5. Washing and Water Heating

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Purpose, Requirements (gallons and temperature)

An adequate and reliable supply of hot water is an essential element in the production of high quality milk on any dairy farm. Water used for cleaning milking systems including milking units, pipelines, receivers, and bulk milk storage tanks must be available in adequate quantities and at required temperatures for each cycle in the cleaning process. Failure to have adequate supplies of hot water at required temperatures can lead to rapid increases in bacterial contamination and subsequent reduction in milk quality. Milk quality reductions can lead to a loss of quality premiums or, in the worst case, an outright refusal to accept the contaminated milk at the processing plant.

Hot water requirements vary from farm to farm and are directly related to number of milking units, pipeline sizes and lengths, and system accessories (receivers, weigh jars or milk meters, plate coolers, etc.). Generally, a minimum hot water requirement is 4 gallons of 170°F (77°C) water per milking unit for each rinse/wash/rinse cycle.
Water temperatures required for various milking equipment rinsing, washing, and sanitizing cycles are as follows:

- Pre-rinse cycle 95°F - 110°F
- Wash cycle 155°F - 170°F
- Acid rinse cycle 95°F - 110°F
- Sanitize cycle 75°F (minimum depending on sanitizer directions)

Hot water is commonly produced by water heaters using one of three energy sources:

1. Fuel oil
2. Natural or propane gas
3. Electricity

Fuel oil or gas fired water heaters are more popular on large dairy farms because they are easily sized for rapid production of hot water. Typical input rates for oil fired water heaters are between 138,000 and 150,000 Btu/hr (about 1 to 1.25 gallons of fuel oil per hour). The recovery rate for oil fired water heaters is about 100 to 120 gallons of hot water (@ 170°F) per hour. Typical input rates for gas fired water heaters range from 75,000 to 150,000 Btu/hr. (about 75 to 150 cu. Ft. of natural gas per hour or 0.8 to 1.6 gal. propane per hour). The recovery rate for natural gas water heaters is 54 to 108 gallons per hour (@ 170°F).

Electric water heaters have some advantages over water heaters using fossil fuels. They are more efficient, there are no flues, they can easily be heavily insulated to reduce heat losses, their first cost is often lower and they are easily located near the point of heaviest hot water use to minimize water line heat losses.

The disadvantages of electric water heaters include slower recovery rates and increases in peak electrical demand and the associated higher demand charges on the farm. Larger volumes of storage for heated water are required to meet the hot water requirement for cleanup if electric water heaters are used.

A minimum electric water heater storage capacity is at least 30% higher than the total hot water requirement for a complete system rinse/wash/rinse cycle. Residential electric water heaters should not be used on dairy farms because they are thermostatically limited to a peak temperature of about 140°F (60°C) to meet federal safety guidelines.

Thus, commercial electric water heaters would be required for dairy farm applications. Commercial electric water heaters can be configured with multiple, higher wattage heating elements that provide faster heat recovery. For example, a 120-gallon commercial electric water heater with three 6,000-watt elements operating simultaneously can heat about 62 gallons per hour to 170°F (77°C). Although such a recovery rate might be adequate for many dairies, the additional 18 kW demand could be quite costly.

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Equipment – Washing & Water Heating

Types of Water Heaters

Direct Water Heater, Conventional with Integral Storage

Conventional water heaters incorporate a storage tank with either electric heating elements or a burner into a single unit. Fuel sources for storage water heaters include electricity, natural gas, propane and fuel oil. Overall efficiency of a storage water heater is a combination of the combustion efficiency of the fuel source and standby losses from the tank.

Storage water heaters range in size from 30 to 120 gallon (with larger sizes available). Fossil fuel units have heating inputs from 80 – 600,000 Btu-Hr and recovery rates of up to 600 gallons per hour. They are commonly connected via a circulating pump to larger insulated storage tanks to provide greater capacity. Useable water passes through the water heater.

