power is lower. Except for Spa R, all spas listed in Table 3 had a peak power demand between 1,000 and 5,000 W, and also spent a significant amount of time drawing zero power. Spa R, however, operated at two lower-power settings, 900 W and 150 W, and never drew zero power. As a result, the uncertainty as a percentage of reading was higher, and any error accumulates as the energy consumption is added up over time.

This issue raises the importance of the accuracy of the power measurement, and several approaches can be taken to improve the accuracy of power measurements in future testing. One option is to obtain power measurement equipment that is accurate to a percentage of reading, not full-scale. A second option is to use two power meters, with one meter limited to a lower range of power. Finally, a third option is to perform a full-range calibration against high-accuracy NIST-traceable equipment like those used in this study, an approach that would require additional equipment and time.

Table 3. NIST comparison results for energy consumption performed on six spas across the three test chambers.

SPA	*Energy Consumption during test (kWh)*		*% Err*
	NIST	*DAQ*	
B	12.5	12.7	1.6%
C	16.4	16.4	0.3%
M	8.7	8.7	-0.2%
R	31.0	32.0	3.3%
U	22.8	22.8	0.3%
V	10.2	10.1	-1.4%

Recommendations and Conclusions

During the course of this study 27 spas of various sizes were tested. Without applying normalization the measured stand-by power of 11 spas was below the maximum power allowed by the CEC requirement, while the remaining 16 spas used more power than allowed by the requirement. Normalizing the measured power using the average temperature difference and an ideal temperature difference of 37 °F increased the number of spas with stand-by power below the requirement to 17, with the remaining 10 spas still exceeding the requirement. By looking at the plots with and without normalization one can see that there does not seem to be a greater passing rate among either the larger, midsized, or smaller spas. While concerns may still exist that the CEC requirement biases certain spas depending on the size, that bias has not been demonstrated in this study.

Our experience with testing has brought up several issues which should be taken into consideration to improve testing in the future. First, the standard window air conditioners used to control the chamber air temperature are not sufficiently precise to maintain the proposed air temperature tolerance. More precise temperature control equipment can be obtained and would be more suitable than window air conditioners for future tests. Second, a full calibration of the power equipment with NIST-traceable equipment could also be carried out as mentioned above. This will decrease the error on the power measurements and ensure greater certainty in the data, especially at low power levels. Third, the effect of using test durations below 72 hours should be investigated. If the effect of shortening the test duration is negligible to the measured stand-by power values than an argument could be made to decrease the test time allowing for quicker testing of spas.

Several potential topics for future testing have also come up during the study. Investigation into these topics will improve the collective understanding of test performance and spa energy usage. The influence of the cover on overall spa performance is once such topic. Tests could include the addition of foam insulation to the hinge of a cover that does not have any insulation at the hinge. A floating pool cover cut to sit on the surface of the spa water could also be tested to determine its effect. In addition, complete replacement of the cover with a Coverplay cover which does not have a gap in the fill material at the hinge could also be done. Included with these tests could also be a parametric study of the relative effect of changing various other spa parameters (shell insulation, pumps, controls, etc.).

Other testing could be carried out to investigate the effect of the average temperature difference and water level on spa stand-by power. For the temperature test, one spa could be tested at several different air and water set temperatures and the measured stand-by power compared with these differences in temperature. Such tests could help to assess the use of temperature normalization in handling power differences due to differences in the average test temperature. Similarly, a single spa could also be tested at different water levels, keeping the set temperatures the same. This would help to determine the actual relationship between water volume and stand-by power for a particular spa.

A final test to consider would be to test spas outside in real-world conditions. It is important to remember that the test chamber is an idealized situation, and the results of such testing may not accurately reflect performance outdoors. The purpose of this test was to develop a standard, not necessarily to simulate real-world conditions precisely. However, the test data obtained in this study are not a guarantee of performance in the home. Three key differences exist between the current tests and real-world conditions.

1. Heat lost to radiation would be larger outdoors, as the spa will radiate heat to the sky as opposed to the walls of the test chamber, which are maintained at around 60 °F.
2. Forced convection would have a greater effect on spa performance in outdoor conditions due to greater wind speeds.
3. Humidity levels are different between the test chamber and outdoor conditions. How ambient humidity affects spa performance is difficult to predict, but the presence of humidity in the air is likely to affect evaporative heat loss.

Discussions with APSP and PG&E have suggested that outside testing may be of value. In such a test, the energy consumption (kWh) could be tracked alongside local weather conditions such as temperature, relative humidity, and wind speed.

Appendices

A. Spa Test Reports (27)

B. “Portable Electric Spa Stand-by Energy Test Protocol” (Final Revision: June 13, 2008)

C. “Analysis of Standards Options for Portable Electric Spas,” PG&E Report, May 12, 2004.

APPENDIX A

Spa Test Reports

Spa Test Results SPA A

Spa Characteristics

Rating (# of Persons)	2+
Voltage	240 VAC 60 Hz
Spa Volume (published)	185 gallons
Spa Volume (as tested)	185 gallons
Measured Total Spa Capacity	220 gallons

Spa Construction *(Information not provided by manufacturer)*

Spa Construction/Insulation type[2]	
Filtration System[3]	
Cover Characteristics:	
Material composition	
Weight	
Density	
Thickness at center	
Thickness at edge	
R-value	
Hinge width	
Hinge fill material	

Data Analysis

Water Temperature:	
Minimum	102 °F
Maximum	104 °F
Average	103 °F
Air Temperature:	
Minimum	56 °F
Maximum	59 °F
Average	58 °F
Average Temperature Difference	44.9 °F
Duration of Test Record [hh:mm]	74:35
Total energy used during Test Record	10,500 Watt-hours
Measured Stand-by Power in Watts	141 Watts
Normalized Stand-by Power in Watts (using ΔT_{ideal} = 37°F)	116 Watts
CEC Allowable Stand-by Watts	
at Tested Volume	162 Watts
at Published Volume	162 Watts
at Total Spa Capacity	182 Watts

[2] FF = full foam to spa cabinet, PF = partial foam shell and plumbing, SF = foamed shell, ML = insulated cabinet multi-layer, SL = insulated cabinet single layer, NI = no insulation, OT = other (describe)

[3] TSP = two-speed pump, low speed, programmed cycles, CP = circulation pump operating 24/7, CPP = circulation pump programmed cycles, OT = other (describe)

Spa Test Results SPA B

Spa Characteristics

Rating (# of Persons)	6-7
Voltage	240 VAC 60 Hz
Spa Volume (published)	264 gallons
Spa Volume (as tested)	264 gallons
Measured Total Spa Capacity	383 gallons

Spa Construction *(Information not provided by manufacturer)*

Spa Construction/Insulation type[4]	
Filtration System[5]	
Cover Characteristics:	
Material composition	
Weight	
Density	
Thickness at center	
Thickness at edge	
R-value	
Hinge width	
Hinge fill material	

Data Analysis

Water Temperature:	
Minimum	102 °F
Maximum	104 °F
Average	103 °F
Air Temperature:	
Minimum	54 °F
Maximum	59 °F
Average	57 °F
Average Temperature Difference	46.0 °F
Duration of Test Record [hh:mm]	77:59
Total energy used during Test Record	12,717 Watt-hours
Measured Stand-by Power in Watts	163 Watts
Normalized Stand-by Power in Watts (using ΔT_{ideal} = 37°F)	131 Watts
CEC Allowable Stand-by Watts	
at Tested Volume	206 Watts
at Published Volume	206 Watts
at Total Spa Capacity	264 Watts

[4] FF = full foam to spa cabinet, PF = partial foam shell and plumbing, SF = foamed shell, ML = insulated cabinet multi-layer, SL = insulated cabinet single layer, NI = no insulation, OT = other (describe)

[5] TSP = two-speed pump, low speed, programmed cycles, CP = circulation pump operating 24/7, CPP = circulation pump programmed cycles, OT = other (describe)

Spa Test Results SPA C

Spa Characteristics

Rating (# of Persons)	6-8
Voltage	240 VAC 60 Hz
Spa Volume (published)	398 gallons
Spa Volume (as tested)	398 gallons
Measured Total Spa Capacity	554 gallons

Spa Construction *(Information not provided by manufacturer)*

Spa Construction/Insulation type[6]	
Filtration System[7]	
Cover Characteristics:	
Material composition	
Weight	
Density	
Thickness at center	
Thickness at edge	
R-value	
Hinge width	
Hinge fill material	

Data Analysis

Water Temperature:	
Minimum	102 °F
Maximum	104 °F
Average	103 °F
Air Temperature:	
Minimum	52 °F
Maximum	60 °F
Average	56 °F
Average Temperature Difference	47.3 °F
Duration of Test Record [hh:mm]	83:07
Total energy used during Test Record	16,414 Watt-hours
Measured Stand-by Power in Watts	197 Watts
Normalized Stand-by Power in Watts (using ΔT_{ideal} = 37°F)	154 Watts
CEC Allowable Stand-by Watts	
at Tested Volume	271 Watts
at Published Volume	271 Watts
at Total Spa Capacity	337 Watts

[6] FF = full foam to spa cabinet, PF = partial foam shell and plumbing, SF = foamed shell, ML = insulated cabinet multi-layer, SL = insulated cabinet single layer, NI = no insulation, OT = other (describe)

[7] TSP = two-speed pump, low speed, programmed cycles, CP = circulation pump operating 24/7, CPP = circulation pump programmed cycles, OT = other (describe)

Spa Test Results SPA D

Spa Characteristics

Rating (# of Persons)	4
Voltage	240 VAC 60 Hz
Spa Volume (published)	300 gallons
Spa Volume (as tested)	282 gallons (This spa had a full line molded onto the spa. The water was filled to this line as recommended by manufacturer's instructions)
Measured Total Spa Capacity	356 gallons

Spa Construction *(Information not provided by manufacturer)*

Spa Construction/Insulation type[8]	
Filtration System[9]	
Cover Characteristics:	
Material composition	
Weight	
Density	
Thickness at center	
Thickness at edge	
R-value	
Hinge width	
Hinge fill material	

Data Analysis

Water Temperature:	
Minimum	102 °F
Maximum	104 °F
Average	103 °F
Air Temperature:	
Minimum	54 °F
Maximum	60 °F
Average	57 °F
Average Temperature Difference	45.2 °F
Duration of Test Record [hh:mm]	77:34
Total energy used during Test Record	24,815 Watt-hours
Measured Stand-by Power in Watts	320 Watts
Normalized Stand-by Power in Watts (using ΔT_{ideal} = 37°F)	262 Watts
CEC Allowable Stand-by Watts	
at Tested Volume	215 Watts
at Published Volume	224 Watts
at Total Spa Capacity	251 Watts

[8] FF = full foam to spa cabinet, PF = partial foam shell and plumbing, SF = foamed shell, ML = insulated cabinet multi-layer, SL = insulated cabinet single layer, NI = no insulation, OT = other (describe)

[9] TSP = two-speed pump, low speed, programmed cycles, CP = circulation pump operating 24/7, CPP = circulation pump programmed cycles, OT = other (describe)

