"High-Efficiency Washing Machine Demonstration, Bern, Kansas"

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Abstract-

The Department of Energy (DOE), the citizens from Bern, Kansas, Maytag Corporation, the Bureau of Reclamation, and the Kansas Rural Water Association cooperated to measure water and energy savings derived from using high-efficiency, horizontal-axis (h-axis) washing machines in a demonstration project in Bern. Maytag provided new machines to participants' homes in and around Bern--a town that has historically suffered from water shortages. The townspeople participated by recording information to determine water and energy savings from using the new machines.

Conventional domestic clothes washers use about 40 gallons of water to wash a load of clothes which typically may weigh only 7 pounds. In addition, an average U.S. home washes one load of laundry each day. These facts make automatic clothes washers one of the highest end-uses of water in today's homes. About 35 billion loads of laundry are washed annually in the U.S. consuming 2.6 percent of the total residential energy use.

Most clothes washers produced for the U.S. consumer are vertical axis (v-axis) washers with a central agitator. While there are variations, most v-axis washers suspend the clothes in a tub of water for washing and rinsing. The horizontal axis (h-axis) washer tumbles the wash load repeatedly through a pool of water at the bottom of the tub to produce the needed agitation. This approach tends to reduce the need for both hot and cold water. The h-axis washer, popular in Europe, has a very limited market share in the U.S. at present.

The objectives of this project were:

- to evaluate the energy and water savings of high-efficiency washers in a community converted to the new design,
- to demonstrate the findings, and
- to help develop information to support moving the current clothes washer market to higher efficiency options. This project is a key element under

DOE's ENERGY STAR market transformation program.

A more detailed account of the study findings (1) can be found on the Internet at: www.energystar.gov.

Introduction-

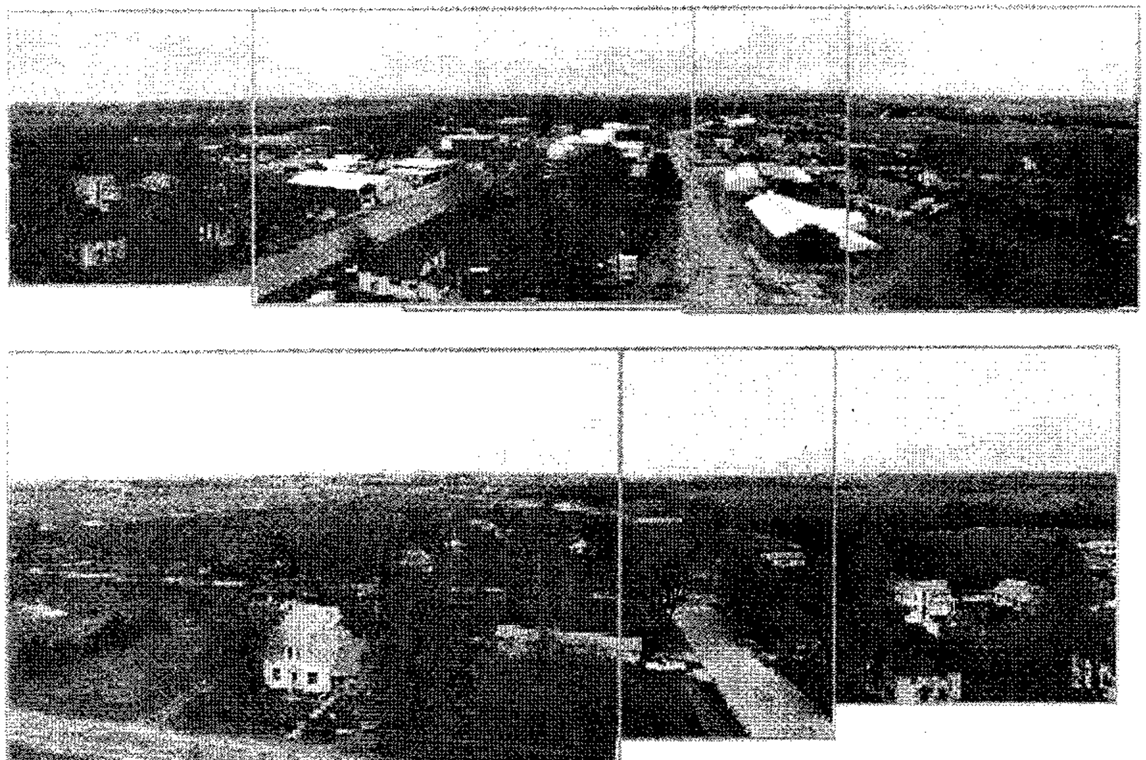

Figure 1 - Panorama view of Bern, Kansas, from grain elevator

The small town of Bern, Kansas (figure 1), population of approximately 200, was selected for this project. During phase I of the study, 103 clothes washers in the town and surrounding Rural Water District (RWD) were instrumented so that data on customer profiles, laundry habits, laundry throughput (loads and load weight), and energy and water consumption could be measured. Following a 2-month data collection period, all of the washers were replaced by new, h-axis clothes washers, and the experiment continued for an additional 3-month period. Detailed data were collected and analyzed on more than 20,000 loads and nearly 70 tons of wash done over a wide range of real-world conditions. Overall, it was found that the changeover to the h-axis washer reduced the average water consumption from 41.5 gallons/load to 25.8 gallons/load a water savings of 38 percent. The h-axis washer's energy consumption including washer energy and hot water energy fell by 58 percent due to hot water savings and the impact of a highly efficient motor in the h-axis. This savings did **not** include reduction of the remaining moisture content of damp loads removed from the h-axis washers. This savings was, on average, 7 percent lower moisture than for loads removed from participants' phase

I v-axis washers, and would further improve the energy savings from the changeover, since the dryer (gas or electric) consumes less energy.

