DOE/EE-0218

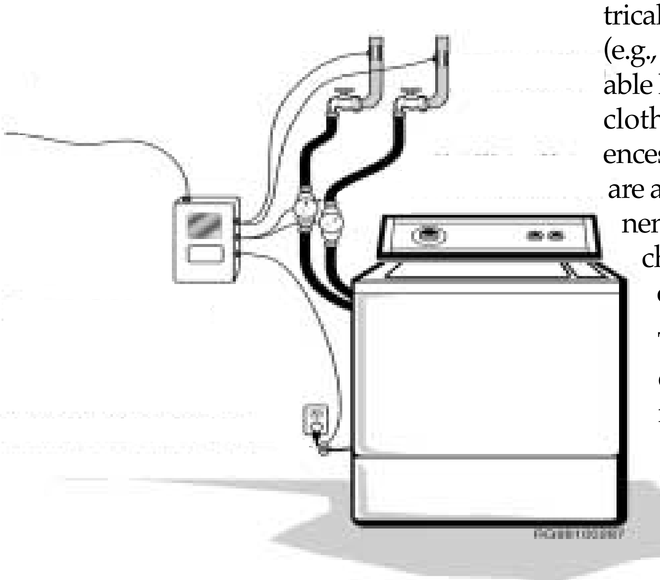
Assessment of High-Performance, Family-Sized Commercial Clothes Washers

High-performance, family-sized commercial clothes washers evaluated for their energy, water, and cost savings

The purpose of this *Technology Installation Review* is to provide an overview of high-performance, family-sized commercial clothes washers. It presents the results of a field demonstration of several brands of high-performance clothes washers performed by the Pacific Northwest National Laboratory for the U.S. Army Forces Command. The new high-performance clothes washer technology is described, and a demonstration of high-performance clothes washers used in barracks buildings at Fort Hood, Texas, is presented. The potential for cost-effective applications of this technology in the Federal sector is also discussed.

To date, there have been no comprehensive field-based studies of the new high-performance, commercial-style clothes washers in the Federal sector, and few publicly available studies have been undertaken in the private sector. The Federal sector, particularly the Department of Defense, is unique because the use of clothes washers is generally free of charge; thus there are no coin boxes or other revenue-collecting devices associated with the washers in most Federal applications.

This study serves to document the water and energy consumption of conventional (baseline) clothes washers, as well as the water and energy consumption of high-performance clothes washers of four different manufacturers (Alliance Laundry Systems, Maytag Corporation, Staber Industries, Inc., and Whirlpool Corporation). The resulting life-cycle costs and net present value of the high-performance clothes washers compared to conventional clothes washers are also discussed.



Fort Hood clothes washer metering equipment and connections.

Technology Description

The high-performance commercial clothes washers that are the focus of this *Technology Installation Review* look very similar to a residential-style clothes washer in terms of size (e.g., physical dimensions), features (i.e., water supply, wastewater discharge and electrical connections), and mounting/installation (e.g., "soft-mount" set up using standard adjustable legs). For most soft-mount commercial clothes washers, the most significant differences compared to a residential clothes washer are a sturdier frame and mechanical components, a modified control panel with fewer choices of control settings, and a shorter cycle time.

The common industry term used for the commercial clothes washers described in this study is "on-premise laundry" (OPL). The OPL-type of clothes washers are similar in durability and construction to full commercial-type clothes washers; however, they do not have coin boxes or debit card readers or

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their coin boxes/card readers are rendered inoperable (i.e., the use of the washers is free).

In the private sector, these clothes washers are generally only available to be purchased "commercially" and thus are sold outside the normal retail sales channels. This is an important distinction since commercial clothes washers are not subject to Federal appliance efficiency testing standards and as such are not sold with a Federal Trade Commission EnergyGuide label indicating their efficiency and comparing their efficiency to similar models. However, some manufacturers of high-performance commercial clothes washers have agreed to voluntarily provide performance testing information as part of their participation in the Consortium for Energy Efficiency (CEE) High-Efficiency Commercial, Family-Sized Clothes Washer Initiative©. Participation in this CEE Initiative is voluntary, and this is the only program that establishes minimum performance criteria for commercial clothes washers. Three of the four manufacturers represented in the case study are a part of the CEE initiative.[a]

Principles of Operation

High-performance, family-sized commercial clothes washers have been available since early 1997. They achieve energy and water savings by reducing the amount of water used per wash cycle. The majority of energy savings are achieved in most high-performance washers by reducing the hot water used while a smaller but significant portion of the energy savings are achieved through the use higher-efficiency motors. Most manufacturers accomplish water savings by changing their washer design from a vertical axis (V-axis), agitator-type design, to a horizontal-axis (H-axis) design. One manufacturer, however, has achieved significant water savings with a V-axis design through the use of spray rinses.

With the H-axis design, the washer drum rotates around a horizontal, rather than vertical, axis. The benefit of the H-axis washer design is that the drum only partially fills with water during the wash and rinse cycles; as the drum turns about its horizontal axis, the clothes are tumbled into and out of the water. In contrast, a *standard* V-axis clothes washer requires the clothes to be fully immersed in water and moving about a central agitator for proper washing and rinsing. As reported by the U.S. Department of Energy (DOE), for residential clothes washers in a residential household, the water and energy savings from an H-axis clothes washer can be as great as 50% over a standard V-axis clothes washer.[b]

H-axis design washers can be either top-loading (like a standard V-axis machine) or loading through a front-opening door. The net drum volume for commercial H-axis washers ranges from 1.9 to 2.9 ft^3; the net drum volume for commercial V-axis washers ranges from 2.5 to 3.0 ft^3.