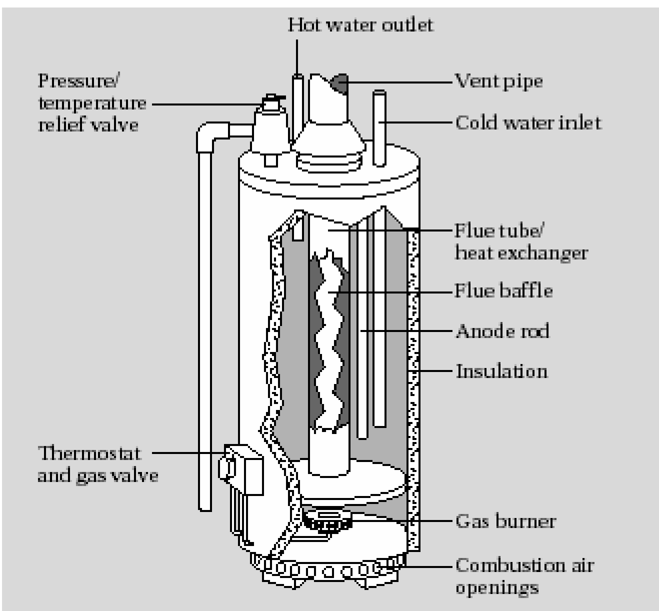

Figure 5-1. Storage Water Heater

Indirect Water Heater

Indirect water heating utilizes separate water heating (usually a boiler), a heat exchanger in storage tank to transfer heat to the water in separate insulated storage tank. The boiler can be natural gas, propane or oil fired. The heat exchanger may be remotely located, but is generally placed within the storage tank. With this arrangement the useable water does not pass through the boiler. This reduces scaling in the boiler. Also, cold water in the storage tank will not be come in contact with the boiler that causes stress in the boiler. The combination of a complete condensing hi-efficiency boiler with a well-insulated storage tank makes indirect water heating very economical.

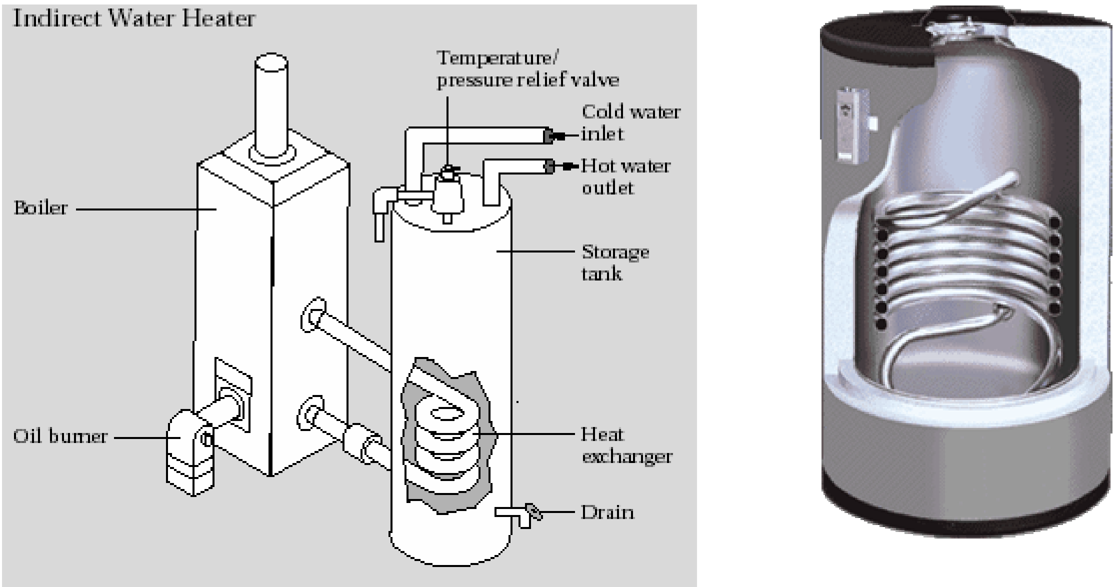

Figure 5-2. Indirect water heater and cross section of storage tank with heat exchanger (Crown)

Heat Pump Water Heater

Heat pump water heaters use electricity as an indirect energy source to move excess heat from another source and transfers that heat to water. See Figure 5-3.

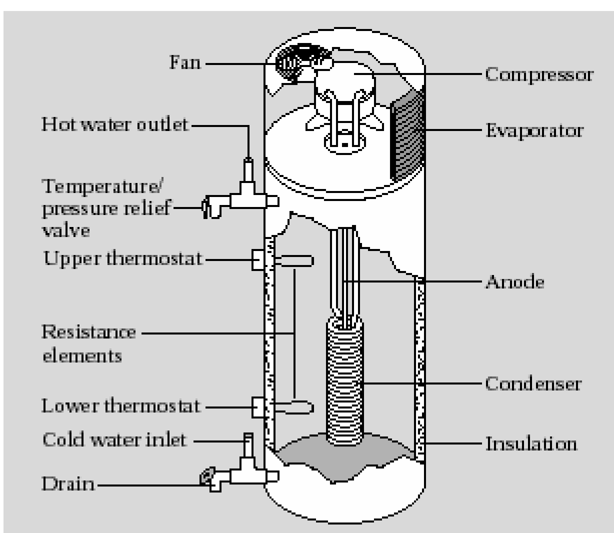

Figure 5-3. Heat pump water heater

They operate like the bulk milk cooling system, but in a reverse manner. Heat is removed from ambient air [evaporator] and transferred through the refrigeration system into water [condenser] in the storage tank.