Spa Test Results SPA E

Spa Characteristics

Rating (# of Persons)	6
Voltage	240 VAC 60 Hz
Spa Volume (published)	455 gallons
Spa Volume (as tested)	440 gallons (This spa had a full line molded onto the spa. The water was filled to this line as recommended by manufacturer's instructions)
Measured Total Spa Capacity	562 gallons

Spa Construction *(Information not provided by manufacturer)*

Spa Construction/Insulation type[10]	
Filtration System[11]	
Cover Characteristics:	
Material composition	
Weight	
Density	
Thickness at center	
Thickness at edge	
R-value	
Hinge width	
Hinge fill material	

Data Analysis

Water Temperature:	
Minimum	102 °F
Maximum	104 °F
Average	103 °F
Air Temperature:	
Minimum	55 °F
Maximum	60 °F
Average	58 °F
Average Temperature Difference	45.2 °F
Duration of Test Record [hh:mm]	84:02
Total energy used during Test Record	28,401 Watt-hours
Measured Stand-by Power in Watts	338 Watts
Normalized Stand-by Power in Watts (using ΔT_{ideal} = 37°F)	277 Watts
CEC Allowable Stand-by Watts	
at Tested Volume	289 Watts
at Published Volume	296 Watts
at Total Spa Capacity	341 Watts

[10] FF = full foam to spa cabinet, PF = partial foam shell and plumbing, SF = foamed shell, ML = insulated cabinet multi-layer, SL = insulated cabinet single layer, NI = no insulation, OT = other (describe)
[11] TSP = two-speed pump, low speed, programmed cycles, CP = circulation pump operating 24/7, CPP = circulation pump programmed cycles, OT = other (describe)

Spa Test Results SPA F

Spa Characteristics

Rating (# of Persons)	3
Voltage	240 VAC 60 Hz
Spa Volume (published)	200 gallons
Spa Volume (as tested)	200 gallons
Measured Total Spa Capacity	276 gallons

Spa Construction

Spa Construction/Insulation type[12]	FF
Filtration System[13]	CP
Cover Characteristics:	
Material composition	Vinyl Covered Styrofoam
Weight	
Density	2 lb/ft^3
Thickness at center	4 inch
Thickness at edge	2 inch
R-value	Ave. 12
Hinge width	1 inch
Hinge fill material	none

Data Analysis

Water Temperature:	
Minimum	102 °F
Maximum	104 °F
Average	103 °F
Air Temperature:	
Minimum	53 °F
Maximum	59 °F
Average	56 °F
Average Temperature Difference	46.8 °F
Duration of Test Record [hh:mm]	72:36
Total energy used during Test Record	15,840 Watt-hours
Measured Stand-by Power in Watts	218 Watts
Normalized Stand-by Power in Watts (using ΔT_{ideal} = 37°F)	173 Watts
CEC Allowable Stand-by Watts	
at Tested Volume	171 Watts
at Published Volume	171 Watts
at Total Spa Capacity	212 Watts

[12] FF = full foam to spa cabinet, PF = partial foam shell and plumbing, SF = foamed shell, ML = insulated cabinet multi-layer, SL = insulated cabinet single layer, NI = no insulation, OT = other (describe)
[13] TSP = two-speed pump, low speed, programmed cycles, CP = circulation pump operating 24/7, CPP = circulation pump programmed cycles, OT = other (describe)

Spa Test Results SPA G

Spa Characteristics

Rating (# of Persons)	5+
Voltage	240 VAC 60 Hz
Spa Volume (published)	300 gallons
Spa Volume (as tested)	300 gallons
Measured Total Spa Capacity	420 gallons

Spa Construction

Spa Construction/Insulation type[14]	FF
Filtration System[15]	CP
Cover Characteristics:	
Material composition	Vinyl Covered Styrofoam
Weight	
Density	2 lb/ft^3
Thickness at center	4 inch
Thickness at edge	2 inch
R-value	Ave. 12
Hinge width	1 inch
Hinge fill material	none

Data Analysis

Water Temperature:	
Minimum	102 °F
Maximum	103 °F
Average	102 °F
Air Temperature:	
Minimum	54 °F
Maximum	60 °F
Average	58 °F
Average Temperature Difference	44.3 °F
Duration of Test Record [hh:mm]	82:04
Total energy used during Test Record	15,744 Watt-hours
Measured Stand-by Power in Watts	192 Watts
Normalized Stand-by Power in Watts (using ΔT_{ideal} = 37°F)	160 Watts
CEC Allowable Stand-by Watts	
at Tested Volume	224 Watts
at Published Volume	224 Watts
at Total Spa Capacity	281 Watts

[14] FF = full foam to spa cabinet, PF = partial foam shell and plumbing, SF = foamed shell, ML = insulated cabinet multi-layer, SL = insulated cabinet single layer, NI = no insulation, OT = other (describe)
[15] TSP = two-speed pump, low speed, programmed cycles, CP = circulation pump operating 24/7, CPP = circulation pump programmed cycles, OT = other (describe)

Spa Test Results SPA H

Spa Characteristics

Rating (# of Persons)	2-3
Voltage	120 VAC 60 Hz
Spa Volume (published)	150 gallons
Spa Volume (as tested)	150 gallons
Measured Total Spa Capacity	223 gallons

Spa Construction *(Information not provided by manufacturer)*

Spa Construction/Insulation type[16]	
Filtration System[17]	
Cover Characteristics:	
Material composition	
Weight	
Density	
Thickness at center	
Thickness at edge	
R-value	
Hinge width	
Hinge fill material	

Data Analysis

Water Temperature:	
Minimum	103 °F
Maximum	104 °F
Average	104 °F
Air Temperature:	
Minimum	48 °F
Maximum	56 °F
Average	52 °F
Average Temperature Difference	51.2 °F
Duration of Test Record [hh:mm]	74:32
Total energy used during Test Record	14,134 Watt-hours
Measured Stand-by Power in Watts	190 Watts
Normalized Stand-by Power in Watts (using ΔT_{ideal} = 37°F)	137 Watts
CEC Allowable Stand-by Watts	
at Tested Volume	141 Watts
at Published Volume	141 Watts
at Total Spa Capacity	184 Watts

[16] FF = full foam to spa cabinet, PF = partial foam shell and plumbing, SF = foamed shell, ML = insulated cabinet multi-layer, SL = insulated cabinet single layer, NI = no insulation, OT = other (describe)

[17] TSP = two-speed pump, low speed, programmed cycles, CP = circulation pump operating 24/7, CPP = circulation pump programmed cycles, OT = other (describe)

Spa Test Results SPA I

Spa Characteristics

Rating (# of Persons)	7
Voltage	240 VAC 60 Hz
Spa Volume (published)	370 gallons
Spa Volume (as tested)	370 gallons
Measured Total Spa Capacity	498 gallons

Spa Construction *(Information not provided by manufacturer)*

Spa Construction/Insulation type[18]	
Filtration System[19]	
Cover Characteristics:	
Material composition	
Weight	
Density	
Thickness at center	
Thickness at edge	
R-value	
Hinge width	
Hinge fill material	

Data Analysis

Water Temperature:	
Minimum	103 °F
Maximum	105 °F
Average	104 °F
Air Temperature:	
Minimum	53 °F
Maximum	60 °F
Average	56 °F
Average Temperature Difference	47.5 °F
Duration of Test Record [hh:mm]	84:02
Total energy used during Test Record	20,926 Watt-hours
Measured Stand-by Power in Watts	249 Watts
Normalized Stand-by Power in Watts (using ΔT_{ideal} = 37°F)	194 Watts
CEC Allowable Stand-by Watts	
at Tested Volume	258 Watts
at Published Volume	258 Watts
at Total Spa Capacity	314 Watts

[18] FF = full foam to spa cabinet, PF = partial foam shell and plumbing, SF = foamed shell, ML = insulated cabinet multi-layer, SL = insulated cabinet single layer, NI = no insulation, OT = other (describe)
[19] TSP = two-speed pump, low speed, programmed cycles, CP = circulation pump operating 24/7, CPP = circulation pump programmed cycles, OT = other (describe)

Spa Test Results SPA J

Spa Characteristics

Rating (# of Persons)	4-5
Voltage	240 VAC 60 Hz
Spa Volume (published)	410 gallons
Spa Volume (as tested)	334 gallons (The water was filled to 6 inches above filter which is about half way up the skimmer opening. The manufacturer's instructions recommend that the water be filled to at least 1 inch above the filter)
Measured Total Spa Capacity	424 gallons

Spa Construction

Spa Construction/Insulation type[20]	PF, SL
Filtration System[21]	CPP
Cover Characteristics:	
Material composition	Vinyl , aluminum support, foam
Weight	30 oz. cover material
Density	1.5-2 lb.
Thickness at center	3 inch
Thickness at edge	4 inch at seam, 3 inch at edge
R-value	R19 Avg.
Hinge width	1 inch
Hinge fill material	Foam rubber

Data Analysis

Water Temperature:	
Minimum	103 °F
Maximum	105 °F
Average	104 °F
Air Temperature:	
Minimum	51 °F
Maximum	57 °F
Average	54 °F
Average Temperature Difference	49.6 °F
Duration of Test Record [hh:mm]	75:31
Total energy used during Test Record	36,142 Watt-hours
Measured Stand-by Power in Watts	479 Watts
Normalized Stand-by Power in Watts (using ΔT_{ideal} = 37°F)	357 Watts
CEC Allowable Stand-by Watts	
at Tested Volume	241 Watts
at Published Volume	276 Watts
at Total Spa Capacity	282 Watts

[20] FF = full foam to spa cabinet, PF = partial foam shell and plumbing, SF = foamed shell, ML = insulated cabinet multi-layer, SL = insulated cabinet single layer, NI = no insulation, OT = other (describe)
[21] TSP = two-speed pump, low speed, programmed cycles, CP = circulation pump operating 24/7, CPP = circulation pump programmed cycles, OT = other (describe)

Spa Test Results SPA K

Spa Characteristics

Rating (# of Persons)	2
Voltage	120 VAC 60 Hz
Spa Volume (published)	140 gallons
Spa Volume (as tested)	142 gallons
Measured Total Spa Capacity	209 gallons

Spa Construction *(Information not provided by manufacturer)*

Spa Construction/Insulation type[22]	
Filtration System[23]	
Cover Characteristics:	
Material composition	
Weight	
Density	
Thickness at center	
Thickness at edge	
R-value	
Hinge width	
Hinge fill material	

Data Analysis

Water Temperature:	
Minimum	102 °F
Maximum	104 °F
Average	102 °F
Air Temperature:	
Minimum	51 °F
Maximum	58 °F
Average	55 °F
Average Temperature Difference	47.5 °F
Duration of Test Record [hh:mm]	72:14
Total energy used during Test Record	5,871 Watt-hours
Measured Stand-by Power in Watts	81 Watts
Normalized Stand-by Power in Watts (using ΔT_{ideal} = 37°F)	63 Watts
CEC Allowable Stand-by Watts	
at Tested Volume	136 Watts
at Published Volume	135 Watts
at Total Spa Capacity	176 Watts