Maintenance, Service, and Operation

High-performance commercial clothes washers, either V-axis or H-axis, are maintained in a similar manner as new standard commercial clothes washers. In the high-performance machines, the controls are a combination of standard electronic and electro-mechanical, with a few added features for controlling door/lid locks and the spin cycle on H-Axis machines. The wash settings/cycles are those commonly found on coin-operated commercial machines. For H-axis machines, the motors and gearing are designed to spin the drum in both directions and are also designed to spin the drum at a very high speed (greater than 700 rpm) in order to remove moisture from the clothes to a lower remaining moisture content[c] than in most standard V-axis machines. As such, the motor/gearing, drum support, and balancing mechanisms are novel compared to standard V-Axis machines and are very sturdy but generally do not require additional maintenance.

For safety purposes, the door or lid is locked on H-axis machines at the start of a cycle and can only be opened after the machine is fully stopped. It may take time for first-time users to become accustomed to this feature. The water level, however, is never above the bottom of the door on front-opening machines; thus there is no chance of a significant water spill if the door is inadvertently opened before the drum has stopped turning. Like most commercial-style machines, wash chemicals (soap, bleach, fabric softener) are added prior to starting a cycle and are dispensed automatically at the correct times during the cycle. Chemicals

(a) The CEE specifies a minimum performance level to qualify for their program and voluntary reporting of the performance level by the manufacturers. See http://www.ceeformt.org for more information.

(b) Tomlinson, J.J., and D.T. Ritzy. *Bern Clothes Washer Study Final Report*. ORNL/M-6382. Oak Ridge National Laboratory, Oak Ridge, TN. March 1998.

(c) Remaining moisture content is the weight of water in a "spun" load of clothes as a percentage of the dry weight of the load.

are added either through a dispenser on the top of the machine or in a drawer at the front of the machine.

Some manufacturers of high-performance clothes washers, primarily those that use H-axis technology, claim savings from reduced use of chemicals, principally soap. H-axis manufacturers state that conventional laundry detergents are designed to work in V-axis clothes washers that have a completely different wash system than H-axis clothes washers. Because H-axis washers have no agitator, the drum baffles help move the clothing through the water, which results in entraining air into the detergent solution. This action creates a greater amount of suds than in a conventional V-axis machine. Thus the combination of less water and the tumbling action requires less soap (either liquid or powder) to obtain the cleaning action. No independent publicly available data is currently obtainable to substantiate or quantify cost savings due to reduced soap usage.

Manufacturers of H-axis technology also recommend using soap specifically designed for H-axis (or high-performance) machines to assure the correct and sufficient concentration of cleaning chemicals and at the same time reduce the potential for excess sudsing. Most H-axis machines have a suds control feature that detects when suds are excessive and alters the cycle during washing to dilute the suds to an acceptable level.

The available capacity (e.g., net drum volume) of high-performance commercial clothes washers is equivalent to the available capacity of standard commercial clothes washers. The volumes range from 1.9 to 3 ft^3 for the high-performance machines compared to volumes of 2.5 to 3 ft^3 for conventional commercial-style clothes washers.

Measures of Efficiency

A measure of clothes washer energy efficiency is the annual energy consumption (kWh/year), which assumes a given number of clothes washing cycles during that period. For residential clothes washers, the calculation is based on 392 cycles per year. As noted, the Federal Trade Commission provides this information on each residential clothes washer in the yellow and black EnergyGuide label attached to every machine sold. In addition, the Federal government sets a minimum standard and a standard testing procedure for residential clothes washer performance in terms of the washer energy factor, noted in units of tub volume ft^3/kWh/cycle (although this value is **not** reported on the EnergyGuide).[a] Energy factor is the normalized (to net tub volume) measure of energy consumption (mechanical/motor and water heating) per standard wash cycle; it is important to note that the *higher* the energy factor the more efficient the clothes washer. The current minimum energy factor for residential washers is 1.18 ft^3/kWh/cycle. The Environmental Protection Agency (EPA)/DOE Energy Star® Program has established a minimum energy factor of 2.5 ft^3/kWh/cycle for all residential clothes washers to qualify as an Energy Star clothes washer. Thus for this study, a commercial OPL clothes washer was considered "high-performance" if it meets this minimum energy factor (as indicated by the manufacturer and/or by CEE), *even though commercial clothes washers are not required by Federal law to be tested and labeled*. The term "conventional" clothes washer is the term used in this study if the clothes washer does not meet this minimum energy factor.

Other measures of clothes washer efficiency are the water factor, which is a normalized (to net tub volume) measure of water consumption per cycle measured in gallons/ft^3/cycle, and remaining moisture content. Here it is important to note that the *lower* the water factor and remaining moisture content, the higher the efficiency. Neither metric is required by the Federal government to be reported as part of the testing and certification process for residential clothes washers, but is voluntarily reported by the manufacturers as part of the CEE Commercial, Family-Sized Clothes Washer Initiative©.