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Washing and Water Heating Energy Utilization Indices (EUIs)

Total hot water use for CIP cleaning is driven by size of milking parlor(s) and size and number of milk tanks or silos. Accepted guidelines for hot water use on smaller dairies may be as high as 2 to 3 gallons per cow per day.

However, on large California dairies with a high degree of automation, the number of cows being milked has reduced the volume of hot water used to one half gallon per cow per day. Factors that will optimize the level of hot water use, while maintaining adequate cleaning performance include:

- Optimization of air injected slug flow cleaning
- Careful design of vacuum pump capacity and vacuum level for washing
- Accurate determination of wash water volumes needed and appropriate settings of water levels in wash sinks.
- Limiting milker unit wash draw rates to 0.8 to 1.0 gpm with appropriate flow restrictors.

The EUI developed as a point of reference for washing and water heating is the commonly used quantity of fuel source (Therms, gallons, kWh) used per cow-year.

Table 5-1. Washing and Water Heating EUI

Fuel Source	Quantity per cow-year	Typical Range
Natural Gas	1.3 Therms	0.8 – 2.0 Therms
Propane	1.4 Gallons	0.9 – 2.2 Gallons
Fuel Oil	0.7 Gallons	0.9 –1.7 Gallons
Electricity	33.5 kWh	22 – 44 kWh

Fossil fuel water heaters are used almost exclusively for water heating on California dairy farms. They provide high recovery rates and adequate storage capacity. Overall energy use for water heating can be minimized by:

- Utilizing waste heat recovery for pre-heating water.
- Selecting high efficiency water heaters.
- Providing adequately sized piping with shortest possible distances from heater to wash sink.
- Periodically maintaining and cleaning the water heater.

Figure 5-4. Conventional water heater with storage

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Washing and Water Heating Energy Conservation Measures (ECMs)

Heat Recovery Systems

A refrigeration heat recovery system links two common functions found on dairy farms to reduce energy consumption and costs. Heat recovery equipment “harvests” heat that would normally be rejected by the milk cooling condenser and applies that heat energy to preheat the water that will be used for washing the milking system prior to final heating. This heat is normally rejected to air or water.

Refrigeration heat recovery equipment economically recovers and transfers this heat to water for a useful purpose. The heat recovery equipment falls into two basic categories: desuperheating units and full condensing units.

Desuperheating Units

Superheat refers to the sensible heat stored in the refrigerant gas when heated above the condensing temperature at a given pressure. A desuperheating heat recovery unit, so called, removes this superheat as the refrigerant gas is cooled to the saturation temperature. The desuperheating unit will also remove some of the heat of condensation. The desuperheater is simply a refrigerant-to-water heat exchanger installed between the milk cooling refrigeration compressor and conventional condenser. See Figure 5-5.

Today, the superheated usually consists of a stainless steel plate spot welded and expanded forming internal refrigerant passages wrapped tightly around a glass lined tank with insulation and an outer wrapper of steel or fiberglass. The refrigerant gas passes thru this expanded plate before going to the condenser. Heat transfers from the hot gas to the water inside the tank. This tank is plumbed ahead of the conventional water heater. The water is typically preheated to 95-115ºF.   When hot water is drawn from the water heater cold water will enter the heat recovery tank. The water heater heats the water to achieve CIP wash temperature of 160-180ºF. Under typical conditions a desuperheater can remove 30% of the total heat that would have been rejected by the condenser.

Desuperheating heat recovery systems:

- Can be added to existing milk cooling systems at less cost.
- Supply significant quantities of medium temperature water.
- Allow for greater recovery rates in water heating equipment because of a reduced temperature rise.
- Offer a substantial reduction of water heating costs.

Fully Condensing Units

Fully condensing heat recovery systems are designed to remove both the superheat and all the heat from condensation of the refrigerant vapor to a liquid. They replace the condenser found in an ordinary refrigeration system. The ability to utilize all available waste heat means fully condensing systems can supply more and higher temperature (120-140ºF) water than a desuperheater. Because all waste heat must be transferred to water, adequate storage must be provided or excess hot water will be discharged from the system and benefits of recovery reduced. For these reasons, full condensing heat recovery units are not widely used.

Since the amount of heat removed from milk on large dairies greatly exceeds the corresponding need for water heating, add-on desuperheaters have more commonly been adopted. They have been able to reduce water heating costs and more reliably than fully condensing units.

Figure 5-5. Desuperheater heat recovery units (5a – Paul Mueller Co.; 5b – Westfalia-Surge)

High-Efficiency Water Heaters

The application of high-efficiency water heaters instead of a conventional efficiency unit offers dairy farm operators a high return on investment when constructing new facilities or when replacing water heating systems. Energy savings can repay the incremental additional cost of the higher efficiency water heater quickly. Given that the service life of a water heating system can exceed ten years, the accumulation of energy savings can pay the added cost many times over. See Figure 5-6.