[22] FF = full foam to spa cabinet, PF = partial foam shell and plumbing, SF = foamed shell, ML = insulated cabinet multi-layer, SL = insulated cabinet single layer, NI = no insulation, OT = other (describe)
[23] TSP = two-speed pump, low speed, programmed cycles, CP = circulation pump operating 24/7, CPP = circulation pump programmed cycles, OT = other (describe)

Spa Test Results SPA L

Spa Characteristics

Rating (# of Persons)	4
Voltage	120 VAC 60 Hz
Spa Volume (published)	220 gallons
Spa Volume (as tested)	220 gallons
Measured Total Spa Capacity	290 gallons

Spa Construction *(Information not provided by manufacturer)*

Spa Construction/Insulation type[24]	
Filtration System[25]	
Cover Characteristics:	
Material composition	
Weight	
Density	
Thickness at center	
Thickness at edge	
R-value	
Hinge width	
Hinge fill material	

Data Analysis

Water Temperature:	
Minimum	102 °F
Maximum	104 °F
Average	103 °F
Air Temperature:	
Minimum	50 °F
Maximum	58 °F
Average	54 °F
Average Temperature Difference	48.9 °F
Duration of Test Record [hh:mm]	72:45
Total energy used during Test Record	6,902 Watt-hours
Measured Stand-by Power in Watts	95 Watts
Normalized Stand-by Power in Watts (using ΔT_{ideal} = 37°F)	72 Watts
CEC Allowable Stand-by Watts	
at Tested Volume	182 Watts
at Published Volume	182 Watts
at Total Spa Capacity	219 Watts

[24] FF = full foam to spa cabinet, PF = partial foam shell and plumbing, SF = foamed shell, ML = insulated cabinet multi-layer, SL = insulated cabinet single layer, NI = no insulation, OT = other (describe)

[25] TSP = two-speed pump, low speed, programmed cycles, CP = circulation pump operating 24/7, CPP = circulation pump programmed cycles, OT = other (describe)

Spa Test Results SPA M

Spa Characteristics

Rating (# of Persons)	6
Voltage	120 VAC 60 Hz
Spa Volume (published)	300 gallons
Spa Volume (as tested)	300 gallons
Measured Total Spa Capacity	377 gallons

Spa Construction *(Information not provided by manufacturer)*

Spa Construction/Insulation type[26]	
Filtration System[27]	
Cover Characteristics:	
Material composition	
Weight	
Density	
Thickness at center	
Thickness at edge	
R-value	
Hinge width	
Hinge fill material	

Data Analysis

Water Temperature:	
Minimum	102 °F
Maximum	104 °F
Average	103 °F
Air Temperature:	
Minimum	51 °F
Maximum	60 °F
Average	57 °F
Average Temperature Difference	45.7 °F
Duration of Test Record [hh:mm]	73:08
Total energy used during Test Record	8,727 Watt-hours
Measured Stand-by Power in Watts	119 Watts
Normalized Stand-by Power in Watts (using ΔT_{ideal} = 37°F)	97 Watts
CEC Allowable Stand-by Watts	
at Tested Volume	224 Watts
at Published Volume	224 Watts
at Total Spa Capacity	261 Watts

[26] FF = full foam to spa cabinet, PF = partial foam shell and plumbing, SF = foamed shell, ML = insulated cabinet multi-layer, SL = insulated cabinet single layer, NI = no insulation, OT = other (describe)
[27] TSP = two-speed pump, low speed, programmed cycles, CP = circulation pump operating 24/7, CPP = circulation pump programmed cycles, OT = other (describe)

Spa Test Results SPA N

Spa Characteristics

Rating (# of Persons)	4
Voltage	240 VAC 60 Hz
Spa Volume (published)	275 gallons
Spa Volume (as tested)	235 gallons (The water was filled to approximately half way up the skimmer opening as recommended by the manufacturer's instructions)
Measured Total Spa Capacity	343 gallons

Spa Construction *(Information not provided by manufacturer)*

Spa Construction/Insulation type[1]	
Filtration System[2]	
Cover Characteristics:	
Material composition	
Weight	
Density	
Thickness at center	
Thickness at edge	
R-value	
Hinge width	
Hinge fill material	

Data Analysis

Water Temperature:	
Minimum	102 °F
Maximum	104 °F
Average	103 °F
Air Temperature:	
Minimum	52 °F
Maximum	58 °F
Average	55 °F
Average Temperature Difference	47.7 °F
Duration of Test Record [hh:mm]	76:29
Total energy used during Test Record	21,221 Watt-hours
Measured Stand-by Power in Watts	277 Watts
Normalized Stand-by Power in Watts (using ΔT_{ideal} = 37°F)	215 Watts
CEC Allowable Stand-by Watts	
at Tested Volume	190 Watts
at Published Volume	211 Watts
at Total Spa Capacity	245 Watts

[1] FF = full foam to spa cabinet, PF = partial foam shell and plumbing, SF = foamed shell, ML = insulated cabinet multi-layer, SL = insulated cabinet single layer, NI = no insulation, OT = other (describe)
[2] TSP = two-speed pump, low speed, programmed cycles, CP = circulation pump operating 24/7, CPP = circulation pump programmed cycles, OT = other (describe)

Spa Test Results SPA O

Spa Characteristics

Rating (# of Persons)	6
Voltage	240 VAC 60 Hz
Spa Volume (published)	384 gallons
Spa Volume (as tested)	345 gallons (The water was filled to approximately half way up the skimmer opening as recommended by the manufacturer's instructions)
Measured Total Spa Capacity	500 gallons

Spa Construction *(Information not provided by manufacturer)*

Spa Construction/Insulation type[30]	
Filtration System[31]	
Cover Characteristics:	
Material composition	
Weight	
Density	
Thickness at center	
Thickness at edge	
R-value	
Hinge width	
Hinge fill material	

Data Analysis

Water Temperature:	
Minimum	101 °F
Maximum	103 °F
Average	102 °F
Air Temperature:	
Minimum	52 °F
Maximum	58 °F
Average	55 °F
Average Temperature Difference	47.7 °F
Duration of Test Record [hh:mm]	77:23
Total energy used during Test Record	25,570 Watt-hours
Measured Stand-by Power in Watts	330 Watts
Normalized Stand-by Power in Watts (using ΔT_{ideal} = 37°F)	256 Watts
CEC Allowable Stand-by Watts	
at Tested Volume	246 Watts
at Published Volume	264 Watts
at Total Spa Capacity	315 Watts

[30] FF = full foam to spa cabinet, PF = partial foam shell and plumbing, SF = foamed shell, ML = insulated cabinet multi-layer, SL = insulated cabinet single layer, NI = no insulation, OT = other (describe)

[31] TSP = two-speed pump, low speed, programmed cycles, CP = circulation pump operating 24/7, CPP = circulation pump programmed cycles, OT = other (describe)

Spa Test Results SPA P

Spa Characteristics

Rating (# of Persons)	2-3
Voltage	240 VAC 60 Hz
Spa Volume (published)	180 gallons
Spa Volume (as tested)	247 gallons (The water was filled to 4 inches above the top of the filter as recommended by the manufacturer's instructions)
Measured Total Spa Capacity	322.4 gallons

Spa Construction *(Information not provided by manufacturer)*

Spa Construction/Insulation type[32]	
Filtration System[33]	
Cover Characteristics:	
Material composition	
Weight	
Density	
Thickness at center	
Thickness at edge	
R-value	
Hinge width	
Hinge fill material	

Data Analysis

Water Temperature:	
Minimum	102 °F
Maximum	105 °F
Average	103 °F
Air Temperature:	
Minimum	52 °F
Maximum	60 °F
Average	57 °F
Average Temperature Difference	46.1 °F
Duration of Test Record [hh:mm]	78:36
Total energy used during Test Record	18,691 Watt-hours
Measured Stand-by Power in Watts	238 Watts
Normalized Stand-by Power in Watts (using ΔT_{ideal} = 37°F)	191 Watts
CEC Allowable Stand-by Watts	
at Tested Volume	197 Watts
at Published Volume	159 Watts
at Total Spa Capacity	235 Watts

[32] FF = full foam to spa cabinet, PF = partial foam shell and plumbing, SF = foamed shell, ML = insulated cabinet multi-layer, SL = insulated cabinet single layer, NI = no insulation, OT = other (describe)
[33] TSP = two-speed pump, low speed, programmed cycles, CP = circulation pump operating 24/7, CPP = circulation pump programmed cycles, OT = other (describe)

Spa Test Results SPA Q

Spa Characteristics

Rating (# of Persons)	5-6
Voltage	240 VAC 60 Hz
Spa Volume (published)	400 gallons
Spa Volume (as tested)	439 gallons (The water was filled to 4 inches above the top of the filter as recommended by the manufacturer's instructions)
Measured Total Spa Capacity	566 gallons

Spa Construction *(Information not provided by manufacturer)*

Spa Construction/Insulation type[34]	
Filtration System[35]	
Cover Characteristics:	
Material composition	
Weight	
Density	
Thickness at center	
Thickness at edge	
R-value	
Hinge width	
Hinge fill material	

Data Analysis

Water Temperature:	
Minimum	103 °F
Maximum	106 °F
Average	104 °F
Air Temperature:	
Minimum	52 °F
Maximum	59 °F
Average	55 °F
Average Temperature Difference	49.0 °F
Duration of Test Record [hh:mm]	81:31
Total energy used during Test Record	35,643 Watt-hours
Measured Stand-by Power in Watts	437 Watts
Normalized Stand-by Power in Watts (using ΔT_{ideal} = 37°F)	330 Watts
CEC Allowable Stand-by Watts	
at Tested Volume	289 Watts
at Published Volume	271 Watts
at Total Spa Capacity	342 Watts

[34] FF = full foam to spa cabinet, PF = partial foam shell and plumbing, SF = foamed shell, ML = insulated cabinet multi-layer, SL = insulated cabinet single layer, NI = no insulation, OT = other (describe)
[35] TSP = two-speed pump, low speed, programmed cycles, CP = circulation pump operating 24/7, CPP = circulation pump programmed cycles, OT = other (describe)

Spa Test Results SPA R

Spa Characteristics

Rating (# of Persons)	7
Voltage	240 VAC 60 Hz
Spa Volume (published)	290 gallons
Spa Volume (as tested)	296 gallons (The water was filled to 0.5 inches below the bottom of the headrest as recommended by manufacturer's instructions)
Measured Total Spa Capacity	458 gallons

Spa Construction

Spa Construction/Insulation type[36]	ML
Filtration System[37]	CP
Cover Characteristics:	
Material composition	Foam covered with vinyl
Weight	40 lbs
Density	1 lbs
Thickness at center	5 inch
Thickness at edge	3 inch
R-value	15
Hinge width	1.5 inch
Hinge fill material	