High-Performance Clothes Washer Energy and Water Savings

Based on the results of the Fort Hood study (see Fort Hood Demonstration below), the baseline, conventional V-axis, large-capacity clothes washer used 35.4 gallons of water/cycle, of which 9.0 gallons was hot water and 26.4 gallons was cold water. The average water use of the four high-performance clothes washers was 18.8 gallons, of which 3.4 gallons was hot water and 15.4 gallons was cold water. Thus the high-performance machines saved an average of 5.6 gallons of hot water and 11.0 gallons of cold water, for a total of 16.6 gallons of water compared to the baseline conventional V-axis washers. The

(a) "Uniform Test Method for Measuring the Energy Consumption of Automatic and Semi-Automatic Clothes Washers," Code of Federal Regulations, Title 10, Part 430, Subpart B, Appendix J.

water use reduction for the high-performance machines averaged 42% of cold water, 62% of hot water, and 47% of total water.

The baseline conventional clothes washer used an average of 0.26 kWh/cycle for the motor and controls (i.e., "machine-energy"). The average of the four high-performance clothes washers used 0.20 kWh/cycle for motor and controls, a savings of 0.06 kWh/cycle, or 23% of baseline use. The baseline clothes washer used an average of 5,610 Btu/cycle of hot water energy while the average of the four manufacturers' high-performance clothes washers used 2,120 Btu/cycle of hot water energy. This data results in a savings (at the clothes washer) of 3,490 Btu/cycle, or 62% of hot water energy use for each wash cycle; note that these savings do not include conversion inefficiencies in generating the hot water.

The average wash cycles of the four high-performance brands at Fort Hood over the time period of the study were 6.4 cycles/day/machine. Based on this daily number of cycles for an entire year (365 days), the water *savings* over the baseline machines was 38,780 gallons/year/machine, the machine-energy *savings* was 140 kWh/year/machine, and the hot water energy *savings* (at the machine) was 8.1 million Btu/year/machine. Based on the Fort Hood hot water delivery system and utility rates,(a) the total water cost savings was $39/year/machine, the total hot water energy cost savings was $43/year/machine, and the machine electrical energy cost was $4/year/machine, resulting in a *total average cost savings of $86/year/machine* for the high-performance brands compared to the average for the conventional baseline clothes washers. The potential savings for the entire Federal sector is given below.

Cost-effectiveness

The cost-effectiveness of these clothes washers varies with energy cost, the combined water/wastewater cost, and washer use. Assuming the usage and performance results from Fort Hood, the average Federal utility rates (electricity at 6.0 cents/kWh, natural gas at 40 cents/therm, and water/wastewater at $3.00/1,000 gallons), the 1999 Federal discount rate of 3.1%, and a 5-year clothes washer life, the present value of savings is estimated to be $850 (see section titled Economic Results). This value represents the accumulated savings over the 5-year life, in 1999 dollars; thus one could pay up to an additional $850 (above the conventional V-axis clothes washer) for a high-performance clothes washer to be life-cycle cost-effective under these performance and economic criteria.

To calculate the net present value of this technology over the baseline technology, one must subtract the incremental capital cost of the high-performance technology (i.e., the additional cost of the high-performance clothes washer over the standard clothes washer) from the present value of savings. For example, if the present value of savings is estimated to be $850, and the incremental cost of the high-performance technology is $400, then the net present value is $850 - $400 = $450. The significance of the net present value can be thought of this way: when making a decision on purchasing this technology, one should be indifferent between purchasing this technology or receiving $450 today.

An average manufacturer's suggested price range for the baseline V-axis clothes washer is $250–$400. For the high-performance clothes washers this range is $600–$1,500 with the V-axis, high-performance clothes washers at the lower end of this range. In all cases, because these are "manufacturer's suggested" price ranges, significant discounting to the Federal sector (via GSA) can be expected.

Federal Sector Potential

The greatest potential for Federal sector application of high-performance commercial clothes washers is in the U.S. Department of Defense (DoD), specifically on military installations. Military installations (CONUS) account for over 85% of the existing commercial clothes washers, primarily in barracks, daycare, and recreation centers.(b) Based on personnel levels, barracks inventory and an average DoD ratio of 1 washer/15 barracks occupants, there are about 26,000 commercial clothes washers in use in the military and the U.S. Coast Guard combined. The total in the Federal sector is estimated at approximately 28,000 to 30,000 commercial clothes washers. The entire Federal sector procures an estimated 6,000 to 7,000 commercial clothes washer each year

(a) Natural gas @32 cents/therm and a 60% efficient hot water generation/distribution system; 3.2 cents/kWh electricity cost and $1.00/1000 gallons water/wastewater cost.