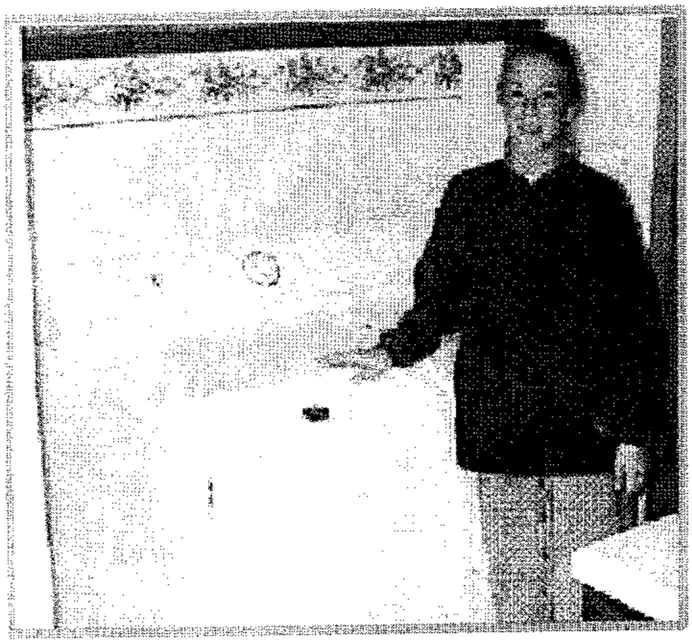

Figure 2- H-axis washer with study participant, Jill Meyers

The field experiment began on June 2 with installation of monitoring equipment on the existing washing machines of each participating family in town and the surrounding rural area. On June 28, a "Super Wash Saturday" was held to monitor the water consumption from the distribution systems for the town and RWD. Participating residents saved their laundry during the week and washed their clothes on the "Super Wash Saturday." A total of 104 h-axis machines (figure 2) were installed in homes during the week of July 28. Townspeople monitored their water usage for a 3-month period. A second total system water measurement was conducted on September 13, when the town held another "Super Wash Saturday" with the new high-efficiency machines.

Project Summary-

The Oak Ridge National Laboratory, part of the DOE, provided project direction, experimental design analysis and reporting for the project. Reclamation provided municipal water measurement, instrumentation, and on-site personnel to determine the town's total water consumption before and after installing the high-efficiency washing machines. These measurements were based on water supplied through the distribution systems for the town and the RWD. The Kansas Rural Water Association provided personnel to assist with measuring individual water meters. The following graphs show comparisons of data collected on the "Super Wash Saturdays." The significant differences are most evident on the rural system data (figures 3 and 4), since most of the larger families are served by the rural system. However, the data from the Bern City Tank (figure 5) also show significant savings. In addition, the outflow to the sewage lagoon (figure 6) reflected a significant reduction due to the h-axis washers.

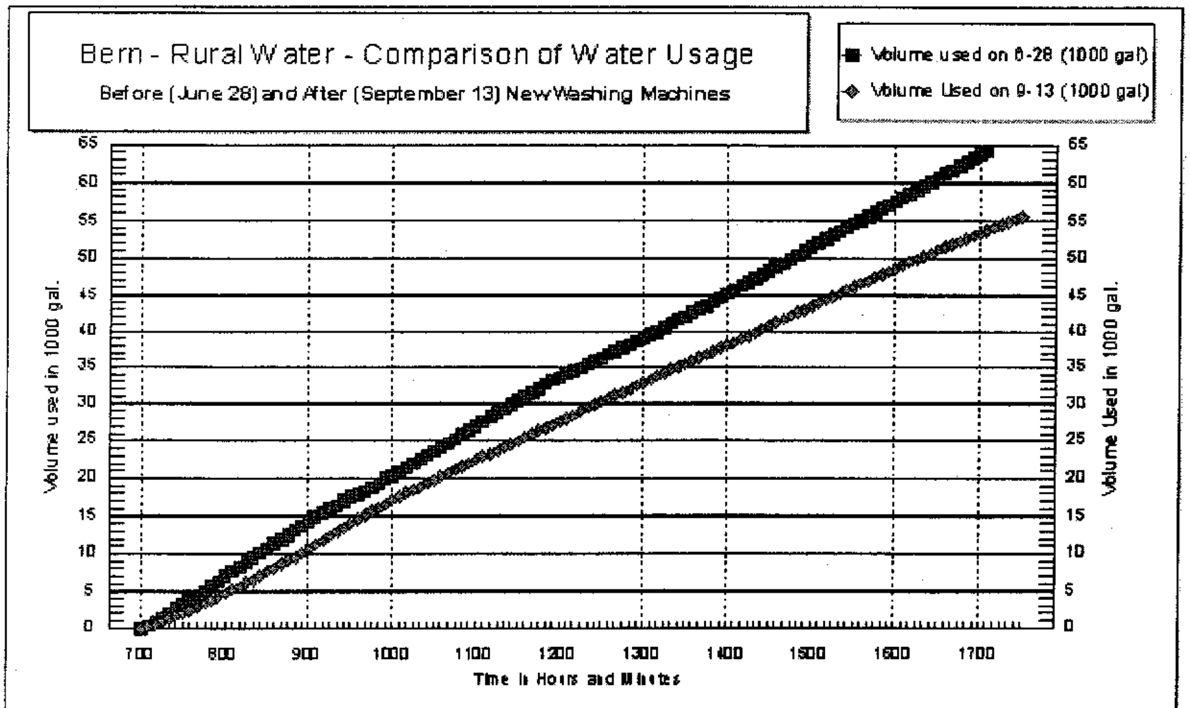

Figure 3 - Water use comparison, "Super Wash Saturdays."