Data Analysis

Water Temperature:	
Minimum	102 °F
Maximum	103 °F
Average	103 °F
Air Temperature:	
Minimum	53 °F
Maximum	58 °F
Average	56 °F
Average Temperature Difference	47.0 °F
Duration of Test Record [hh:mm]	77:48
Total energy used during Test Record	32,000 Watt-hours
Measured Stand-by Power in Watts	411 Watts
Normalized Stand-by Power in Watts (using ΔT_{ideal} = 37°F)	324 Watts
CEC Allowable Stand-by Watts	
at Tested Volume	222 Watts
at Published Volume	219 Watts
at Total Spa Capacity	297 Watts

[36] FF = full foam to spa cabinet, PF = partial foam shell and plumbing, SF = foamed shell, ML = insulated cabinet multi-layer, SL = insulated cabinet single layer, NI = no insulation, OT = other (describe)

[37] TSP = two-speed pump, low speed, programmed cycles, CP = circulation pump operating 24/7, CPP = circulation pump programmed cycles, OT = other (describe)

Spa Test Results SPA S

Spa Characteristics

Rating (# of Persons)	4-5
Voltage	240 VAC 60 Hz
Spa Volume (published)	403 gallons
Spa Volume (as tested)	293 gallons (The water was filled to above the highest jet and below the lowest headrest as recommended by manufacturer's instructions)
Measured Total Spa Capacity	408 gallons

Spa Construction

Spa Construction/Insulation type[38]	FF
Filtration System[39]	CP
Cover Characteristics:	
Material composition	PVC
Weight	
Density	1.5 lb
Thickness at center	4.5 in
Thickness at edge	2.25 in
R-value	13.5
Hinge width	1.25 in
Hinge fill material	n/a

Data Analysis

Water Temperature:	
Minimum	102 °F
Maximum	104 °F
Average	103 °F
Air Temperature:	
Minimum	52 °F
Maximum	60 °F
Average	55 °F
Average Temperature Difference	47.3 °F
Duration of Test Record [hh:mm]	74:17
Total energy used during Test Record	23,604 Watt-hours
Measured Stand-by Power in Watts	318 Watts
Normalized Stand-by Power in Watts (using ΔT_{ideal} = 37°F)	248 Watts
CEC Allowable Stand-by Watts	
at Tested Volume	220 Watts
at Published Volume	273 Watts
at Total Spa Capacity	275 Watts

[38] FF = full foam to spa cabinet, PF = partial foam shell and plumbing, SF = foamed shell, ML = insulated cabinet multi-layer, SL = insulated cabinet single layer, NI = no insulation, OT = other (describe)

[39] TSP = two-speed pump, low speed, programmed cycles, CP = circulation pump operating 24/7, CPP = circulation pump programmed cycles, OT = other (describe)

Spa Test Results SPA T

Spa Characteristics

Rating (# of Persons)	2
Voltage	240 VAC 60 Hz
Spa Volume (published)	150 gallons
Spa Volume (as tested)	150 gallons
Measured Total Spa Capacity	187 gallons

Spa Construction

Spa Construction/Insulation type[40]	ML
Filtration System[41]	CP
Cover Characteristics:	
Material composition	Foam core covered with marine grade vinyl
Weight	33 lbs
Density	2 lb
Thickness at center	4 in
Thickness at edge	3 in
R-value	13.2
Hinge width	
Hinge fill material	

Data Analysis

Water Temperature:	
Minimum	102 °F
Maximum	104 °F
Average	103 °F
Air Temperature:	
Minimum	51 °F
Maximum	60 °F
Average	58 °F
Average Temperature Difference	45.6 °F
Duration of Test Record [hh:mm]	84:00
Total energy used during Test Record	11,800 Watt-hours
Measured Stand-by Power in Watts	140 Watts
Normalized Stand-by Power in Watts (using ΔT_{ideal} = 37°F)	114 Watts
CEC Allowable Stand-by Watts	
at Tested Volume	141 Watts
at Published Volume	141 Watts
at Total Spa Capacity	163 Watts

[40] FF = full foam to spa cabinet, PF = partial foam shell and plumbing, SF = foamed shell, ML = insulated cabinet multi-layer, SL = insulated cabinet single layer, NI = no insulation, OT = other (describe)
[41] TSP = two-speed pump, low speed, programmed cycles, CP = circulation pump operating 24/7, CPP = circulation pump programmed cycles, OT = other (describe)

Spa Test Results SPA U

Spa Characteristics

Rating (# of Persons)	7
Voltage	240 VAC 60 Hz
Spa Volume (published)	470 gallons
Spa Volume (as tested)	470 gallons
Measured Total Spa Capacity	574 gallons

Spa Construction *(Information not provided by manufacturer)*

Spa Construction/Insulation type[42]	
Filtration System[43]	
Cover Characteristics:	
Material composition	
Weight	
Density	
Thickness at center	
Thickness at edge	
R-value	
Hinge width	
Hinge fill material	

Data Analysis

Water Temperature:	
Minimum	101 °F
Maximum	103 °F
Average	103 °F
Air Temperature:	
Minimum	54 °F
Maximum	59 °F
Average	57 °F
Average Temperature Difference	46.0 °F
Duration of Test Record [hh:mm]	75:06
Total energy used during Test Record	22,816 Watt-hours
Measured Stand-by Power in Watts	304 Watts
Normalized Stand-by Power in Watts (using ΔT_{ideal} = 37°F)	244 Watts
CEC Allowable Stand-by Watts	
at Tested Volume	302 Watts
at Published Volume	302 Watts
at Total Spa Capacity	345 Watts

[42] FF = full foam to spa cabinet, PF = partial foam shell and plumbing, SF = foamed shell, ML = insulated cabinet multi-layer, SL = insulated cabinet single layer, NI = no insulation, OT = other (describe)

[43] TSP = two-speed pump, low speed, programmed cycles, CP = circulation pump operating 24/7, CPP = circulation pump programmed cycles, OT = other (describe)

Spa Test Results SPA V

Acura Equipment

Spa Characteristics

Rating (# of Persons)	7
Voltage	240 VAC 60 Hz
Spa Volume (published)	350 gallons
Spa Volume (as tested)	350 gallons
Measured Total Spa Capacity	409 gallons

Spa Construction

Spa Construction/Insulation type[44]	Frame-Acrylic/ foam fill
Filtration System[45]	
Cover Characteristics:	Compression Angle Hinge
Material composition	Vinyl clad EPS foam
Weight	40 lb
Density	1.5 lb foam
Thickness at center	4 inch
Thickness at edge	2.5 inch
R-value	13
Hinge width	None
Hinge fill material	n/a

Data Analysis

Water Temperature:	
Minimum	101 °F
Maximum	103 °F
Average	103 °F
Air Temperature:	
Minimum	51 °F
Maximum	57 °F
Average	54 °F
Average Temperature Difference	48.1 °F
Duration of Test Record [hh:mm]	74:03
Total energy used during Test Record	10,088 Watt-hours
Measured Stand-by Power in Watts	136 Watts
Normalized Stand-by Power in Watts (using ΔT_{ideal} = 37°F)	105 Watts
CEC Allowable Stand-by Watts	
at Tested Volume	248 Watts
at Published Volume	248 Watts
at Total Spa Capacity	276 Watts

[44] FF = full foam to spa cabinet, PF = partial foam shell and plumbing, SF = foamed shell, ML = insulated cabinet multi-layer, SL = insulated cabinet single layer, NI = no insulation, OT = other (describe)
[45] TSP = two-speed pump, low speed, programmed cycles, CP = circulation pump operating 24/7, CPP = circulation pump programmed cycles, OT = other (describe)

Spa Test Results SPA W

Spa Characteristics

Rating (# of Persons)	5
Voltage	240 VAC 60 Hz
Spa Volume (published)	450 gallons
Spa Volume (as tested)	382 gallons (The water level at published volume rose over skimmer opening, so the tested volume reflects level at just above the center of the skimmer opening)
Measured Total Spa Capacity	496 gallons

Spa Construction

Spa Construction/Insulation type[46]	FF
Filtration System[47]	CP
Cover Characteristics:	
Material composition	Polystyrene
Weight	--
Density	1.5 lb
Thickness at center	3.5 inch
Thickness at edge	2.5 inch
R-value	13
Hinge width	2 inch
Hinge fill material	None

Data Analysis

Water Temperature:	
Minimum	102 °F
Maximum	103 °F
Average	102 °F
Air Temperature:	
Minimum	53 °F
Maximum	59 °F
Average	56 °F
Average Temperature Difference	46.2 °F
Duration of Test Record [hh:mm]	76:37
Total energy used during Test Record	17,342 Watt-hours
Measured Stand-by Power in Watts	226 Watts
Normalized Stand-by Power in Watts (using ΔT_{ideal} = 37°F)	181 Watts
CEC Allowable Stand-by Watts	
at Tested Volume	263 Watts
at Published Volume	294 Watts
at Total Spa Capacity	313 Watts

46 FF = full foam to spa cabinet, PF = partial foam shell and plumbing, SF = foamed shell, ML = insulated cabinet multi-layer, SL = insulated cabinet single layer, NI = no insulation, OT = other (describe)

47 TSP = two-speed pump, low speed, programmed cycles, CP = circulation pump operating 24/7, CPP = circulation pump programmed cycles, OT = other (describe)

Spa Test Results SPA X

Spa Characteristics

Rating (# of Persons)	5
Voltage	240 VAC 60 Hz
Spa Volume (published)	411 gallons
Spa Volume (as tested)	422 gallons (This spa had a full line molded onto the spa. The water was filled to this line as recommended by manufacturer's instructions)
Measured Total Spa Capacity	556 gallons

Spa Construction *(Information not provided by manufacturer)*

Spa Construction/Insulation type[48]	
Filtration System[49]	
Cover Characteristics:	
Material composition	
Weight	
Density	
Thickness at center	
Thickness at edge	
R-value	
Hinge width	
Hinge fill material	

Data Analysis

Water Temperature:	
Minimum	102 °F
Maximum	104 °F
Average	103 °F
Air Temperature:	
Minimum	53 °F
Maximum	59 °F
Average	56 °F
Average Temperature Difference	46.3 °F
Duration of Test Record [hh:mm]	76:30
Total energy used during Test Record	23,933 Watt-hours
Measured Stand-by Power in Watts	313 Watts
Normalized Stand-by Power in Watts (using ΔT_{ideal} = 37°F)	250 Watts
CEC Allowable Stand-by Watts	
at Tested Volume	281 Watts
at Published Volume	276 Watts
at Total Spa Capacity	338 Watts

[48] FF = full foam to spa cabinet, PF = partial foam shell and plumbing, SF = foamed shell, ML = insulated cabinet multi-layer, SL = insulated cabinet single layer, NI = no insulation, OT = other (describe)
[49] TSP = two-speed pump, low speed, programmed cycles, CP = circulation pump operating 24/7, CPP = circulation pump programmed cycles, OT = other (describe)

Spa Test Results SPA Y

Spa Characteristics

Rating (# of Persons)	3
Voltage	240 VAC 60 Hz
Spa Volume (published)	200 gallons
Spa Volume (as tested)	200 gallons
Measured Total Spa Capacity	259 gallons