(b) Note that military/federal family housing is not included since most of the purchases for family housing are by the residents, and these purchases are predominantly residential-style clothes washers.

with DoD accounting for 5,000 to 6,000 of those purchases.[a]

The estimated savings for the Federal sector if all commercial clothes washers procured each year were high-performance machines based on purchasing 6,000 high-performance clothes washers/year is 232 million gallons of water/year, 840 MWh/year (motor and controls energy savings), and 64.8 billion Btu/year (assuming water is heated using natural gas with a conversion efficiency of 75%). The resulting total water and energy cost savings are estimated at $1 million per year.[b]

Appropriate Applications

High-performance commercial clothes washers are suitable for use in any application where conventional (V-axis) residential style or commercial clothes washers are currently being used. They are dimensionally the same size as standard large/super large capacity residential clothes washers. High-performance commercial clothes washers can weigh up to 60% more than a conventional (V-axis) residential large/super capacity washer, due primarily to the added weight needed for proper balancing during high spin speeds. All manufacturers' high-performance, family-sized commercial clothes washers (except those currently available from Staber Industries and Whirlpool) are offered in models with a stacking dryer for applications where space is limited. And, with the exception of the model currently offered by Whirlpool, the high-performance machines are also available with coin boxes or electronic debit card readers for applications where customers pay to use the machine.

The primary and most cost-effective application in the Federal sector is in military barracks laundry rooms and other locations where the clothes washers are in use several times each day. The high-performance clothes washer machines have a higher first cost than most conventional commercial clothes washers, but have significant operating cost savings; thus they become more cost-effective the greater the number of cycles they are used each day.

Maintenance Issues

Manufacturers offer the same standard warranty on high-performance, family-sized commercial clothes washers as they do for their standard family-sized commercial clothes washers, ranging from 1 to 3 years. Once the washers are properly installed and balanced by the supplier of the equipment (very important for H-axis machines since the drum spins at a very high speed), and the maintenance contractor/staff is trained to maintain the new high-performance family-size commercial clothes washers, there are no special or additional routine maintenance requirements for this equipment compared to conventional family-size commercial clothes washers.

Two common maintenance issues for high-performance machines, particularly the H-axis washers, are over-sudsing due to using too much conventional washer-type soap, and, predominantly from one manufacturer, broken lid locks. It is typical for first time users of H-axis, high-performance machines to add the same amount of soap as they are used to adding to standard machines. H-axis machines, as noted above, are designed to use less soap. The H-axis machines all have a sensor that is designed to take corrective action in the event of over-sudsing. In general, over-sudsing does not require maintenance unless the over-sudsing causes overflowing and results in machine damage.

It is also typical for users of H-axis machines to initially attempt to open the access door without waiting for the lid to unlock, thus either breaking the lock mechanism or otherwise disabling it and requiring repair. User training regarding use of soap and instructions about the lid lock, combined with a robust design of the locking mechanism, will reduce this occurrence.

Utility Incentives

Many utilities are offering incentives, principally direct rebates ranging from $50 to $150/washer to the buyers, for the purchase of commercial high-performance clothes washers (OPL as well as coin/card-operated). Utilities include energy utilities as well as water/wastewater utilities. For all utility programs for commercial clothes washers, the minimum performance levels to qualify for the rebates are based on criteria established by the CEE that include a combination of energy factor, water factor and remaining moisture content. An up-to-date listing of the participating utilities, the minimum

(a) Assumes a 5-year life for the washers. Procurement includes purchase as well as leasing from clothes washer distributors, route operators, etc.

(b) Assuming an average electricity rate of 6.0 cents/kWh, average natural gas rate of 40 cents/therm, and average water/wastewater rate of $3.00/1000 gallons. This also assumes that all hot water is generated by steam fed from a natural gas-fired central plant with a 75% efficient delivery system.

qualification criteria, and qualifying clothes washers can be found on the CEE website at www.CEEforMT.org; other information, including the latest utility incentives, can be received by calling CEE at (617) 589-3949.

Fort Hood Demonstration

Fort Hood Army installation located near Killeen, Texas, was a site for a demonstration of high-performance, family-sized commercial clothes washers. This demonstration was conducted by the Pacific Northwest National Laboratory for the U.S. Army Forces Command.

The objective of the study was to measure, analyze, and report on the efficiency of the high-performance clothes washers relative to the conventional (baseline) V-axis clothes washers in use at the installation. While the information reported here is believed to be accurate, it is not from a controlled experiment. All findings presented here are "average" consumption and use findings specific to the Fort Hood barracks setting and thus represent an accurate long-term "average" use profile of clothes washers at Fort Hood. The characteristics of the clothes washers evaluated in this study are shown in Table 1.

The Demonstration

The demonstration involved three nearly identical barracks buildings of the same style, size, and occupancy levels (~ 140 troops/barracks). The barracks also housed soldiers from the same military assignment/training and thus had similar laundry use requirements. Each of the three barracks buildings has one central laundry room containing six clothes washers and six clothes dryers.

Each of the three barracks buildings' laundry rooms received identical end-use metering equipment that included a central data logger to record and store the relevant per-cycle energy and water data from each of the six clothes washers. The baseline V-axis and the high-performance clothes washers were all identically monitored for the following parameters: hot and cold water temperature (using resistance temperature devices—RTDs), water use (using separate hot and cold water meters), and washer electricity use (using a current transformer—CT).

All data stored in the central data logger was retrieved on a weekly basis over a phone line through the central polling computer. Figure 1 details the metering arrangements common to each clothes washer.