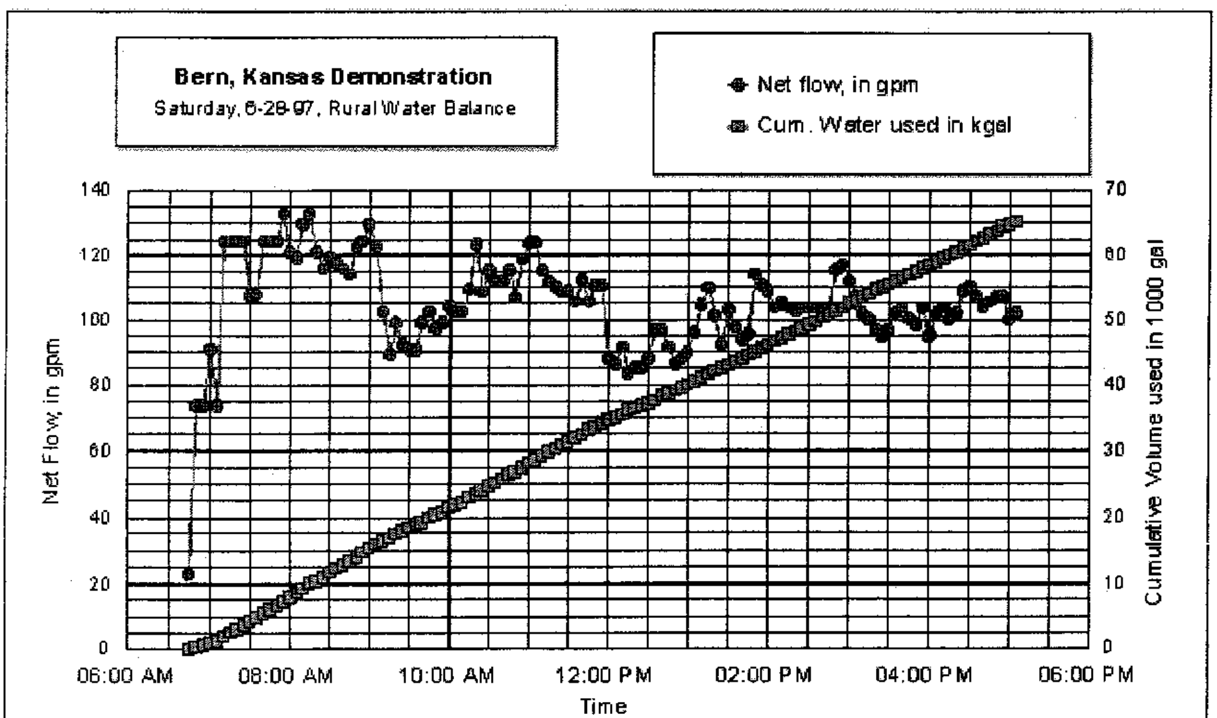

Figure 4 - Cumulative rural water usage, June 28, 1997.

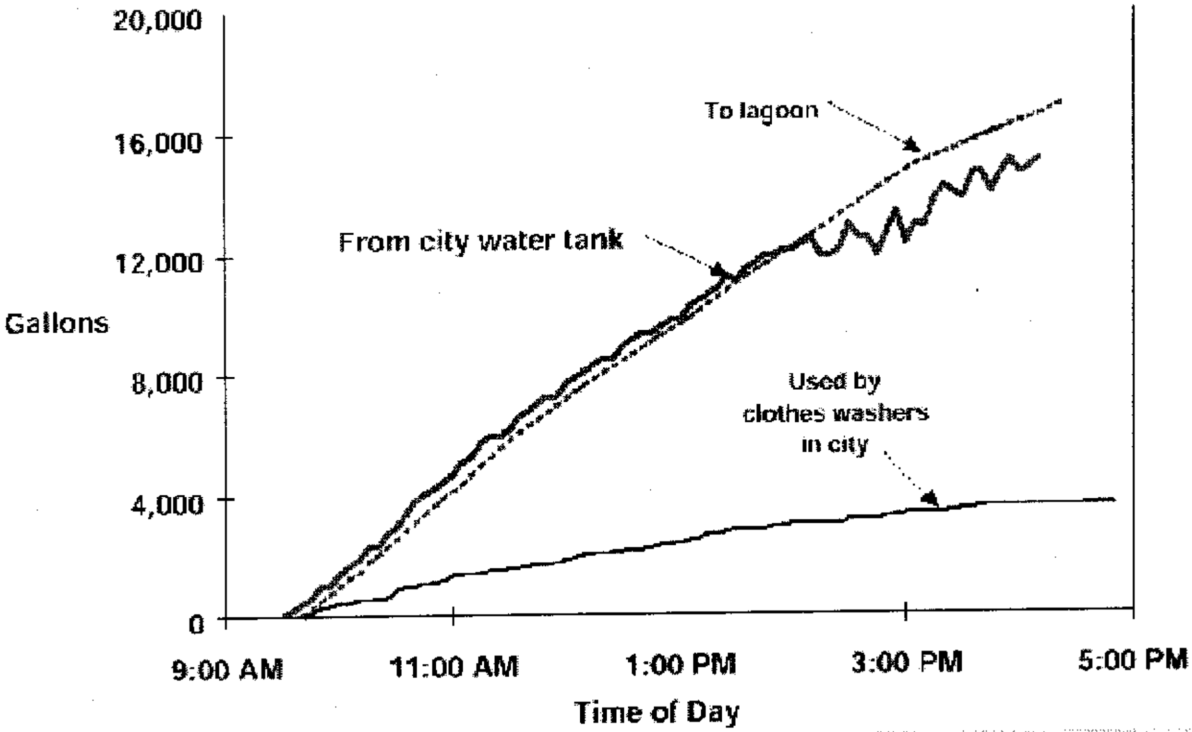

Figure 5 - Water use in city of Bern, September 13, 1997.