Spa Construction *(Information not provided by manufacturer)*

Spa Construction/Insulation type[50]	
Filtration System[51]	
Cover Characteristics:	
Material composition	
Weight	
Density	
Thickness at center	
Thickness at edge	
R-value	
Hinge width	
Hinge fill material	

Data Analysis

Water Temperature:	
Minimum	102 °F
Maximum	105 °F
Average	104 °F
Air Temperature:	
Minimum	53 °F
Maximum	60 °F
Average	58 °F
Average Temperature Difference	46.0 °F
Duration of Test Record [hh:mm]	72:30
Total energy used during Test Record	19,599Watt-hours
Measured Stand-by Power in Watts	270 Watts
Normalized Stand-by Power in Watts (using ΔT_{ideal} = 37°F)	218 Watts
CEC Allowable Stand-by Watts	
at Tested Volume	171 Watts
at Published Volume	171 Watts
at Total Spa Capacity	203 Watts

[50] FF = full foam to spa cabinet, PF = partial foam shell and plumbing, SF = foamed shell, ML = insulated cabinet multi-layer, SL = insulated cabinet single layer, NI = no insulation, OT = other (describe)

[51] TSP = two-speed pump, low speed, programmed cycles, CP = circulation pump operating 24/7, CPP = circulation pump programmed cycles, OT = other (describe)

Spa Test Results SPA Z

Spa Characteristics

Rating (# of Persons)	4
Voltage	120 VAC 60 Hz
Spa Volume (published)	260 gallons
Spa Volume (as tested)	260 gallons
Measured Total Spa Capacity	311 gallons

Spa Construction *(Information not provided by manufacturer)*

Spa Construction/Insulation type[52]	
Filtration System[53]	
Cover Characteristics:	
Material composition	
Weight	
Density	
Thickness at center	
Thickness at edge	
R-value	
Hinge width	
Hinge fill material	

Data Analysis

Water Temperature:	
Minimum	102 °F
Maximum	104 °F
Average	103 °F
Air Temperature:	
Minimum	53 °F
Maximum	58 °F
Average	56 °F
Average Temperature Difference	47.3 °F
Duration of Test Record [hh:mm]	77:17
Total energy used during Test Record	17,230 Watt-hours
Measured Stand-by Power in Watts	223 Watts
Normalized Stand-by Power in Watts (using ΔT_{ideal} = 37°F)	174 Watts
CEC Allowable Stand-by Watts	
at Tested Volume	204 Watts
at Published Volume	204 Watts
at Total Spa Capacity	229 Watts

[52] FF = full foam to spa cabinet, PF = partial foam shell and plumbing, SF = foamed shell, ML = insulated cabinet multi-layer, SL = insulated cabinet single layer, NI = no insulation, OT = other (describe)
[53] TSP = two-speed pump, low speed, programmed cycles, CP = circulation pump operating 24/7, CPP = circulation pump programmed cycles, OT = other (describe)

Spa Test Results SPA AA

Spa Characteristics

Rating (# of Persons)	3
Voltage	120 VAC 60 Hz
Spa Volume (published)	200 gallons
Spa Volume (as tested)	219 gallons (This spa had a full line inscribed onto the spa. The water was filled to this line as recommended by manufacturer's instructions)
Measured Total Spa Capacity	267 gallons

Spa Construction *(Information not provided by manufacturer)*

Spa Construction/Insulation type[54]	
Filtration System[55]	
Cover Characteristics:	
Material composition	
Weight	
Density	
Thickness at center	
Thickness at edge	
R-value	
Hinge width	
Hinge fill material	

Data Analysis

Water Temperature:	
Minimum	102 °F
Maximum	104 °F
Average	103 °F
Air Temperature:	
Minimum	52 °F
Maximum	60 °F
Average	56 °F
Average Temperature Difference	47.1 °F
Duration of Test Record [hh:mm]	73:00
Total energy used during Test Record	18,339 Watt-hours
Measured Stand-by Power in Watts	251 Watts
Normalized Stand-by Power in Watts (using ΔT_{ideal} = 37°F)	198 Watts
CEC Allowable Stand-by Watts	
at Tested Volume	181 Watts
at Published Volume	171 Watts
at Total Spa Capacity	207 Watts

54 FF = full foam to spa cabinet, PF = partial foam shell and plumbing, SF = foamed shell, ML = insulated cabinet multi-layer, SL = insulated cabinet single layer, NI = no insulation, OT = other (describe)

55 TSP = two-speed pump, low speed, programmed cycles, CP = circulation pump operating 24/7, CPP = circulation pump programmed cycles, OT = other (describe)

APPENDIX B

"Portable Electric Spa Standby Energy Test Protocol" (Final Revision: June 13, 2008)

Final Version (DRAFT #10)

June 13, 2008

Portable Electric Spa Stand-by Energy Test Protocol

APSP CEC/Spa Advisory Group

Rev. 20080613

Purpose:

To measure the energy consumption of a portable electric spa in stand-by mode, using repeatable and reproducible environmental and testing controls. Said results will be utilized to calculate the standby power demand, which will be used to determine how spas perform relative to the California Energy Commission Title 20 maximum standby power requirement.

Definitions:

Stand-by mode – All settings at default as shipped by the manufacturer, except water temperature which may be adjusted to meet the test conditions.

Spa Volume – The advertised and marketed water fill capacity of the tub in gallons. This measurement is generally found on the tub specification label on the tub, in the owner's manual or within advertising of the tub.

Total Spa Capacity – The total fill capacity of the tub in gallons (this measurement is greater than the Spa Volume). This is measured by filling the tub to the point where the entire vessel is full, at the threshold of spilling out of the tub.

Test Equipment:

Note: All equipment shall be calibrated and traceable to the National Institute of Standards and Technology (NIST).

Recording Watt Hour meter – Accuracy: Class-2 or better.
Temperature measurement system - Accuracy: +/- 1°F
Water meter to measure fill water in gallons – Accuracy: +/- 1.5%

Test Conditions:

Chamber internal dimensions

Minimum 7 feet high
Minimum 1 foot from spa to chamber wall or other internal barrier

Air Flow

If air circulation from the air temperature control equipment is intermittent, install 1 fan in one corner of the chamber, 6 feet from the floor. Direct toward the center of the floor. The fan should move at least 80 CFM of air, and not more than 100 CFM. If the air temperature control equipment continuously circulates air in the chamber, no fan is required.

Chamber Insulation

Walls shall be insulated adequately to maintain proper ambient temperatures. 2” thick Dow TUFF-R Commercial Insulating Sheathing, or equivalent will create an adequate insulation barrier for a chamber that is located indoors.

Chamber Floor

The floor shall be insulated with 2” thick Dow TUFF-R Commercial Insulating Sheathing, or equivalent (R-13 polisocyanurate with radiant barrier on both sides). This insulation shall be laid directly on a level concrete floor or slab or other firm, level surface created for it. The insulating layer shall be sheeted with minimum 1/2” thick ACX plywood to protect the insulation layer and provide a smooth surface to properly position the spas to be tested.

One ambient chamber temperature thermocouple location

Maximum of 1.5 feet above spa cover level.
Minimum of 1 foot above spa cover level
6 inches from chamber wall, out of the direct air flow from air temperature control system or circulation fan.

Water temperature thermocouple locations

Primary thermocouple –

Between 5 and 6 inches below the water surface
1 foot from skimmer
If spa has no skimmer, the water temperature sensor will be centrally located relative to the shape of the vessel

Redundant thermocouple –

Within 3 to 6 inches radius of the primary thermocouple, on the same horizontal plane relative to water depth.

Test Parameters:

Ambient air temperature shall remain at or below 60º F during the test.
Water temperature shall remain at or above 102º F during the test.
Spa in Stand-by mode as shipped by the manufacturer to the customer

Test Procedure:

Place Spa in chamber directly on the chamber floor.
The spa shall be centered in the chamber.
Do not leave the spa on a skid or pallet.
Fill Spa with water to manufacturer’s specified Spa Water Capacity.
Install manufacturer-supplied cover.
Connect electrical power, meters, and thermocouples

Set controls to meet test parameters, if required.
Allow spa to heat to finish the initial heat cycle (warm up).
Record the set temperature on the control system.
Allow temperatures to stabilize for a minimum of 4 hours.
NO additional temperature adjustments may be made during or after the stabilization period until the end of the test.
Begin the Test Period.
Begin the Test Record at the end of a filter cycle, purge cycle or a heat cycle after the Test Period begins.
* NOTE:
"Some hot tubs utilize non-conventional methodologies to either supply all of the heat to the tub or as a supplementary or secondary heat source to help maintain heat. During the initial heat up (bringing the water from the water supply temperature to set temperature, ie. 102) the tub may operate in a heat call or the heater will be running. Once the desired temperature is met, the tub may not go into a "heat call" or formal heating cycle at all or ever. The system being employed to circulate the water and/or filter the water may have sufficient heating abilities (either by design or as a by-product of the system) to maintain the desired temperature of the water. For this reason, a formal "heat call" or heat cycle may not be entered in to. It is for this reason that the procedure for ending the test period was modified."
The end of the Test Record is the end of a corresponding filter cycle, purge cycle or a heat call that occurs 72 hours or more after the start of the Test Record.
End Test Period.
Fill spa to top (near overflowing) to determine Spa Volume

Data Recording:

Temperatures at a maximum interval of 4 minutes.
Voltage, current, and power factor at a maximum interval of 4 minutes.
Watt-hours used during entire Test Period.
Elapsed time during Test Record.

Spa characteristics

Manufacturer
Brand name
Model name or #
Volts VAC 60 HZ (1)
Spa Volume (see Definitions above) and note (2) below
Spa Water Capacity (see Definitions above and note (1) below)
Rating for # of persons (1)
Spa construction/ insulation type (3)
Spa cover height in inches (2)
    Center
    Edge
Spa cover density (lbs per cubit ft.) (1)
Filtration system (1, 4)
Number of spa volume turnovers per 24 hours (2)
Standby test Watts (1)
Standby Watts std. (5)

1- MFG'S PUBLISHED RATING
2- ACTUAL TEST MEASUREMENT
3- FF = FULL FOAM TO SPA CABINET
PF = PARTIAL FOAM SHELL AND PLUMBING
SF = FOAMED SHELL
ML = INSULATED CABINET MULTI LAYER
SL = INSULATED CABINET SINGLE LAYER
NI = NO INSULATION
OT = OTHER, DESCRIBE
4- TSP = TWO SPEED PUMP , LOW SPEED, PROGRAMMED CYCLES
CP = CIRCULATION PUMP OPERATING 24 / 7
CPP = CIRCULATION PUMP PROGRAMMED CYCLES
OT = OTHER, DESCRIBE
5- AS CALCULATED UNDER CEC GUIDELINES

Cover characteristics

Material composition
Weight
Thickness
R value
Hinge width
Hinge fill material

Data Analysis:

Determine minimum, maximum and mean temperatures for the test duration.
The primary thermocouple measurements will be used to validate the test.
The redundant thermocouple will be considered a backup.
Verify all temperatures meet the acceptability standards for a good test.
Divide watt hours used during the Test Record by the hours of the Test Record.