An important tool for evaluating and comparing the overall efficiencies of water heating equipment is available from the Gas Appliance Manufacturers Association (GAMA). GAMA's *Consumers' Directory of Certified Efficiency Ratings For Heating and Water Heating Equipment* publishes an "Energy Factor" rating that allows comparison of tested efficiency for participating manufactures.

The "Energy Factor" provides a measure of a water heater's overall efficiency, based on the recovery efficiency, standby loss, and energy input. GAMA October, 2003 "Energy Factor" ratings for commercial water heating equipment:

- Gas Water Heaters
- Oil Water Heaters
- Electric Water Heaters

are available thru the following link. To view these tables, please click on the file below:

Commercial Heaters - GAMA.pdf

If you have a hard copy of this guide, please refer to the blue pages at the end of the section.

Examples of high-efficiency water heaters are given in Figure 5-6.

Recent advancements in water heater technology have lead to significantly improved efficiencies. Features to consider when evaluating fossil fueled hi-efficiency water heating equipment include:

- *Hi-efficiency atmospheric burners* – Advancements in burner design technology have improved combustion efficiency in conventional storage water heaters.

- *Forced combustion (Power burner*) – Forced combustion or power burners are used to attain greater input capacity and efficiency. A blower or fan maintains positive pressure and promotes turbulent flow thru the combustion chamber and flue. This improves mixing of air and fuel, improves combustion efficiency, and enhances heat transfer to water in flue passages.

Hi-efficiency natural
Gas-fired boiler
(Weil-McLain)

Hi-efficiency Oil
water heater
(Bock Water Heater)

Hi-efficiency storage tank
natural gas or
propane water
heater (Bradford White)

(Weil-McLain)

Figure 5-6 High efficiency water heaters.

- *Complete condensing* – conventional burner design does not allow flue gases to drop below 212º F when moisture in combustion products condenses to liquid form. Complete condensing systems continue to extract heat below this temperature and transfer to water. A forced combustion burner is required to ensure adequate exhaust flow and a drain for condensate must be provided. Plastic pipe may be used for venting since fuel gases are so cool.

- *Pulse combustion* – Pulse combustion technology uses a power burner with a specially designed resonant combustion chamber and intermittent spark ignition of fuel air mixture. Combustion takes place in rapid pulses instead of a continuous flame and resonant pressure waves in the combustion chamber promote exhaust gas scavenging, heat transfer and increase efficiency. Complete condensing of exhaust gas products occurs and can be vented with plastic pipe.

- *Pilotless ignition* - The pilot is lit by an electronic spark on a signal from the thermostat, instead of burning continuously. The pilot lights the main burner and is extinguished at the end of the heating cycle.

- *Vent damper* – An automatic vent damper minimizes standby losses thru the water heater when combustion is not taking place.

Heat Pump Water Heaters

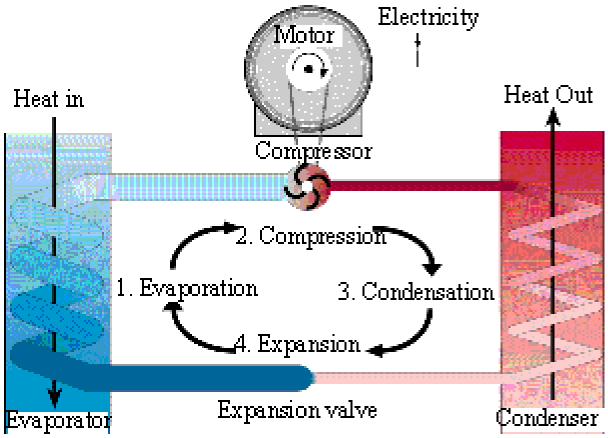
A heat pump water heater (HPWH) uses a reverse application of the standard vapor compression refrigeration cycle. An electrically driven refrigeration compressor is used to remove heat energy from a lower temperature source (usually ambient air) via the evaporator and transfers the heat to a higher temperature heat sink (water in a storage tank) via the condenser.

Greater efficiency than resistance electric water heating is achieved because HPWHs are able to move more energy than they consume by taking advantage of the large amount of heat absorbed and released when the refrigerant evaporates and condenses, respectively. The efficiency of a heat pump water heater can be given in terms of Coefficient of Performance (COP), the ratio of energy output [Btu/hr] to energy input [Btu/hr]. EER [energy efficiency ratio] is a current means of expressing efficiency. EER is the ratio of the cooling or heating output and the watt input to the motor [Btu/hr, W].