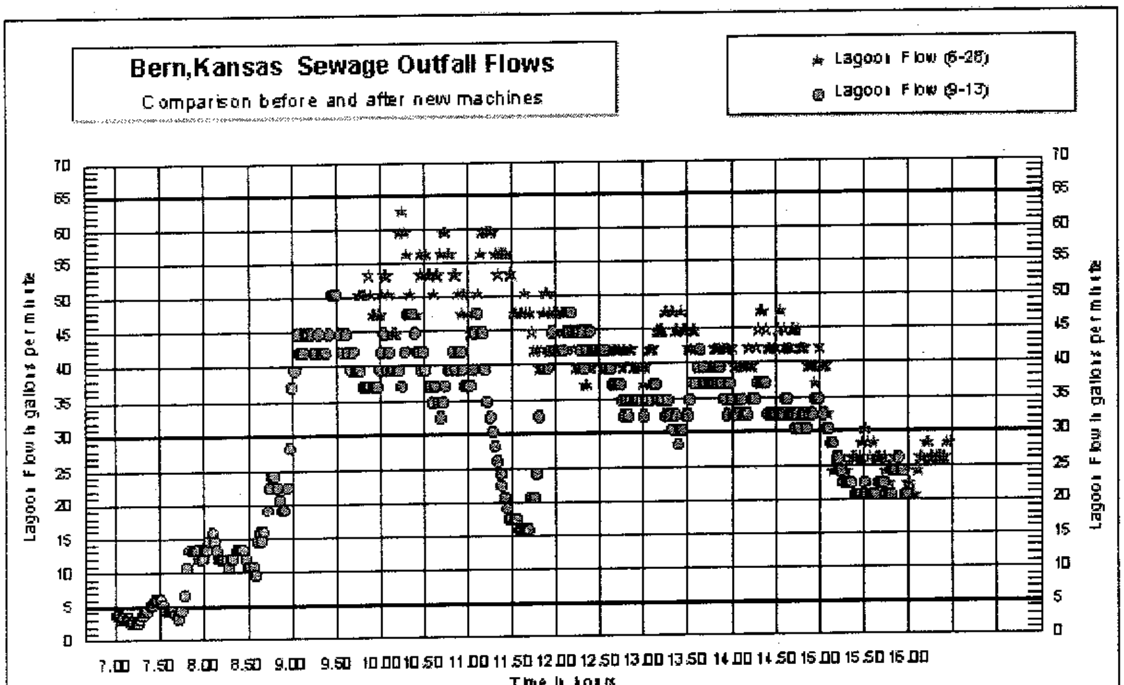

Figure 6 - Sewage outfall flows, effect of h-axis machines.

Project Findings-

The data and subsequent analyses showed that participants found the cleaning performance of the h-axis technology to be generally superior to their v-axis washer irrespective of its age. Participants seemed to adapt easily to the h-axis design, and laundry habits (average load weights, detergent use, how loads were dried, when loads were washed during the week, wash/rinse temperatures and other factors) remained largely unchanged from phase I to phase II. These findings demonstrate convincingly that the tumble-action technology (h-axis design) is much more energy and water-efficient than the technology present in clothes washers found in the field today. These findings suggest that a changeover to h-axis technology would deliver large savings in energy and water to the customer with an improvement in cleaning performance and utility.

Municipal Utility Impacts-

The water used by clothes washers comes from the same source as all of the drinking water to a house. After each wash/rinse cycle, most of the water that is used ends up going down the drain. Consequently, the amount of water used by clothes washers has an impact on the service providing the water to washers as well as the service for treating an equal amount of wastewater from the washer. In the study, the systems for supplying water and disposing of waste water were different depending on whether a participant lived in Bern proper or in the region which surrounds the city. Both water and sewer services are provided to residents who live in the town. Water is provided from a few community wells, some far away. One large (50,000 gal.) water tower located inside the city limits is used to provide most of the capacity needed by the town. This tower has also served Bern faithfully as a landmark since its erection in 1953.

Market Challenges -

High-efficiency washing machines face challenges to wide-scale adoption by consumers. First, these machines tend to cost more than the conventional machines. Increased sales will foster higher production volumes and better, more efficient plant assembly line utilization, and, combined with increased competition between manufacturers for market share, will tend to reduce first costs to the consumer. However, indications from manufacturers are that a price premium for high-efficiency washers will remain even in a fully developed market. The ultimate market for high-efficiency washers will depend largely on the extent to which performance advantages of these machines can be made known to justify the higher price. According to a survey conducted through a consortium of utilities and DOE, 17 percent of households who own a washing machine intend to purchase a new machine in the next 2 years. Of this number, only 0.4 percent reported that they will probably buy a horizontal-axis, high-efficiency washer in this time period. These results are not surprising in view of the fact that only 2 percent of the current U.S. clothes washer market is for horizontal-axis, high efficiency washers. The survey found that a major reason for consumers not opting for the high-efficiency machine is due to lack of awareness; consumers were simply not aware of the technology and its benefits in terms of cleaning performance, reduced operating cost, less water use, and lowered energy consumption. This lack of awareness extends from consumers shopping for a clothes washer, to electric and gas utilities who manage energy efficiency and customer service programs, and to water utilities looking at ways to encourage water conservation. The survey also showed that only 25 percent of respondents were aware of horizontal-axis washers in residential settings, and in focus groups held as part of the study, very few participants mentioned this type of machine when asked to describe the different types of washers currently available. Other work has confirmed that increased awareness of the benefits of high-efficiency washers is the key to transforming the market.

The Bern washer study

To (1) evaluate the real-world performance of h-axis washers and (2) to help bring about increased awareness of the benefits of h-axis washers, a small town, Bern, Kansas was located and used as a test bed for evaluating the performance and acceptability of h-axis washers. The 5-month study consisted of (A) gathering water consumption data on the existing washing machines in Bern to establish a baseline against which the water use pattern of high-efficiency washers can be measured, (B) switching out these washers with high-efficiency h-axis models, and (C) determining the savings in water, energy consumption, and changes in laundry habits and other impacts experienced by the town and its residents from a changeover to the h-axis machines.

How the study was conducted-

The study was conducted through a CRADA between Lockheed Martin Energy Research Corporation and Maytag Appliances with additional participation by the Kansas Rural Water Association, and the U.S. Bureau of Reclamation (providing municipal water metering and on-site personnel to help monitor Bern's community water systems). The study involved:

- establishing criteria for the field test site,
- locating the site (community) which best fulfilled the criteria,
- conducting the field study, and
- reporting the findings as through this report.

Further dissemination of project results to target audiences remains an important objective.