Data Reporting:

Spa Manufacturer and Model
Spa Volume
Total Spa Capacity
Hours of Test Record
Total energy used during Test Record
Standby Power in Watts.

The total Watt-hours of energy used during the Test, divided by the duration of the Test in hours (rounded to the nearest $1/60^{th}$ hour).

Calculated allowable Watts for vessel (CEC Title 20 formula) - $5(V^{2/3})$ where V is the spa volume measurement gallons.

Calculated Watts using Total Spa Capacity - $5(V^{2/3})$ where V is Total Spa

END

APPENDIX C

"Analysis of Standards Options for Portable Electric Spas," PG&E Report, May 12, 2004.

Codes and Standards Enhancement Initiative
For PY2004: Title 20 Standards Development

Analysis of Standards Options For Portable Electric Spas

Prepared for:
Gary B. Fernstrom, PG&E

Pacific Gas and Electric Company™

Prepared by:
Davis Energy Group
Energy Solutions

May 12, 2004

This report was prepared by Pacific Gas and Electric Company and funded by California utility customers under the auspices of the California Public Utilities Commission

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Table of Contents

1 Overview

The Pacific Gas and Electric Company (PG&E) Codes and Standards Enhancement (CASE) Initiative Project seeks to address energy efficiency opportunities through development of new and updated Title 20 standards. Individual reports document information and data helpful to the California Energy Commission (CEC) and other stakeholders in the development of these new and updated standards. The objective of this project is to develop CASE Reports that provide comprehensive technical, economic, market, and infrastructure information on each of the potential appliance standards. This CASE report covers standards and options for portable electric spas.

2 Product Description

Portable electric spas are pre-fabricated, self-contained electric spas or hot tubs, as opposed to "in-ground" units (such as those attached to a pool), other permanently installed residential spas, public spas, or spas that are operated for medical treatment or physical therapy.[1] We define portable spas to be electrically heated; this constraint has the advantages of fitting with the market reality of the portable spa as a consumer product, and of defining a category sufficiently narrow to facilitate the adoption of a reasonably streamlined, uniform standard. Although some portable spas exceed 500 gallons, the most popular models range from around 210 to 380 gallons. Filtration pumping, water heating, shell insulation, and cover, are the primary components affecting energy efficiency. There is no current standard testing procedure for measuring the energy efficiency of portable spas. While the National Spa and Pool Institute (NSPI) has a standard that covers certain aspects of spa design, equipment characteristics, and operation and installation issues, the standard does not address energy use or efficiency issues.[2]

The vast majority of electrically-heated portable spas are located in single family homes—96% according to RECS 1997. Typical owners of portable spas are married, middle-aged, well educated and live in middle-to-upper-income areas of cities or suburbs. Recent research suggests that spa ownership is extending to a younger and less affluent group of Americans, which may reflect the drop in spa prices in recent years[3].

The term "portable" might seem to imply that owners relocate their spa when they move to a new home, and indeed specialty "spa relocation" firms do exist. However, a spa upgrade often happens coincident with the move. Portability is better understood as representing the advantage of a straightforward and low-cost installation.

[1] In addition, portable spas are usually operated to maintain a constant water temperature level, while in-ground units use natural gas and typically are only turned on to heat up water for each use.
[2] ANSI/NSPI-6 1999.
[3] Personal communication, NSPI

Figure 1: Example of a Portable Spa

3 Market Status

3.1 Market Penetration

The spa market is quite diffuse, with the number of manufacturers entering into the hundreds. According to the NSPI, in 2000 there were 3.4 million portable spas in use within the US, and annual sales were 370,000 units. California has around 12% of the nation's population, but spa penetration is thought to be substantially above the national average. The number of electric portable units currently in use in California is not well known, but several estimations exist, and are summarized in Table 1.

Table 1. Stock Estimates of Electrically Heated Portable Spas in California

Source	*Total Stock Nationwide*	*Percent in CA*	*Penetration in CA*	*Single Family CA Residences*	*Total Units in California*
NSPI (2000)	3.4 million	--	--	--	--
CEC Demand Forecast (03-13)	--	--	5.4%	7.8 million	421,000
DOE RECS 2001 (HC5-7a)	3.3 million	12.1%	--	--	400,000
PG&E RESR (1997)	--	--	5.7%	7.8 million	445,000

The RECS national stock number is close to the NSPI estimate, but their California stock estimate is questionable as it has not increased since 1997 and we believe that the penetration for California is higher than the nationwide average. We therefore use the nationwide NSPI data and a portion of total US stock of 13%--slightly higher than the nationwide average, resulting in an estimate of 440,000 spas.

3.2 Sales Volume

Using 13% as California's portion of national sales, we estimate approximately 48,000 spas are sold in the state each year. Treating this as an average annual sales figure, with a 10-year turnover of the existing stock and sales growth of 1% per year, the projected long-term population would be around 544,000 units in the year 2013.

3.3 Market Penetration of High Efficiency Options

Given both the demographics of spa ownership, and the spa's typical place as the largest electric load in homes that possess one, many spa owners recognize energy use as an important issue and one deserving of attention and potential added investment. Typically, after a first experience with an inexpensive spa that was energy intensive and perhaps inadequate in other ways, long-time spa owners eventually upgrade to a unit that is perceived to be more efficient, as well as possibly outfitted with additional features.[4] However, because there are no standard tests or ratings, consumers have no way of knowing which spas are truly energy efficient.

Higher-end spas tend to have more insulation under the shell and in the cover, and some have an independent circulation pump that saves energy over the more common standard two-speed pump configuration. They may also have LED lighting - more efficient than standard incandescent lighting that comes in most spas. Additionally, some spas market control features such as an "economy mode" allowing the temperature decrease during periods of nonuse. Each of these options might be considered an energy efficiency measure. Some of the options offered as "efficient" generate substantial savings and some may not; sales and marketing representatives from manufacturers tend not to provide information regarding the specific energy savings associated with individual measures.

4 Savings Potential

4.1 Spa Construction

4.1.1 Shell

Rather than the familiar wooden tub of old, the vast majority of new portable spas are made of a shell of molded fiberglass or acrylic. The shell may be solid-surface or laminated; various manufacturing techniques exist. Stated shell lifetimes vary from around 8 to 15 years or longer. Manufacturer warranties against shell leakage or delamination range from 5 to 12 years. Single piece construction decreases leaks as compared to older wooden tubs.

[4] Anecdotal evidence indicates that a common scenario is that a consumer replaces an older unit at least partly due to perceived high operating costs.

4.1.2 Insulation Characteristics

High R-value is the single most important factor affecting spa energy efficiency. The majority of heat loss is from the water surface, and thus improved covers are important for overall efficiency improvements.[5] The spa cover presents particular challenges for efficiency. Covers with insulation comparable to that of the rest of the spa are often sold as options, while a less efficient cover comes standard. In addition to having denser and thicker insulation, high-efficiency covers may be designed with form-fitting gaskets and skirts around the tub exterior. The cover is the first component of the spa that is likely to be replaced by the user, creating the possibility of variable efficiency through the life of the spa. In any case, test procedures should specify that each unit's standard cover be used.

Insulation of the spa shell itself is also important. Insulation method, uniformity and thickness vary between manufacturers. Most spas will have at least a 1-2" layer of open- or closed-cell insulation spray-coated directly onto the underside of the tub shell during assembly. Depending on the manufacturer, spas may have little additional insulation, may use fiberglass batts within the interior cavity, or may have the entire cavity filled with foam insulation.[6] For purposes of efficiency, more insulation is better, but there is a diminishing rate of return and the longevity and serviceability impacts of different insulation methods and materials can be significant.

4.1.3 Heating Systems

Heating energy accounts for over half the energy consumed by a typical spa. Heating requirements are in large part determined by standby losses through the cover and shell, and heat loss and water evaporation during use. Most portable electric spas rely on resistance heaters to maintain their temperature, though some inexpensive ones use just pump friction. Most resistance heated spas use direct-contact heaters, which can boast efficiencies of 98% or higher. The element and other heater components must be of high quality to resist corrosion and decay from constant contact with the spa's chemical-charged water. Some firms tout the maintenance benefits from heaters that separate the spas water from the heating element itself. Up to 96% efficiency claims are made for these systems. Thus heater efficiency is generally quite high, with little difference between different design approaches.

4.1.4 Pumping Systems

Pumping is the second major component of spa energy use, accounting for around 25-50% of the energy used in a portable spa. Portable spas have at least one pump to provide filtering and circulation and to run the jets when the user turns them on. Several configurations are possible, resulting in widely variable pumping energy use; some models include a separate, small pump for filtration and circulation duties, which can

[5] Joe Stone, Balboa Instruments, current president of the Hot Tub Council, Personal communication, 10/24/02.

[6] Filling the cavity with foam has the advantage of adding structural rigidity to thinner-walled shells as well as providing insulation value. Open-cell foam can vary in quality, but will generally absorb water and will thus lose some of its insulation qualities if allowed to get wet. Some manufacturers place an ABS tub beneath the foam to prevent water uptake from the ground surface. Foam has the added drawback that leaks are difficult to find and fix since many components are embedded. Foam is, however, a formidable insulator and can be a low-cost manufacturing method to increase the R-value of a one-piece tub.

reduce energy requirements. Smaller spas, and less expensive spas generally, tend to have one multi-speed pump that both runs the circulation and filtration system, and powers the jets.

Pumping energy use is further complicated by the fact that a significant portion of heat generated by the motors and pumps effectively contributes to heating the spa. Therefore a fraction of the energy savings from pump and motor improvements will have to be replaced by resistance heat. How much waste heat is lost depends on the location of the pump and the insulation configuration of the spa. The heat from filter pump operation may also overheat a well insulated spa during warm summer months.

Related to pumping is the presence of increasing numbers of jets and hoses in new spas. Ever more powerful jets are incorporated to provide health and relaxation benefits to the user. In essence the hoses can act as heat exchangers with the surrounding air, losing heat and increasing heating energy requirements. Additionally, air is often introduced to the water being pumped to the jets. Ambient air used for this purpose can accelerate the spa's cool-down. Some spas use air from the pump cabinet for this purpose and so take advantage of the pump's waste heat, thus saving some energy.

4.1.5 Controls

Controls for spas in all sectors of the market focus on keeping the water adequately filtered and heated to the temperature programmed by the user. Most new controls are equipped with many of the advantages enabled by simple electronic circuitry: digital temperature controls, password-protection prohibiting unauthorized use, timed automatic jet shut-off, etc. Some models already include energy-saving set-backs that lower the temperature when indicated by the user, or by a programmable time clock. As a rule, however, control panels do not include these and other so-called "smart" features. Smart controls could save significant amounts of energy—perhaps 5-10% of a spa's heating energy requirement—and could provide important reductions in peak load per unit, although the coincidence between peak spa heating demand and utility summer on-peak periods is low.