Metering Duration and Cycles

The metering of the six baseline conventional (Roper) clothes washers in one laundry room took place over a 2-month time period in late 1997 and included 1,050 wash cycles. The baseline clothes washers were then replaced by six high-performance clothes washers from a single manufacturer and these were likewise metered. High-performance clothes washers were also located in the other two identical-sized laundry rooms and were metered. Each metered laundry room was equipped with six high-performance clothes washers from the same manufacturer. Metering of the high-performance clothes washers took place over a 17-month time period from

***Table 1**. Fort Hood clothes washer characteristics.*

Clothes Washer Brand/Manufacturer (Model #)	Age of Equipment at Start of Study	Tub Volume[1] & Machine Weight	Axis of Rotation of Tub	Clothes Loading Location	Number of Access Doors for Loading
Roper/Whirlpool Corp. (AL6245VWO) **Baseline Clothes Washer**	6 years	2.50 ft^3 ~170 lb	Vertical	Top	1
Maytag/Maytag Corp. (MAH14PNAWW)	New	2.86 ft^3 181 lb	Horizontal	Front	1
Speed Queen/Alliance Laundry Systems (SWF561)	New	2.80ft^3 240 lb	Horizontal	Front	1
Staber/Staber Industries, Inc. (2300)	New	1.93 ft^3 220 lb	Horizontal	Top	2
Whirlpool/Whirlpool Corp. (LSW9245)	New	3.0 ft^3 ~175 lb	Vertical	Top	1

(1) Volume determined according to US DOE test procedure: "Uniform Test Method for Measuring the Energy Consumption of Automatic and Semi-Automatic Clothes Washers," Code of Federal Regulations, Title 10, Part 430, Subpart B, Appendix J.

In comparing clothes washers it is important to note their tub volumes; smaller tub volume may result in more clothes washing cycles (thus more energy and water use) to wash a given volume of laundry.

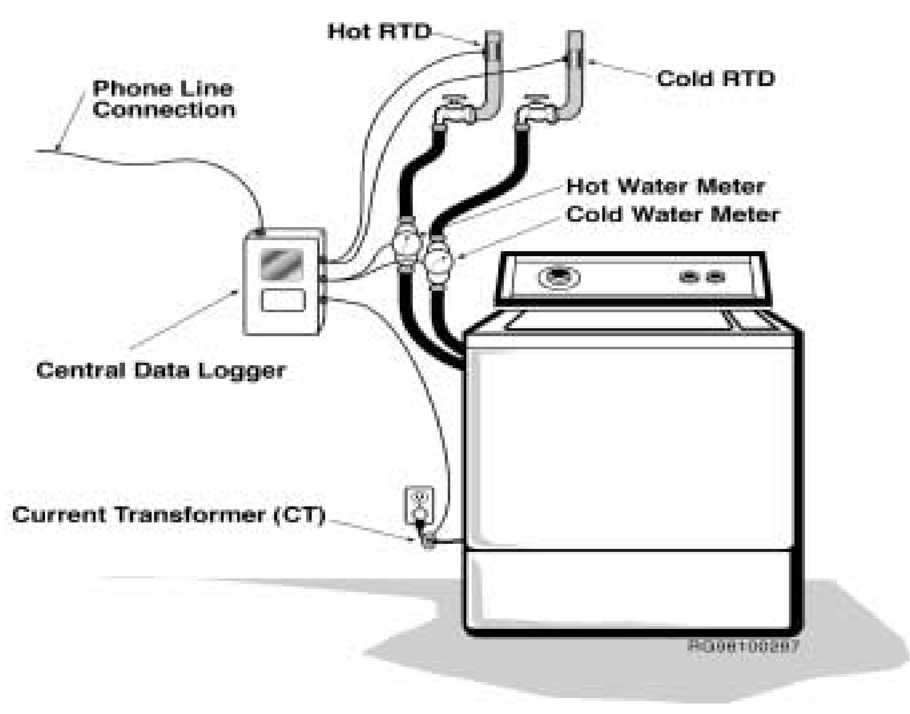

Figure 1. Fort Hood clothes washer metering equipment and connections.

February 1998 through July 1999. During this metering period, the use of the high-performance washers ranged from 1,918 to 5,078 cycles/manufacturer, with an average of 3,026 cycles/manufacturer.[a]

Performance and Operations Results

Figure 2 presents the average motor and controls electricity (machine electricity) use in kWh/cycle. The four high-performance brands showed a reduction in machine electricity use over the baseline machine electricity use of 0.26 kWh/cycle. The average high-performance machine electricity use was 0.20 kWh/cycle. This resulted in an average electricity use reduction of 0.06 kWh/cycle (or 23%) for the four high-performance brands.

Figure 3 presents the average gallons/cycle with both the hot water and cold water components of the average total water use shown. The four high-performance brands showed a significant reduction in total average water use over the baseline machine water use of 35.4 gallons/cycle. The average high-performance total water use was 18.8 gallons/cycle, resulting in water savings of 16.6 gallons/cycle. These savings represent a 47% reduction in total water use.

The baseline conventional machines used an average of 9.0 gallons hot water/cycle whereas the average high-performance hot water use was 3.4 gallons/cycle.

The average reduction in hot water use by the four high-performance brands was 5.6 gallons/cycle, or 62% of the baseline machine.