Site selection criteria-

It was anticipated that much of the success of the field study depended on (1) developing a set of desirable characteristics for the test site to possess, and (2) finding a site which had these characteristics and whose residents were willing to participate in the study. The principal attributes to be possessed by the town included the following:

- A small size. The available resources (funds, equipment, instrumentation, and personnel) limited the number of participants in the study to about 80 to 100. This represents the number of clothes washer sites (e.g., homes) which could be instrumented and used to evaluate the performance of the existing washer as well as the h-axis model. It was also important that a large fraction of the total number of washers in the town be included in the study so that the impact of clothes washers on the entire town's water consumption and waste water generation could be evaluated. Estimates have shown that the penetration of clothes washers in homes is about 78 percent nationally. By assuming that the chosen town would have the same penetration of clothes washers as found nationally, the selected town would need to have 100 to 130 homes and have a population in the range of 200 to 300 persons. This estimate was based on the assumption that most homeowners with washers would qualify and become participants in the study.

- Presence of community water utilities. An objective of the study was to determine the impact of clothes washers on municipal utilities, that is, the impact on a town's water supply and wastewater disposal systems. To meet this objective, the study needed to take place in a town which had a central water utility which metered the water sold to each customer, and a sewer system for collecting and treating waste water. While they may have a community water supply, many smaller, rural towns would tend to rely on subsurface waste disposal (septic tanks). A much smaller number of towns were expected to have centralized water and sewage disposal facilities, yet it was deemed essential that the town selected for the study have these features.

- Presence of a water problem. It was felt that interest and participation would be enhanced by conducting the study in a community which either had experienced a water problem or was currently plagued with a water-related problem, and to evaluate the degree to which h-axis washers could contribute to the solution. The community's "water problem" could have taken many forms, such as: chronic seasonal droughts, inadequate waste water treatment facilities, a population growth which is outstripping the capacity of the water providers, or lack of availability of fresh water all were candidate considerations in the site selection.

- Participant willingness and enthusiasm. The conventional approach to field studies of this type involves instrumentation and data collection that does not involve the participant and does not require assistance by participants. In this study, it was essential that the participants be willing to help gather the data from instrumentation placed on their washer and to provide information on each load of laundry washed. This approach was taken because the expense of distributed automatic data acquisition systems was far beyond the study's resources, and because some of the information needed for the study required input from the participants.

Site selection process-

Anticipating that small, rural towns would be likely to satisfy the criteria for the study, we contacted the National Rural Water Association to get their assistance in identifying candidate sites, communities, or towns. Through this association and with the assistance of other groups, we contacted all of the state rural water associations and/or state environmental agencies requesting a listing of sites which met the criteria for the study. A list of potential sites was screened, and where information was missing, calls to the appropriate state agency or town official were made. In some cases, site visits were made. The town of Bern, Kansas, was selected based on a high ranking of all of the criteria mentioned.

Bern, Kansas-

Located about 75 miles west of St. Joseph, Missouri, and 4 miles south from the Nebraska state line, Bern is a thriving, mostly farming community producing corn, sorghum, and wheat. A survey of the town indicated that the primary occupation of 40 percent of the head of household is farming. Before 1954, the residents of Bern obtained their water from individual wells. However, in 1954, Bern elected to drill several community water wells, erect a 50,000-gallon water tower and install underground water mains to serve the town. Subsequently, Bern installed three sewage treatment lagoons (cells) to handle wastewater generated by the town. In addition, a RWD was formed, wells sunk, and more than 70 miles of piping was installed to provide water to the residents living outside of the city of Bern. Periodically, Bern and the surrounding areas have experienced problems with water availability. In the mid-1980's Bern's water supply came from four, low-production, 8 gpm wells, and these wells were dropping in production. In addition, the city was interconnected with the surrounding RWD. The district's water supply consisted of two operating wells which had an average production of 15 gpm. Water quality was very poor with high iron and manganese content. In 1988, northeast Kansas experienced severe drought conditions. The water production for the City of Bern and the RWD declined dramatically. Based on its limited water availability, the RWD and city of Bern were both identified by the State of Kansas as priorities (drought vulnerable) to obtain additional water resources. Along with this application for assistance, Bern implemented conservation practices and the RWD instituted water rationing in March 1989. The RWD increased its water rates from $1.35 to $3.00 per 1000 gallons. To alleviate the shortage of water, several patrons of the RWD loaded water from farm ponds or hauled water from other locations to supplement their livestock water needs. To meet demand and improve water supply sources, Bern initiated a project to drill new wells in neighboring Nebraska. Project costs to install two new wells in Nebraska approximately 4 miles from any existing rural water transmission line, connecting pipeline and a booster station, were estimated at $233,500. Funding came in the form of $23,800 by the City of Bern, the RWD contributed $47,600, and a neighboring community of Oneida paid $7,600. An emergency grant of $154,000 was awarded by special appropriation by the Kansas Department of Commerce & Housing. Rates were increased by the City of Bern as a result of the increased debt and need to conserve water. This was in November 1990. Monthly rates adopted then remain in force today for the residents of Bern.

Participant selection-

Information about the project, a survey form and invitation to join the project were mailed to each of the 175 homeowners in Bern and the surrounding RWD. The residents were made aware of the project's goals of measuring the performance of high-efficiency clothes washers using the entire town as a test bed and for developing other information to determine the impact on the community of a changeover to high-efficiency clothes washers. The homeowners were told that if they were selected, they should be prepared to help collect data of each load of laundry washed during a 5-month period. For the first 2 months, data would be collected on their current clothes washer, the washers would be changed out to the Maytag Neptune (h-axis) clothes washers, and data collection continued on the new washers for a 3-month period. In return for their cooperation and assistance, the participants could elect to keep the new washer if they so desired. The initial plan was to select about 90 homes with clothes washers to participate in the study. With the help of a three-person volunteer Bern Washer Study Team, information from applicants including laundry habits, customer profiles, types of existing washers, dryers, and hot water heating systems was received and analyzed. A total of 104 participants (washer owners) elected to join the study and submitted an application in time to be included. These "participants" included three washers in Bern's local Laundromat, one washer in the Bern High School, one in Bern's vet clinic, and one in Bern's meat plant. All of those electing to join the study (1) had a water meter and purchased water either from the city of Bern or from the RWD, (2) currently had a clothes washer, and (3) were sufficiently interested in the study to commit to a 5-month data collection period. Bern's laundromat had six coin-operated, commercial washers and an equal number of dryers. A decision was made to collect data on three of these washers for the 2-month baseline period, then to replace these with three coin-operated, commercial, h-axis washers for the balance of the study. In all other cases, the replacement washer was Maytag's domestic h-axis model. Of the 104 who joined initially, one single homeowner elected to withdraw about 3 weeks into the study, leaving 103 participants. Notably, all 103 completed the study. At the initiation of the project, the participants were surveyed to gain demographic, lifestyle, and laundry behavior information. Some of the findings from this survey included:

General information:

- The average Bern household comprises two adults and two children; in some cases, households have as many as two adults and five children; 21 percent of the households cited housewife/homemaker as the primary occupation of the female head of household;
- Forty percent of the households cited farming as the primary occupation of the male head of household;
- About 47 percent of the participants live in the Bern city limits; the balance live around Bern and are tied into the surrounding RWD.

Laundry behavior and equipment:

- The majority of washers (71 percent) were located on the first floor of the home;
- The majority of washers (65 percent) had a fabric softener dispenser although 49 percent of households with the dispenser indicated that they never use it;
- The majority of washers (60 percent) also have a bleach dispenser; of this fraction, 48 percent of the participants sometimes use the dispenser, and 45 percent indicated that they never use the dispenser;
- Eighty-eight percent of the participants used an electric dryer; 11 percent used a gas dryer and 1 percent did not own a dryer; the average age of a Bern dryer is 12 years;
- Sixty-four percent of the participants used propane for water heating; 36 percent used electricity; natural gas is not available;
- Twice as many participants use powder detergent as use liquid detergent, and 25 percent had both types of detergent on hand;
- The number of loads washed per week depended on the household size; estimates made by Bern residents indicated that the average Bern household washed 11 loads/week.

Experimental design-

A central objective of the field study was to determine the impacts of replacing existing, conventional washers with high-efficiency h-axis washers. There are a number of potential impacts that a replacement, h-axis washer could have, including:

- Changes in water consumption and its effect on the customer and water/sewer utility;
- Changes in energy consumption of the washer itself and in the amount of hot water used;
- Changes in load weights. For the same "throughput" of laundry, the weight of each load determines the number of loads of wash needed to be done;
- Changes in detergent use and patterns;
- Changes in the "dryness" of loads removed from the washer. The ability of the washer to extract water in the final spin affects the energy needed by the

dryer;
- Changes in customer satisfaction as related to cleaning/drying performance;
- Changes in customary laundry habits.

The experimental design included individually metering the participant's conventional washers and recording data from this instrumentation as well as from participants on each load of laundry that they washed for a 2-month period (phase I of the project). Following phase I, all of the participant's washers were replaced by the high-efficiency, h-axis washer, the instrumentation reinstalled, and the experiment continued for a 3-month period (phase II of the project). The changes in performance, laundry patterns, participant satisfaction, and other potential impacts listed above were determined by comparing phase I and phase II data. In addition, the influence that clothes washers had on Bern's water supply and waste water generation for 2 days of heavy washing - one during phase I and the other during phase II - was determined.

Instrumentation and Measurements-

Water Meters - Two water meters were installed on each washer in the project one to measure the hot water consumption and the other for the cold. These meters (Badger Model 50) had been modified and adapted to work with a remote digital readout. The meter modification provided the readout with a measurement precision of almost 1/200 of a gallon. Participants simply recorded the readings from the hot and cold readouts after each load of laundry was completed, and the conversion of these readings into gallons of water was done during the data analysis phase of the project. Each meter also had the conventional analog register from which cumulative hot and cold water consumption could be determined. These registers were read periodically by project staff and used to check digital readout recordings made by participants.

Weighing Scale - Each participant was given a scale for weighing wash loads. For most of the study, the scales, with a measurement precision of ±1 oz., were used twice for each load: first, for obtaining the pre-wash weight of each load and a second time for determining the post-wash load weight which was the weight of the load after washing but before drying. All recorded weights included the weight of the clothes and the laundry basket. As part of the analysis, load weights were determined by subtracting the weight of the basket from recorded weights.

Laundry Basket - Each participant was given a standard laundry basket to use for weighing the loads, thus simplifying determination of load weights.

Measuring Cup - Each participant was given a standard detergent cup to meter detergent use for each load. As before, participants recorded detergent use on individual load data sheets.

Temperature Measurements - Water meters were installed on each washer during the first week of the study and, at this time, hot and cold water temperatures were carefully measured by the installation team and used in the analysis for both phases of the study. These temperatures were measured once again during the changeover to the h-axis washer.

Washer Energy Consumption The electrical energy consumption (kWh required to operate a washer's motor and controls for a cycle) of most of the original phase I washers in the study was determined from available data based on brand and model number. In those cases where a washer was too old and energy consumption information was unknown, washer energy consumption was taken to be the average of the washer energy consumption of the remaining phase I washers. This provided a conservative (lower energy use) estimate for the older washers. The average washer energy consumption from prior field experiments on the h-axis washer was used in phase II of the Bern Study.

Data Sheets/Notebook - Finally, each participant in the project was given a notebook containing data sheets to be filled out one for each load of laundry, and a set of instructions for data entry and managing the notebook. The two sheets are quite similar; they differ only in the "Settings" sections where the phase II settings are based on the controls for the Maytag Neptune model h-axis washer. Item 1 consisted of the date and time that a load was washed so that information on laundry habits could be determined. In items 2 and 8, participants recorded pre-wash and post-wash weights to provide information on load weights and residual moisture. In items 3, 4, 5, 6, and 11, participants recorded information characterizing the load, describing washer settings, detergent use, and indicating how the load would be dried. In item 7, participants recorded numbers from the digital displays connected to the two water meters on their washers. Finally, in items 9 and 10, participants could indicate satisfaction with the dampness and cleanliness of the load after washing.