4.1.6 Lighting

Some manufacturers' spas include LED lighting systems, which are more efficient and longer-lived than more typical incandescent lighting. While incandescent lights each require 12-15 watts or more, LED lights (replacement or OEM) demand around 3 watts. Further, LED lights can last up to 100,000 hours of operation, whereas incandescents typically last 500 to 2,000 hours of use at best. As with pumps, waste heat from inefficient lighting to some extent offsets heating loads and therefore reduces the benefits of efficiency lighting. No data is available on the time of use for typical in-spa lighting systems, so no definitive conclusions can be made about the cost-effectiveness of such an upgrade. It is presumed, however, that spa lighting would not be on during daylight, on-peak hours.

4.2 Baseline Energy Use

Spa energy usage can be divided into three phases for purposes of energy use analysis: startup, standby, and use phases. First is the "startup" phase, during which the newlyfilled, or cold spa is brought up to a stable temperature. Ninety to ninety-five percent of the energy used in this phase is used by the heater, with the remainder used by the circulation pump, which must run continuously when the heater is on. Startup might be expected to take place around twice per year, or whenever the user is restarting the spa after an extended un-heated period. Given that most spas' heaters are of comparable efficiency, energy use during this phase will depend solely on volume, regardless of their relative overall efficiency or construction quality. The main difference between units is the time required to heat the water; this depends on the individual heater's power and the spa volume. Heaters using 220VAC will heat 4 times as fast as the same model wired for 110VAC, though the overall amount of energy used will be similar. All other factors being equal, a spa with twice the volume will take twice the time to heat up and use twice the energy to do so. A typical 350 gallon spa will use 36 kWh to bring the water to 102°F for each fill.

Second is the "standby" phase. While a heated spa is on but not being used, it consumes energy only to maintain its temperature and to keep the water mixed and filtered. This "standby" energy consumption is a true reflection of the efficiency of a given unit, since it represents the majority (75%) of the spa's annual energy use.

Finally, the "use" phase might be described as the intended operating environment of the portable spa. That is, the spa is being used perhaps once per day for at most an hour, with the cover off and the jets operating, with some external air being introduced through them. Such a usage pattern will increase energy requirements by around 25-35% over the standby scenario; the actual proportional increase depends on the particulars of the spa, its inherent efficiency, the type of use it receives, the ambient air temperature, and any on-demand features dormant during standby phase.

4.2.1 Spa Energy Consumption Estimates

Spa per unit energy consumption depends on a variety of factors including the unit's volume, design and construction (described section 4.1), the climate, hours of use per week, amount of jet use, etc. In determining average energy use and power draw of a portable spa, we drew upon many available sources of energy use data, which are summarized in Table 2.

The wide variation of unit energy consumption is notable in the table. Also, the test procedures, including usage profile and ambient temperature (two items that most influence energy consumption even among similar models) are without uniformity. Additionally, several of the estimates shown, including the lowest ones, likely include gas-heated spas not covered by this document.

Table 2: Spa End-Use Data Sources

Source	*UEC (kWh/year)*	*Notes*
Rainer, Leo, Steve Greenberg and Alan Meier 1990 "The Miscellaneous Electrical Energy Use in Homes" ACEEE Summer Study 1990.	Range:1,500-4,000 Average. 2,300	Subsequently referenced in the E-Source Tech Atlas (1996), ACEEE Consumer Guide to Home Energy Savings (1999), and various other journal articles and reports
DOE RECS (1997)	2,300	Source quoted in RECS: "Elect. Consumption by small end uses in Residential Buildings" A.D.Little, Inc., 1998
PG&E R&D, "Spa Testing Report" Report 008.1-89.9 (1989)	Standby use only: 970; 2,370; 4,200	Calculated by the authors from this report. Based on results of one test over 54 hours, for three specific spas from three different manufacturers. Spas were fully covered and unused during test period.
J-Rad Engineering "Energy Consumption Analysis of Watkins 115V Classic and 230V Classic Spa Models (1992, Sponsored by Watkins)	San Francisco: 2,214; 2,999 Sacramento: 2,136; 2,890	Model of annual use based on chamber data collected at 0, 20, 40 and 70F. Includes daily use of 1 hour with cover off and 30 minutes with jets running.
Manufacturer Data (1992-2002)	2,232 @ 60ºF ambient	www.hotspring.com; tests reported were done by Exponent Inc. Usage regimen: 6 times per week; 30 min. with cover off and 15 min. jet use.
A.D. Little (2001)	Average: 2,600	Quoted 10/24/02 by Joe Stone, Balboa Instruments, President of the Hot Tub Council. The report was commissioned by the NSPI and is confidential so details were not available.
PG&E (2004) Field Tests of Ten Portable Electric Spas	Standby use only: Range: 1,127 - 2,392 Average: 1,879	Measured standby energy use of ten new spas extrapolated to average California outdoor temperature.

Several reports warrant additional comment. First, Rainer et al (1990), the first study to list this end use explicitly, was widely quoted over the subsequent 6 years (ACEEE, Meier et al (1992 and 1994), E-Source Tech Atlas, others), and so the annual consumption figure of 2,300 kWh became a widely established reference point.

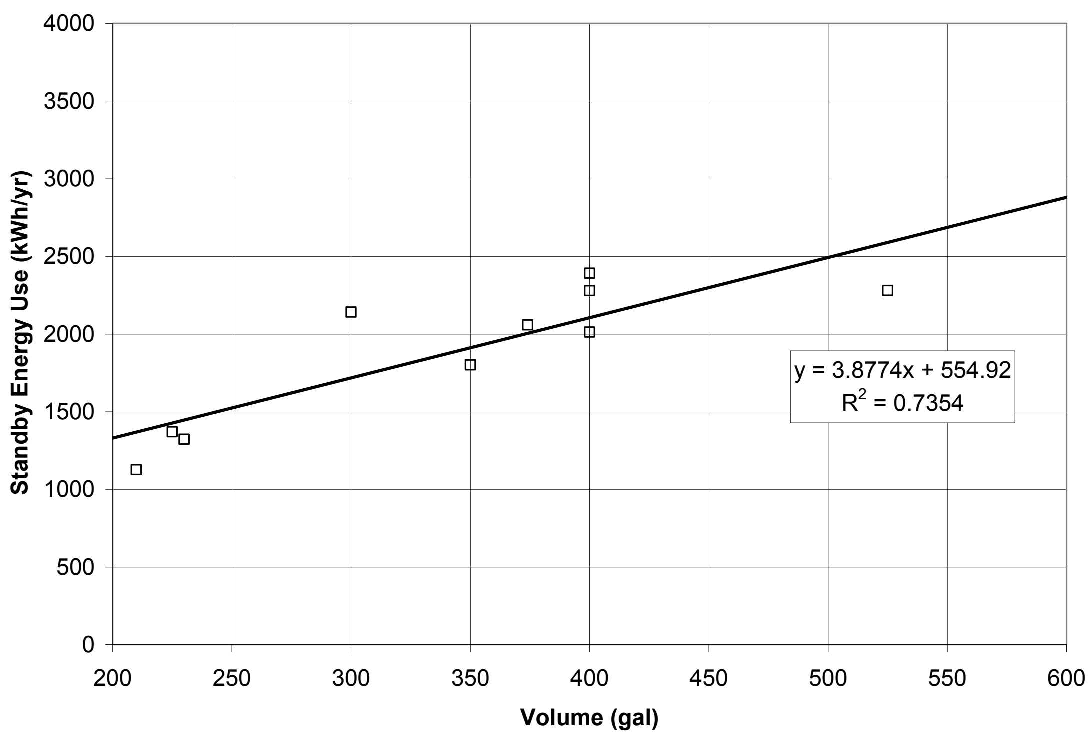
Second, PG&E (1989) testing showed a very large variation in the energy use for different spa models, particularly in the standby phase that is most relevant for the standard proposed here. The document reports only one set of tests on three particular spas, and makes no claim to be comprehensive; it is also the oldest source encountered in the literature.

Third, J-Rad's report (1992) for Watkins Manufacturing, Inc. (makers of HotSpring and other brands) gives numbers that would seem to be realistic for a generally efficient Spa receiving regular daily use of up to one hour. More recent tests contracted by Watkins, conducted by Exponent Inc. and reported on Watkins' web site, indicate UEC of 2,232 kWh for a 115V mid-size (Sovereign) model at 60ºF ambient, with just one-half of the usage assumed by J-Rad.

Fourth, RECS 1997 indicates a UEC of 2,300 kWh/year as well. It is interesting that this number, or ranges around it, appears consistently in various unrelated sources either as a bulk average usage or as a usage level representing a relatively efficient new individual spa. This makes some intuitive sense since such an average likely includes the entire range of efficiencies and usage patterns and possibly including older, smaller less powerful (and less efficient) spas.

Fifth, and last, the most recent PG&E monitoring study (2004) was designed to support this CASE study and used a consistent monitoring protocol to measure the standby energy use of new spas under field conditions. Ten spas ranging in volume from 210 to 525 gallons were monitored for three days at constant water temperature with their covers on. During this period water temperature, air temperature, and pump and heater status were all recorded and the resulting energy use was normalized to temperature difference. Figure 2 shows the distribution of annual standby energy, normalized to 60°F average outdoor temperature, by spa volume for the ten monitored spas. Adding 70 kWh for two startup cycles and 565 kWh for spa use results in a total average energy use of 2,514 kWh per year.

Figure 2: Monitored Spa Standby Energy Use



Drawing upon varied consumption data from these sources, we estimate that the average annual consumption of residential spas is around 2,500 kWh, in rough agreement with Rainer et al, RECS, and A. D. Little. In other words, given the convergence around 2,500 kWh/year as a typical consumption level for the spa population as a whole, we consider this number to represent a reasonable basis for calculations to determine recommended maximum allowable energy use under a proposed standard.

Comparing models from the same manufacturer, overall energy use is higher for larger units than the average, but per-gallon energy use tends to be lower due to decreased surface area per unit volume. Similarly, smaller units may consume less energy, but per-gallon consumption can be higher due to larger proportional losses.

4.2.2 Peak Demand

Based on a unit consumption of 2,500 kWh per year, the average load of the typical spa is 0.29 kW[7]. Because spa usage and heating energy requirements both decrease with rising temperature, the demand that is coincident with the summertime system peak will be lower. A.D. Little estimated the load factor for electric spas to be 42%[8] which results in a load of 0.12 kW, most of which will be pumping load.

4.3 Proposed Test Method

No broadly accepted standard test method currently exists for portable spas, but manufacturers literature exhibit two general approaches for comparing spas. Most common, is the calculated-energy approach, derived from component characteristics and time-of-use estimates. This approach is of limited usefulness for obtaining real-world results. Second, and rarer, are actual performance tests: prior to the field testing done in support of this CASE study work, we have found only two such studies available to the public, one funded by PG&E and one commissioned by a manufacturer. NSPI member companies indicate that the group has begun working towards the definition of an acceptable testing protocol.