The EER is going to depend on the operating conditions. The temperature of the heat source [air], higher air temperatures give higher efficiency and the temperature of the heated water, higher water temperature give lower efficiency. HPWH will not heat water to the temperatures needed for CIP washing. The milk cooling system with heat recovery could be considered a HPWH where the milk is the heat source and the water is the heat sink. The first priority for such a heat pump is to cool milk while a HPWH is to heat water. A supplemental benefit of an air source HPWH is the cooling and dehumidification of the heat source air.

Heat pump water heaters can be three to five times more efficient than resistive electric water heaters, but do suffer from the following drawbacks:

- High initial equipment expense,
- Modest recovery rates,
- Greater mechanical complexity and associated maintenance costs,
- Require appropriate environment to extract heat from,
- Will not heat water to CIP wash temperatures and
- Are not applicable where a heat recovery is installed.



(Calmac Coil HPWH)

Figure 5-7. Diagram and picture of a heat pump water heater

Alternative Sources Of Water Heating

- Gas fired absorption heat pumps
- Solar water heating
- Combined Heat and Power options

Wash System Analysis – Wash Cycle (CIP) Tuning for energy efficiency

Washing Basics of Milking Systems

The network of equipment used to extract, collect, and transfer milk from the cows to the storage tank requires thorough cleaning between uses. A considerable amount of energy is used to clean and sanitize the milking system. Optimizing the wash cycle can improve effectiveness and reduce energy use by the cleaning process.

Washing must be performed without disassembling the equipment (clean in place or CIP). Cleaning is performed through a combination of chemical and mechanical action. Chemical action is achieved through the use of detergents, acids, sanitizing agents, and the proper water temperature. Mechanical action is provided by passing the cleaning solution through the equipment at an appropriate velocity to create adequate sheer stresses on the sides of the equipment. All surfaces must be subjected to both chemical and mechanical action of sufficient duration to ensure adequate cleaning.

The milk pipeline is washed by drawing a solution of water and cleaning agents from the wash sink or vat into the pipe. See Figure 5-8. This is followed by admission of a specific volume of air by the air injector to create a slug of cleaning solution. Flooding each unit with cleaning solution and allowing water to be drawn though them typically clean individual milking units. Air bleeds cause small slugs to form thereby increasing the velocity and coverage of the wash solution. A key objective is to have uniform flow to all the units.

Figure 5-8. Wash sink on California dairy

Vacuum Pump Sizing for Washing

To assure proper washing, the vacuum pump must be capable of supplying enough vacuum to draw the wash solution through the system. Sizing the vacuum pump for wash is similar to sizing the vacuum pump for milking. The required size for each function should be similar but the pump should be the larger of the two.

The vacuum required to wash is the sum of:

- Vacuum needed to create slug flow in each simultaneous air injected loop.
- Amount of vacuum each unit requires to wash (2 cfm per unit).
- Any extra air admitted by jetter or milk meter air bleeds. Wash jetter air bleeds can add up to 2 cfm per jetter.

The amount of vacuum needed to develop a slug flow of different velocities in different size milk lines is shown in Table 5-2. This amount of air does not change regardless of line length.

Table 5-2. Air injection rate for slug flow

Slug Speed	Air injection rate (scfm) for various milk line sizes		
ft/sec	2.5 inch	3 inch	4 inch
23	20	28	49
25	24	33	55
27	29	39	65
29	34	46	76
31	39	54	88
33	46	63	102

Example of vacuum pump sizing for washing:

- Consider a double 27 parlor
- with 2 loops of 4 inch milk line
- milk lines are air injected simultaneously
- slug velocity will be 25 fpm.

The vacuum pump capacity required is calculated as follows:

2 loops X 55 cfm per loop (from Table 5-2)	= 110 cfm
Plus 54 units X 2 cfm per unit	= 108 cfm
Total vacuum pump capacity	= 218 cfm

A 25 hp vacuum pump would be required to wash this parlor because both milk lines are air injected at the same time.

Sequencing the air injection so that only one line is injected at a time would reduce the vacuum requirements as follows:

1 loop X 55 cfm per loop (from Table 5-2)	= 55 cfm
Plus 54 units X 2 cfm per unit	= 108 cfm
Total vacuum pump capacity	= 163 cfm

The required vacuum is reduced by 55 cfm and the vacuum pump downsized to 20 hp. The 5 hp reduction of vacuum pump capacity lowers initial cost of pump and motor. The largest savings is reduced energy costs, by not operating 5 hp of motor load for the milking parlor's lifetime.

A 20 hp vacuum pump producing 200 cfm will meet the effective reserve requirement for milking for this parlor:

35 cfm base + 3 cfm per unit X 54 units = 197 cfm

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Vacuum Level Required for Washing

Vacuum systems are quite commonly set at higher vacuum levels during wash than for milking. The perception is that higher vacuum levels will wash the system better. This may be true in isolated instances but higher vacuum levels are not a sound corrective measure for wash system problems.