Data collection and analysis procedure-

The overall approach to data collection and analysis was to create database tables of project information and link these databases according to information queries. The information in these tables included recorded experimental information, detailed participant information, information about phase I washer characteristics, and other information which were recorded on the data sheets and submitted to Oak Ridge National Laboratory (ORNL) for analysis. These individual tables of information were joined together as needed for analysis and for reporting results to individual participants. The key to the approach lay in the development of a normalized database in which all tables of information and data were linked through a single parameter, a unique number assigned to each data sheet. The tools used to build the databases and to process data from the study included Microsoft Access 97 and Microsoft Excel 97. Access is a relational database management system that provides features for importing data and for creating tables, queries, forms, and reports. In Access, data are represented as a table (a matrix of data in rows and columns). Access provides a number of routines for operating on the data such as queries, macros, visual Basic modules, forms, and reports. Queries and reports were the two main components used in the study. The queries could be created either in a graphical view or by writing Sequential Query Language (SQL) statements. Queries were used to filter, sort, and screen the data from the study as well as to perform calculations such as sum and average the data. Access was linked to Excel as needed to perform histograms, create full-page graphics, and to perform calculations which otherwise would have required extensive programming using Access.

Summarizing, the overall process for assembling a database of information for the study consisted of the following six steps:

- Data entry by the Bern participants on pre-formatted data sheets;
- Optical scanning of the data sheets supplemented by keyboard entries to generate a data table;
- Formatting and importing the data table into Excel;
- Conversion of the spreadsheet to comma-delimited ASCII file;
- Importing this file into Access;
- Creating SQL queries to assign data records to participants;
- Creating SQL queries to sort, filter and screen all data and to perform calculations and analysis needed to address the study objectives.

Overall findings and impacts-

The tumble-action principle of the h-axis washer and design of the h-axis washer based on this principle represents a major design change from the conventional, v-axis washers. Therefore, it was reasonable to expect that in the Bern Study, there could be significant impacts resulting from a changeover from conventional, v-axis washers to the h-axis design. These impacts include, for example, changes in average load sizes and weights, changes in detergent use patterns, changes in energy and water consumption, changes in cleaning performance, and changes in the post-wash moisture content of loads. In the following sections of this report, we examine first some of the overall impacts and findings between phases I and II of the study.

Impacts on load size-

The size of loads washed with each cycle can be an important measure of the "throughput" of laundry because it can determine the number of loads washed by a customer. More loads take more time and can consume more energy and water than fewer loads. This is particularly the case on laundry days when loads are done one after another. Its volume or its weight or perhaps some combination of the two could characterize the size of a load of laundry. Although the weight of any wash load and its volume are linked, the relation between the two depends on the type of clothing in the load, e.g., a laundry basket full of cotton towels, sweatshirts, bedding, etc. may weigh more than one filled with permanent-press shirts or delicates. A participant's lifestyle would likely determine the type of clothing worn and washed most often, and over the course of the study, the lifestyles for most of the participants remained fixed. This meant that load weights used in the study were a good indicator of load size. Participants measured and recorded load weights for each load washed during phases I and II.

In phases I and II, most of the loads weighed between 6 and 8 pounds, and about as many loads

weighed less than 2 pounds as weighed more than 14 pounds. Across all washers and participants, the average load weight in phase I was 6.65 pounds and the average for loads done in phase II was 6.98 pounds. Interestingly, a larger fraction of loads was done by the phase I washers. Less than 8 pounds were done by the phase II washers in those same load weight categories. During phase II and as the summer progressed into the fall, participants tended to wash heavier loads (those weighing more than 8 pounds) more often than they did in phase I. These results are based on average pre-wash weight measurements from 7,523 loads (50,035 pounds) of laundry done in phase I and 12,759 loads (89,063 pounds) done in phase II (Table 1).

We found that as the study progressed, the average load weight increased slightly for each week of the study and throughout both phases at a rate of about 0.04 lb/load per week. Consequently, the average load weight for the first 2 months of the study (phase I) is a little smaller than the average load weight for the last 3 months of the study (phase II). The finding that the average load weight tended to increase throughout the study suggests that the increase in average load weight between the two phases is not necessarily due to the type of washer. Instead, it appears to be timing-related and results from differences in the type of laundry being washed by the participants as the study progressed through the summer and into the fall. Measurable changes up or down in laundry "throughput" (weight per load) as a result of washer type were not found.

Water consumption-

The water consumed by each washer in both phases of the study was determined through individual, positive displacement (nutating disk) water meters applied to the hot and cold water lines to each clothes washer. After each load was washed, the digital display affixed to each meter was read and recorded by each participant. These readings simply indicated "counts," and during the data analysis phase of the study, these "counts" were converted to gallons through a conversion factor. The water consumed during one cycle was determined during analysis by subtracting the meter reading from the prior wash cycle from the reading for the current wash cycle. In each case, the difference in meter readings was converted into gallons of water. In phase I, the average total water use ranged from about 18 gallons to more than 60 gallons per load with an average of 41.5 gallons/load. In phase II, the total water consumption ranged from 17 gallons/load to about 37 gallons/load with an average of 25.8 gallons/load (figure 7). Across all study participants, this represents an average per load water savings of 15.7 gallons, or 37.8 percent. Figure 8 shows the water consumption with projected savings through the study duration.