The average cycles/day for each machine in the study varied considerably ranging on average from 3.2 to 10.9 cycles/day for all 30 machines (six conventional baseline machines

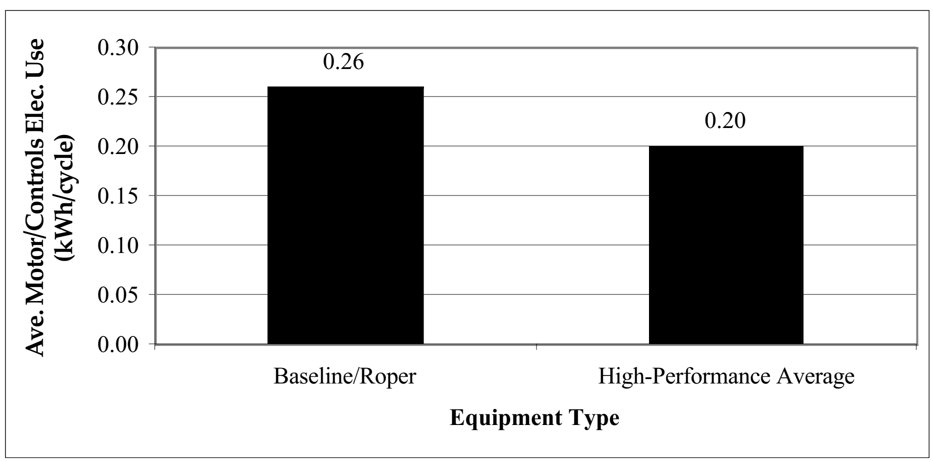

Figure 2. Average motor and controls electricity use (average kWh/cycle).

(a) The relatively short duration of metering the baseline clothes washers compared to duration of the metering of the high-performance clothes washers was due to the site scheduling the replacement of all their V-axis washers with new high-performance washers during the time of the baseline metering.

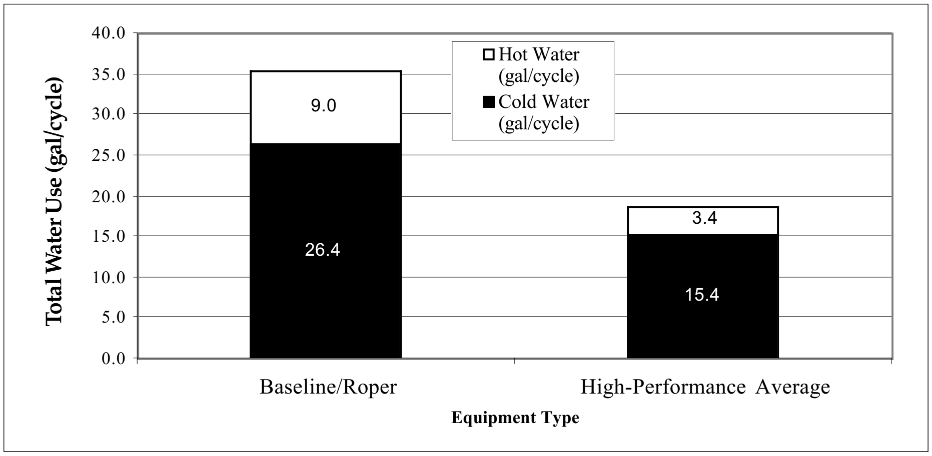

Figure 3. Average total water use (average gallons/cycle).

plus 24 high-performance machines) that were monitored. For the baseline (Roper) conventional machines, the average over the time period of monitoring for all six machines was 4.2 cycles/day. For the high-performance machines, the average was 7.0 cycles/day over the time period of the monitoring for all 24 machines.

In most cases, the variance in individual machine use was related to troop activity (i.e., variable occupancy levels due to field exercises). Other variables included the physical location of the machine relative to the laundry room door. The machines closest to the door received the greater use, which was expected. On average, the first two clothes washers nearest the door were used 55% more often than the two clothes washers farthest from the door.(a)

It should be noted that in comparing between the high-performance clothes washers studied, consideration should be given to the clothes washer tub volume. Clothes washers of different tub volumes will have an impact on the amount of clothes washed per cycle and therefore on the amount of annual energy and water use and savings; the relevance of this point is that three of the four washers studied here have significantly larger tub volumes than the fourth. In fact, while showing relatively similar energy and water use, the three larger machines theoretically would be capable of washing a load about 30–40% larger (based on their relative tub volumes) and thus have a higher efficiency per unit of laundry washed. This point is relevant in situations where full loads are commonly washed.

Economic Results

Based on Figures 1 and 2, the four high-performance brands **saved** an average of 5.6 gallons of hot water, 11.0 gallons of cold water, and 16.6 gallons of total water for each cycle of use compared to the average for the baseline conventional V-axis washers. Thus the savings by the four high-performance brands was 62% of hot water, 42% of cold water, and 47% of total water.

The baseline conventional clothes washers used an average of 5,610 Btu/cycle of hot water energy (at the clothes washer), and the average of the four high-performance brands used 2,120 Btu/cycle/machine in hot water energy. This is an average hot water energy savings of 3,490 Btu/cycle/machine and does not take into account hot water conversion inefficiencies. Given the average use of all five manufacturers' machines (baseline plus high-performance) at Fort Hood over the time period of the study of 6.4 cycles/day/machine and extrapolated for an entire year (365 days), the total water savings of the high-performance machines compared to the baseline conventional machines at Fort Hood is 38,780 gallons/year/machine. The machine energy savings is 140 kWh/year/machine, and the hot water energy savings at the clothes washer is 8.1 million Btu/year/machine.