When the wash system has been properly tuned cleaning will be thorough and complete, even with vacuum levels as low as 9 inches of mercury. Reduced vacuum levels during washing creates a number of advantages including:

- Increased milk pump capacity.
- Increased vacuum pump capacity.

The increase in capacity is due to reduced head across each milk pump. The load on each pump is also reduced at reduced vacuum levels. Water drawn from the wash sink during the closed period of air injector cycle will be reduced and the amount of air admission or leakage is also reduced at lower vacuum. Individual restrictors at each unit need to be larger at reduced vacuum. Larger restrictors reduce the likelihood that they will become plugged with debris.

Air Injected, Slug Flow Cleaning of Milking Systems

Research has been performed at the University of Wisconsin - Madison to identify optimal characteristics of slug formation. These findings indicate a slug of cleaning solution to be approximately 10 feet in length and travel at a speed of between 23 and 33 feet per second. At the instant the slug completes a trip through the pipeline and reaches the receiver, the air injector closes to initiate the formation of the next slug. The slug must travel the entire loop of pipeline before the air injector is closed or the slug will decelerate and break apart.

Each separate loop of pipeline should have an air injector so that slug formation and acceleration are controlled independently in each loop. Multiple air injectors should be sequenced such that only one air injector is open at one time to reduce vacuum demand. Slug action should be checked with a multiple channel vacuum recorder.

Figure 5-9. Air Injectors

A sample vacuum trace of slug action in a pipeline is shown in Figure 5-10. Each channel represents a measurement point along the pipeline. To find the slug velocity between two measurement point represented by channels 0 [red] and 1 [green] divide the distance between the measurement points by the time denoted by “a” in the Figure. The time is approximately 1 second. The time denoted by “a” starts when the channel 0 experiences a vacuum drop and ends when the channel 1 experiences a vacuum drop. If the distance between the location of channels 0 and 1 is 30 feet,

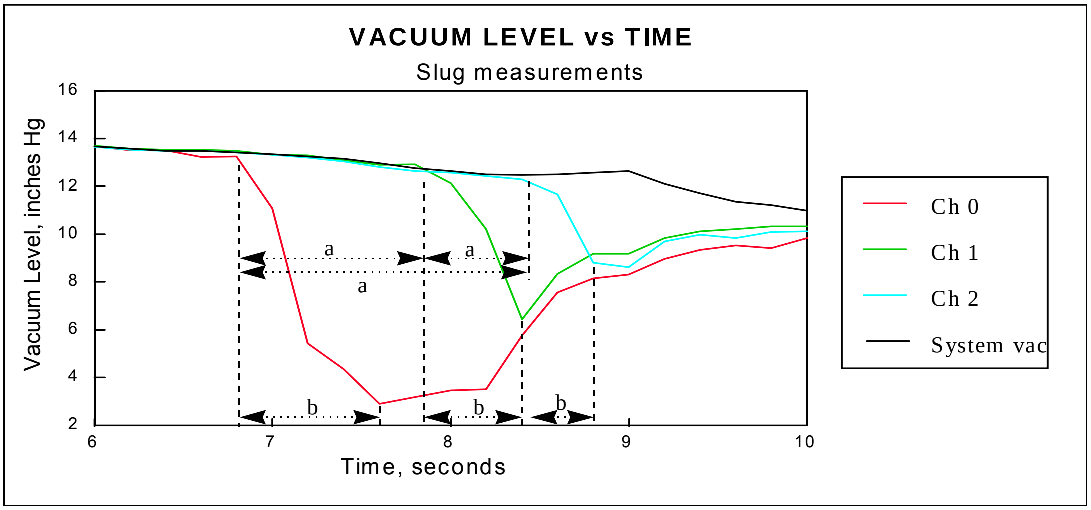

Figure 5-10. Vacuum measurements of slug travel

then the slug is traveling at an acceptable velocity of 30 feet per second (fps). The velocity between points 1 and 2 would be computed in like manner.

The time interval denoted by “b” represents the time it takes for the slug to pass by the transducer. The time interval, “b” starts when a channel experiences a vacuum drop and ends when the vacuum has reached the lowest point. By multiplying the average velocity obtained above, by this time an estimate of the slug length is attained. If the length of time interval “b” is 0.33 seconds, then the estimated slug length will be 30 fps multiplied by 0.33 seconds, or 10 ft.

One important point should be made about interpreting slug flow vacuum traces. When equal vacuum levels are measured at two different points at the same time, there is a direct air passage between those points. At around 8.5 seconds Ch 0 and Ch 1 approach the same vacuum. This is because the slug has passed Ch 1 and there is now no slug between Ch 0 and Ch 1.