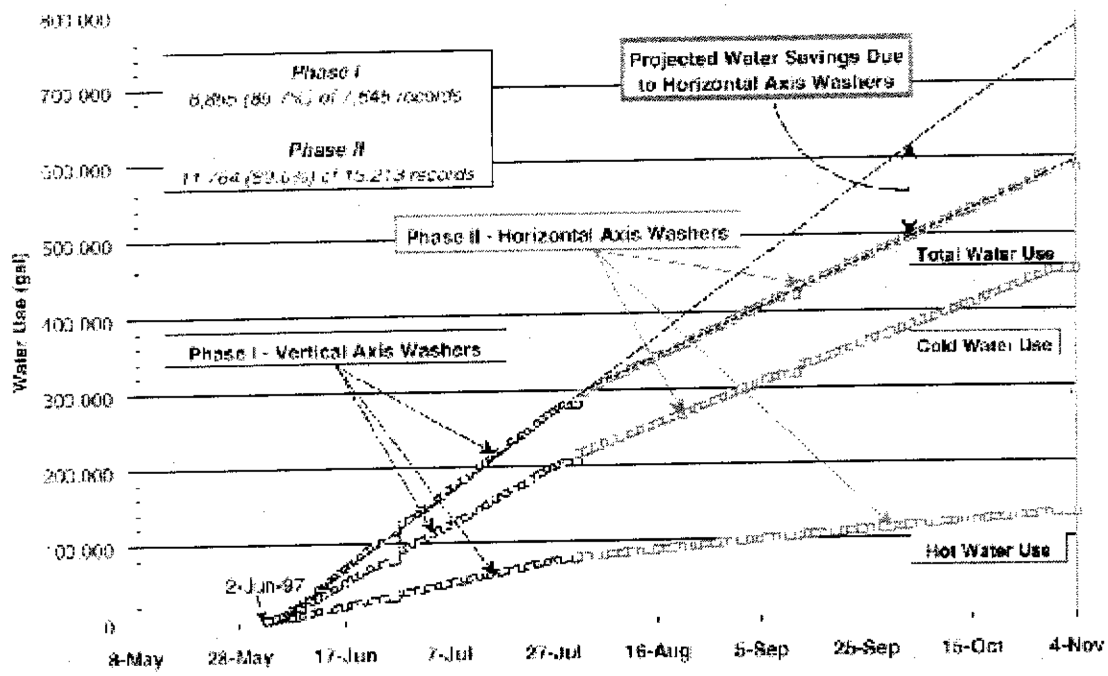

Figure 8 - Water use projections from v-axis to h-axis washers.

Energy consumption-

Washers consume energy through two main mechanisms: first, energy is needed to produce hot water used by the washer, and second, the washer itself uses energy to operate the motor and controls. In this analysis, the hot water energy was taken to be the thermal energy in the hot water used by the washer. This energy was determined by measuring the temperature of the hot and cold water at a sink or faucet after the water had run for a time so that the temperatures were stable. This was done on three separate visits to each participant during the progress of the experiment. The hot and cold water temperatures were entered into a spreadsheet to be included in the analysis. The amount of hot water consumed was measured by the water meters described earlier, and based on the volume of hot water consumed and the temperature difference between the hot and cold water, the energy content of the hot water to the washer was determined (Btu/gallon). It should be noted that although this procedure puts the energy contained in hot water on a consistent footing to compare washer performance, it understates the actual amount of energy purchased by the participants to heat the water used by these washers. From the survey administered to participants at the outset of the project, 64 percent of the participants heated water using propane and the rest used electricity. By applying national averages for the efficiency of water heaters (52 percent for gas/propane and 85 percent for electric), ignoring any heat losses from the hot water distribution piping in homes and standby losses, it can be shown that only about 64 percent of the energy purchased for water heating actually ends up as hot water. In every case, the phase II washer used less total energy than the phase I washer, and in some cases, the savings were dramatic. One must keep in mind that the phase I washers in Bern spanned the gamut from washers which were fairly new and relatively efficient, to ones which were much older and probably less efficient. Moreover, the phase I water and energy consumption information shows the large variability in the water and energy and water consumption among the population of washers in Bern. Some of this variability was due to the washer, while the rest of the variability was due to different settings used by each participant. From the complete data set taken during phase I and II on loads, load weight and hot/cold water consumption, the impact of the replacement of all participants' vertical-axis phase I washers by the phase II h-axis washers was determined, and the findings are shown in Table 1. As can be seen from Entry 1 in the table, there were a total of 7,645 data sheet records received from participants during phase I and 13,213 data sheets received in phase II. From a review/analysis of these sheets, we determined the number of loads washed by participants. The difference between these two numbers of records represents occasions when participants provided information other than load data such as readings from water meter registers that were made periodically during the study as a check on the information from the digital readouts. Overall, solid information on load weights (pre- and post-wash) and hot/cold water readings were provided on data sheets at least 92 percent of the time.

These results show that, on average, the h-axis washer used 62.2 percent of the water used by the v-axis washer, and this yielded total water savings of 37.8 percent (table 1). Moreover, the average h-axis washer consumed 42.4% of the energy used by a typical v-axis washer in the study, resulting in energy savings of 57.6 percent. With both washers, the majority share of the energy consumed is the energy needed to heat water. Therefore, a reduction in hot water consumption has a direct and beneficial effect of reducing overall energy consumption. Table 1 shows that the hot water consumption of the h-axis washer is less than half of the hot water energy used by the average v-axis washer in the study.

Table 1- Average Energy and Water Consumption in Phases I and II.

#	Calculation	Units	Phase I		Phase II	
			Data	Records	Data	Records
1	Total Records		**7645**	**7645**	13213	13213
2	Number of Loads		**7633**	**7633**	13130	13130
3	Total Hot Water Use	gallons	**81405**	**7033**	**58000**	**12011**
4	Total Cold Water Use	gallons	**209286**	**7002**	250462	11950
5	Total Water Use	gallons	**290691**		308462	

6	Total Laundry Weight	pounds	50035	7523	89063	12759
7	No. of Participants Reporting		103		103	
8	Average Load Weight	lb/load	6.65		6.98	
9	Number of wash days	days	61		105	
10	Average Hot Water Temperature	F	72		72	
11	Average Washer Energy Use	kWh/load	0.23		0.11	
12	Average Hot Water Use	gallons/load	11.57		4.83	
13	Average Cold Water Use	gallons/load	29.89		20.96	
14	Average Total Water Use	gallons/load	41.46		25.79	
15	Average Total Energy Use	Btu/load	7710		3272	
16	Average load/day per Participant	loads/day	1.21		1.21	
	% Water Savings *				37.8	
	% Energy Savings *				57.6	

*Comparison of items 14 and 15, respectively, for water and energy.

1. Tomlinson, J. J., D.T. Rizy, "Bern Clothes Washer Study, Final Report," Energy Division, Oak Ridge National Laboratory, for U.S. Department of Energy, March 1998, Internet address: www.energystar.gov.