A simple testing protocol focusing on the most common features and usage scenarios will encourage consistent compliance on the part of manufacturers. We propose to focus solely on standby use, since this state is where the important efficiency differences between units are most clearly revealed. This approach avoids apples-to-oranges comparisons inherent in nonstandard usage patterns and user-controlled options across brands. In addition it simplifies the test method, eliminates disagreements over what are typical spa usage patterns, and avoids penalizing added features that use energy only during the use phase such as additional jets. A reasonable test protocol would include the following elements:

- At least one test must be performed for each spa, at an ambient temperature of 60ºF[9].

---

[7] 2,500 kWh divided by 8,760 hours per year.
[8] From "Spas: The Straight Story" in Aqua Magazine, January, 2002.
[9] The average annual air temperature of California's 16 climate zones. Tests at higher temperatures may be reasonable if the energy use is normalized to temperature difference. This would ease the burden on manufacturers to perform tests in specialized test chambers.

- Minimum continuous testing time of 72 hours[10].
- Minimum spa water temperature of 102ºF. That is, the water temperature must remain at or above the test temperature of 102ºF for the duration of the test.
- Maximum ambient air temperature of 60ºF. That is, the air temperature must remain at or below the test temperature of 60ºF for the duration of the test.
- The standard cover that comes with the unit must be used during the test.
- Begin the test after water temperature has been at 102ºF for at least four hours.
- Record total energy use for period of test, starting at the end of the first heating cycle after the four hour stabilization period, and finishing at the end of the first heating cycle after 72 hours has elapsed.
- Unit is to remain covered and in the default operation mode during the test. Energy-conserving circulation functions, if present, must not be enabled if not appropriate for continuous, long-term use.
- Data reported will include: spa identification (make, model, S/N, specifications); volume of the unit in gallons; cover R-value; supply voltage; relative humidity; min/max/average water temperature; min/max/average ambient air temperature; date of test; length of test (hours:minutes); total energy use during the test to the nearest 0.1 kWh; and standby power (energy use divided by length of test).

4.4 Efficiency Measures

Measure 1: Improved cover and increased spa insulation levels.

Plentiful insulation in the spa cover and body, properly installed, is the main route to decreasing spa energy consumption, and would decrease energy use by up to 30% for a spa of average-to-low efficiency—more for the least efficient spas. It is likely that these measures would be the first ones deployed, since they require little additional engineering and design work.

Measure 2: Circulation/filtering pump Improvements.

In general this change would be understood as the addition of a low-wattage circulation pump, but other equivalent options could be imagined to achieve the same effect, such as improved pump efficiency, innovative multi-speed motor designs, variable speed control and the like. This option could save roughly 15% of the energy consumption of the average-efficiency spa and up to half of the pumping energy used for circulation and filtering. This measure would require some manufacturers to invest in product development and design work, and would likely be deployed after insulation improvements.

Measure 3: Automated programmable controls.

Controls could save about 5% of a spa’s energy consumption by permitting the user to customize settings based on anticipated usage patterns. Another potentially important

[10] This is especially important for efficient 240V spas which may have less than two heater cycles per day.

benefit would be the demand savings associated with deferring load, whether heating or routine circulation, to off-peak hours.

4.5 Standards Options

The two potential regulatory strategies for portable spas are a prescriptive standard and a performance-based standard. Prescriptive standards are advised in product categories with very similar products, few manufacturers and/or little technological or design evolution. The market for portable spas does not conform to these characteristics, and so the end goal here is to improve efficiency of spas without dictating design elements or otherwise limiting manufacturers' action within the market.

In order to implement a performance standard, a test procedure such as proposed in section 4.3 above must be used. Adoption of such a procedure would establish an objective data set with which different spas from distinct manufacturers could be compared. An appropriate performance standard should set a target maximum standby electricity consumption, in units of kWh/year, kWh/day, or simply average watts. Three approaches to defining performance requirements in terms of maximum standby consumption were considered:

1. A fixed maximum standby energy or average power limit. This has the advantage of simplicity, but could penalize large spas if set too low and could forgo savings from improvements to small spas if set too high.
2. A maximum standby energy or average power indexed to spa volume. Although there is no standard method for measuring spa volume, it is the most universally used indicator of spa size and appears to be used consistently within the industry. This method would remove the penalty imposed by a fixed limit on large spas but because spa standby energy use is directly related to total surface area (top, sides and bottom together) and not volume, it would allow large spas to be less efficient.[11]
3. A maximum standby indexed to total spa surface area. This would require all sizes of spas to be equally efficient. However, spa area is not easily defined and there is no standard for measuring it. A simpler solution that approximates indexing to surface area is to use spa volume raised to the 2/3 power. This is a value that increases linearly with total spa surface area.

The third approach for defining maximum standby consumption is proposed due to its simplicity and neutrality towards spa volume.

Given the dearth of consistent, measured, standby performance data, it was possible to establish a reasonable estimate for the average standby consumption, but more difficult to infer the distribution of performances of available models. So, rather than comparing a range of somewhat arbitrary standards levels or options, the savings associated with a series of discrete efficiency measures were assessed. This efficiency measure analysis indicates generally what savings (and associated cost-effectiveness) are available relative

[11] For a fixed proportion solid, the ratio of volume to surface area increases with size. Thus, adopting a maximum energy standard that is proportional to volume makes achieving the standard relatively easier at the larger sizes.

to a typical model. From that analysis, an appropriate performance requirement can be established.

4.6 Energy Savings

The efficiency measures discussed in section 4.4 would result in approximate average energy and demand savings as summarized in Table 3. Energy and demand savings assume 48,000 units sold per year. Aggregate numbers assume stock of 440,000 units statewide.

Table 3: Estimated Long-term Savings for Efficiency Measures

Improvement Options	*Projected Unit Savings (%)*	*Average Unit Annual Savings (kWh)*	*Projected Statewide Annual Savings (GWh)*		*Projected Statewide Demand Savings (MW)*[b]	
			1st Year	*Potential*	*1st Year*	*Potential*
Cover[a]	10%	250	12	110	0.6	5.3
Insulation	10%	250	12	110	0.6	5.3
Motor	15%	375	18	165	0.9	7.9
Controls	5%	125	6	55	0.3	2.6

[a] assumes replacement after year 5 with a second efficient cover.
[b] based on reductions from a peak-coincident unit load of 0.12kW.

As suggested in section 4.5 above, specific measures are not used to define the standard option in section 7 below, but show a range of possible efficiency gains that support the selection of a surface area normalized standby performance requirement.

5 Economic Analysis

From the point of view of energy consumption the most important factors are insulation characteristics and pumping system configuration. Lighting plays a minor role in energy consumption, though improvements are possible. In addition, the use of "smart controls", heretofore underutilized in the market, presents the potential both for lessened energy consumption and reductions of coincident loads associated with spas. This section provides cost and lifetime assumptions for the four primary efficiency measures, and then presents an incremental cost analysis for the four levels of efficiency improvements that would result from their adoption.

5.1 Incremental Costs

Table 4 lists the estimated incremental costs for the most common energy efficiency measures applicable to portable spas. With respect to controls, while the first units might require a larger adder as the market adapts to such a change and fully develops the technology for wider application, with increased acceptance the added cost should decrease significantly.

Table 4: Incremental Cost for Various Energy Efficiency Measures

Measure	*Incremental Cost*
Improved cover	$100
Improved spa insulation	$200
Improved motor configurations and efficiency	$300
Intelligent controls	$50

5.2 Design Life

The design life of a new portable spa is estimated to be 5-15 years; the more reputable manufacturers indicate 10-15 years. We assume 10 years for the spa including motors and controls, and 5 years for the cover.

5.3 Life Cycle Costs

Based on the costs, savings and lifetimes for the efficiency measures described above, we calculated the net present values for four efficiency measures, relative to the market average of 2,500 kWh/year. Note that we are considering here the actual projected savings from actual consumption, not simply from the standby use measured by the proposed testing protocol. Also, these are average savings for the spa population. Savings generated by improvements to the least efficient spas will be considerably greater than those shown here.

Table 5: Analysis of Customer Net Benefit

Improvement Options	*Design Life (years)*	*Annual Energy Savings (kWh)*	*Present Value of Energy Savings**	*Incremental Cost*	*Net Present Value***
Cover	5	250	$118	$100	$18
Insulation	10	250	$233	$200	$33
Motor	10	375	$349	$300	$49
Controls	10	125	$116	$50	$66

*Present value of energy savings calculated using a Life Cycle Cost of $0.47/kWh for 5 year options and $0.931/kWh for 10 year options (CEC 2001).

**Positive value indicates a reduced total cost of ownership over the life of the appliance

Measures that could improve efficiency by a total of almost 40% for a spa of average-to-low efficiency (annual consumption of 2,500 kWh or greater) are cost-effective from a life cycle perspective. Three of four of the savings measures are possible with current technology and within the design parameters currently in use among most if not all spa manufacturers. Beyond that, “smart” controls and increased user programmability, involve a certain amount of market development on the part of the manufacturers.

6 Acceptance Issues

6.1 Infrastructure Issues

The proposed standard is meant to spur basic efficiency upgrades to the least efficient new spas being sold in California. The majority of new portable electric spas currently sold in California would already comply with the proposed standard. For noncompliant units, current manufacturing techniques would allow straightforward implementation of the principle efficiency measures outlined here. Thus, no major infrastructure obstacles exist that might hamper the adoption of the proposed standard.

6.2 Existing Standards

The ANSI/NSPI-6 1999 standard covers portable spas. While it is commendable that the industry has made the effort to create this standard, the standard contains little to no information with respect to energy efficiency. Article 10 covers electrical connections, and article 12 covers heater and temperature requirements; both of these articles largely focus on mitigating safety risks, including both that associated with the electrical connection itself and that to the user from excessive water temperature. NSPI is said to be working on a testing protocol that would address energy efficiency issues, but no date has been established for completion of a final rule.

7 Recommendations

7.1 Recommended Standards Options

In order to require improvements to the lowest performing models, for which simple and cost effective improvements are readily available, without eliminating average and better performance products, we recommend that spa standby energy use have an upper limit calculated according to the following equation:

$$P_S = 5 \times V_S^{2/3}$$

Where:

P_S = maximum average standby power at 60°F (in watts)

V_S = spa volume (in gallons)

For a typical 350 gallon spa this results in a maximum average power use of 248 watts or 2,175 kWh/year. This is 16% greater than the average standby power found in the PG&E field monitoring study. We believe that using watts for units makes the most sense in this instance as it is measuring average standby power, not total energy use. Using kWh/year or kWh/day, while somewhat familiar units to consumers, might be misconstrued to indicate expected energy use.

7.2 Proposed Changes to the Title 20 Code Language

The following standards language is proposed for section 1605.3:

(X) Portable Electric Spas
The standby power of portable electric spas sold on or after January 1, 2006, shall be not greater than the applicable values shown in Table 6 .

Table 6

Standards for Portable Electric Spas

Appliance	*Maximum Standby Power (watts)*
Portable Electric Spa	$5V^{2/3}$

V = total volume (gallons)

8 Bibliography

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