Figure 5-11 shows a slug flow vacuum trace from a farm. Observe in Figure 5-11 that around 39 - 41 seconds the vacuum level at channels 0 and 1 are the same as the system vacuum. This denotes that there is no slug present and a direct air passage exists between the two channels. This indicates that either the slug that has passed channels 0 and 1 has broken apart or there is a short circuit of air through the milk/wash valve behind the slug. Corrective steps include checking the milk/wash valve or increasing the amount of water in the slug.

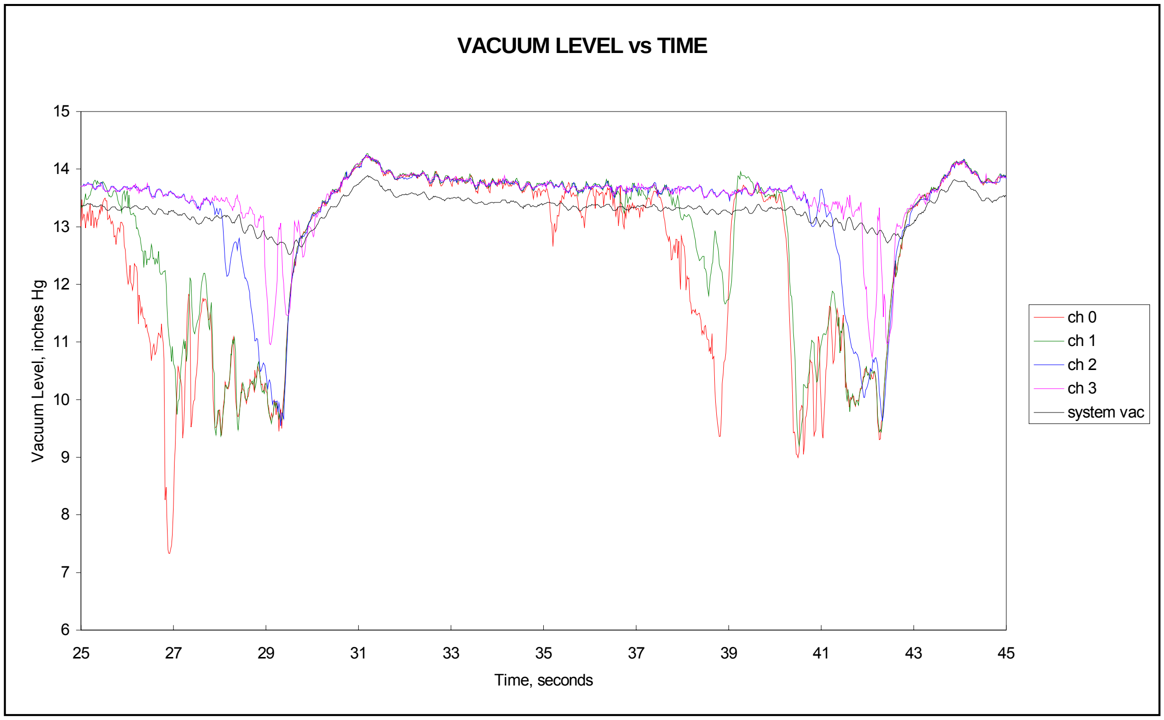

Figure 5-11. Farm Slug Measurement

ECM

Tuning of Wash Cycle

Energy conservation measures for the wash cycle involve tuning the operation of the cycle for optimum performance. The following can summarize optimum performance for a CIP system:

- Adjustment of air injector close time to form a slug approximately 10 feet long.
- Maintaining slug velocity throughout the milk line between 23 and 33 fps. By admitting a sufficient rate of air to keep the slug moving and cohesive, but not excessive amounts of air to blast right through the slug.
- Ensuring the slug travels the entire length of the milk line, and the air injector closes before the slug has fully entered receiver thereby minimizing direct air admission from air injector to receiver.
- Utilizing 0.8 to 1.0 gallons per minute to each milking unit.

Operating with the parameters above will then minimize water use and vacuum pump energy use.

There are several control points involved with tuning the mechanical action of a CIP cycle and each control point exerts a different effect on the system. Table 5-3 details those control points and the corresponding effect.