Based on Fort Hood utility rates,(b) the total water cost savings is $39/year/machine, the total machine electrical cost savings is $4/year/machine, and the hot water energy cost savings is $43/year/machine for the high-performance machines. This results in a *total cost savings of $86/year/machine* for the average of the four high-performance brands compared to the conventional baseline clothes washers.

(a) In discussions with commercial clothes washer route operators, this same phenomenon necessitates these operators to rotate equipment so that equipment is used uniformly thus extending its life.

(b) Assuming 60% efficient hot water generation and distribution system, 32 cents/therm natural gas cost, 3.2 cents/kWh electricity cost, and $1.00/1000 gallons water/wastewater cost for Fort Hood.

Data is presented in Figures 4 and 5 showing expected lifetime water and energy cost savings of the high-performance clothes washers compared to conventional (baseline) V-axis clothes washers. The values used to develop the curves in Figures 4 and 5 are given in Table 2.

Figure 4 presents the present value of lifetime combined energy and water savings for the average of the four manufacturers' high-performance clothes washers (compared to the conventional baseline clothes washer) as a function of water/sewer price ($/1,000 gallons) and natural gas price (cents/therm), assuming water is heated using natural gas with a 75% conversion efficiency.

Figure 5 presents the present value of lifetime combined energy and water savings for the average of the four manufacturers' high-performance clothes washers (compared to the

How to Read and Use the Graphs

For either Figure 4 or Figure 5, select your combined water and sewer rate ($/1,000 gallons) on the horizontal (X) axis and trace a vertical line to the curve representing your natural gas or electricity rate. At that intersection, trace a horizontal line to the vertical (Y) axis to identify the value corresponding to "Present Value of LifeTime Energy and Water Savings ($1999)." This dollar value is the present value of life-cycle savings of a high-performance clothes washer compared to a conventional clothes washer. This value does not include the incremental capital cost of the high-performance clothes washer (if any) over a conventional clothes washer. Therefore, this value represents the maximum incremental (or additional) capital cost one should pay for a high-performance clothes washer over the cost of a conventional clothes washer, given the assumptions for this analysis in Table 2. For example, from Figure 4, at a water/sewer rate of $3.00/1000 gallons and a natural gas cost of 40 cents/therm, the present value of lifetime savings is $850. Thus one could pay up to an additional $850 (above the cost of a conventional V-axis clothes washer) for a high-performance clothes washer to be life-cycle cost-effective under these performance and economic criteria.

The economics and cost-effectiveness of high-performance clothes washers based on water and energy savings will vary greatly with utility rates and clothes washer usage (i.e., cycles/day/machine). The lifetime energy and water savings will also vary by the performance (water and energy used) of individual manufacturer's machines. Since Figures 4 and 5 are based on the aggregated average performance of the four manufacturers' high-performance machines, the lifetime energy and water savings of individual manufacturer's high-performance machines may be different than the values show in the figures.

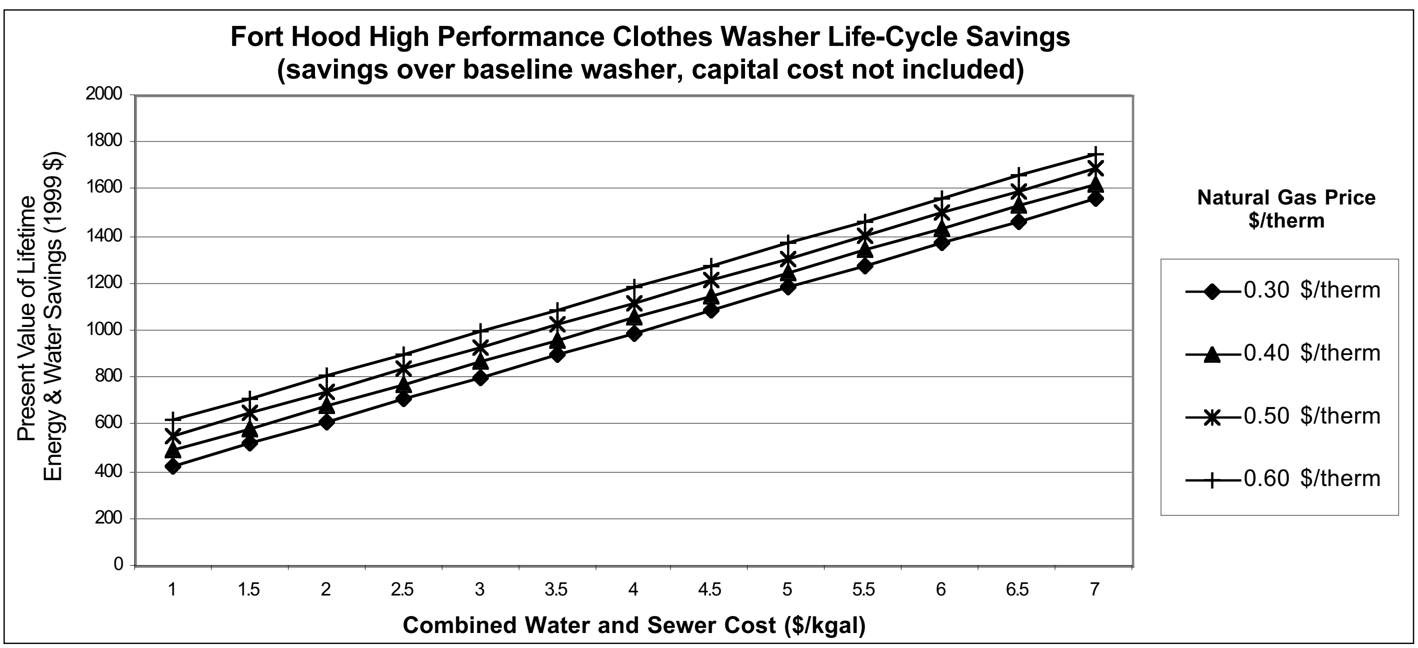

__Figure 4__. Average high-performance clothes washer lifetime savings—natural gas water heating.

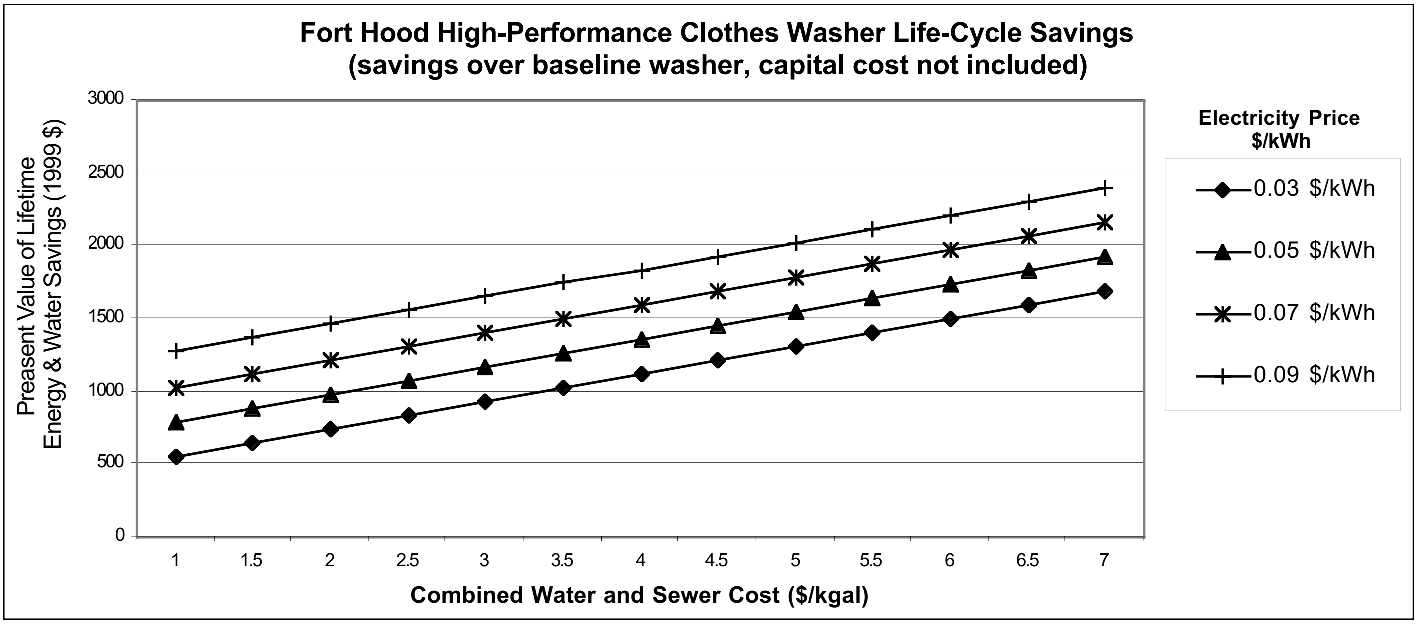

Figure 5. Average high-performance clothes washer lifetime savings—electric water heating.

conventional/baseline clothes washers) as a function of water/sewer price ($/1,000 gallons) and average electricity price (cents/kWh), assuming water is heated using electricity with a 100% conversion efficiency. In Figure 4, the savings for the machine (motor and control) electrical energy is fixed at 6 cents/kWh and included in the analysis; in Figure 5, this savings is calculated based on the selected electricity rate.

***Table 2**. Values used for clothes washer economic analysis.*

Economic Analysis Metric	Value	Source/Notes
Baseline motor/controls electricity (kWh/cycle)	0.26	Average of the baseline (conventional) machines metered values
Baseline machines water consumption: hot/cold/total (gal/cycle)	9.0/26.4/35.4	Average of the baseline (conventional) machines metered values
High-performance machines motor/controls electricity Consumption (kWh/cycle)	0.20	Average of the four high-performance brands metered values
High-performance machines water consumption: hot/cold/total (gal/cycle)	3.4/15.4/18.8	Average of the four high-performance brands metered values
Clothes washer use (cycles/day/machine)	6.4	Average value of all machines metered in the study
Clothes washer life (years)	5	Typical commercial (OPL) washer life or lease term
Discount Rate (%)	3.1	Federal government discount rate for 1999

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