Table 5-3. CIP Control Points

Control Point	Effect
Air injector open time	Slug travel distance
Air admission rate	Slug velocity
Air injector close time	Water draw per slug and initial slug size
Water flow restrictor on wash line	Slows water intake to allow milk pump to keep up
Water flow restrictors at units	Even water flow distribution to each unit
Water Volume	Prevent draining of sink and unintended air admission
Wash vacuum level	Air admission rate, water draw rate, milk and vacuum pump capacity

Tuning Guidelines:

1. Sketch and measure the system
2. Eliminate dual loops on single air injector controls. Each separate loop should have an independently controlled air injector to prevent more than one air injector from opening at the same time.
3. Set air injector open time to set travel distance
4. Set air injector admission rate to set slug speed
5. Select unit restrictors to give even flow to each milker unit between 0.8 and 1.0 gpm. Do not restrict manifold line, as this will make it very difficult to balance flow.
6. Select a combination of air injector closed time and proper size water draw restrictor on air injected wash draw line to achieve 10 foot slugs without exceeding milk pump capacity to evacuate water from receiver.
7. Set wash sink level high enough to prevent sink running empty and unintended air admission at the sink.
8. Fine tune the system using vacuum analysis to evaluate

Sketching and measuring the system is a very good place to start. In addition to determining how far the slug must travel, the size and layout of the system will be needed to determine how much water is needed to properly wash.

<u>Tuning of Air Injector</u>

The existence of any dual loops controlled by the same air injector will also be found during the sketch and measure phase. Each separate loop in the system must be sequenced such that no two air injectors are open at the same time. This causes a much lower peak vacuum demand and a smaller vacuum pump can be employed for washing.

The sketch will reveal how far the slug must travel. Then the air injector open time can be set, so the slug will travel that distance at 23 to 33 fps. Set the air injector air admission rate so that enough air is introduced behind the slug to continue travel at the appropriate speed between 23 and 33 feet per second. Air injection admission of approximately 35 cfm is ideal for a 3-inch milk line. Higher velocities are not advantageous when dealing with wash slugs. Slug stability suffers at higher velocities and performance of the slug becomes erratic throughout the milk line. Cleaning performance declines substantially at slug velocities higher than 33 feet per second.

Excessive air admission will blast right through the slug, reduces washing effectiveness and forcing the vacuum pump to move excessive amounts of air through the system. This extra air may cool pipeline surfaces, allowing suspended particles to be redeposit.

Milking Unit Washing

Individual milking units should be flow measured using a water trap to determine the actual amount of wash water passing through each unit. Between 0.8 and 1.0 gallons per minute is required for every unit. Restrictors should be used to regulate and balance water flow at each unit. There should be no restriction at the wash sink end of the wash manifold line. Restricting the wash manifold at the sink reduces the capability of the wash manifold line to deliver the required 0.8 to 1.0 gpm to each unit.

Air injecting the wash manifold can result in increased velocity in the units but is usually not required. Care should be taken if air injecting the wash manifold. Timing of wash manifold air injection is different than air injection for the milk line. Wash manifold air injection can cause milk line slugging problems if the timing of the air injection is not correct

Air injection on the wash manifold should move the water from the wash line, through the manifold or jetters, through the milking units, and then into the milk line. Once the wash water has passed into the milk line, the manifold air injector should close. The milk line air injector should then open to push the slug around the milk line. In addition to requiring less vacuum capacity, sequencing the manifold and milk line air injector to not open at the same time prevents disruption of slug travel.

Other Considerations

The capacity of the milk pump to remove water from the receiver acts as a limit on how quickly slugs can be formed. It is necessary to select the correct combination of air injector closed time, restrictor size on the main draw line, and wash vacuum level such that slugs are the appropriate size and sequenced far enough apart that the receiver does not flood and trap over. Increasing the air injector closed time increases the size of the slug and increases the total flow of water into the receiver. Decreasing the water draw restrictor size causes each water draw period to draw less water, causing smaller slugs and lower total flow of water to the receiver. Reducing the vacuum level both reduces the amount of water drawn in during each injection cycle, and increases the milk pump capacity to evacuate the receiver.

The wash sink level should not be depleted during the course of a wash cycle. Depleting the water level in the wash sink causes the wash line to draw air in an uncontrolled fashion. When this happens air injector control of slug formation is lost. The level of water in the sink needs to be adjusted so that wash lines do not draw air.

Vacuum Analysis

At this point the wash system will function and perform adequately. Vacuum analysis and keen observation are needed when fine-tuning the air injection to optimize system performance. If the air injector is open too long, too much air passes directly into the receiver. This extra air causes higher vacuum demand and higher energy use for variable speed vacuum systems. As well as rapid temperature drops of the wash water. This temperature drop is particularly pronounced in cool or very dry climates. This extra air can also cause significant water carry over into the trap.

Figure 5-12 shows a CIP vacuum trace with the air injector open too long. The air injector and vacuum pump speed signals were fed into the data acquisition system and plotted on the graph. Notice that the air injector is opened for about 3.5 seconds. By the time the air injector closes, the system vacuum has dropped sharply nearly a second earlier. The vacuum pump speed rose sharply as well, indicating air passing directly into the receiver.

Figure 5-13 shows the same system with the air injector closed after about 2 seconds open. Notice that the system vacuum does not drop sharply as the slug enters the receiver and the vacuum pump does not experience a sharp rise in speed indicating that excess air has not been admitted into the system.

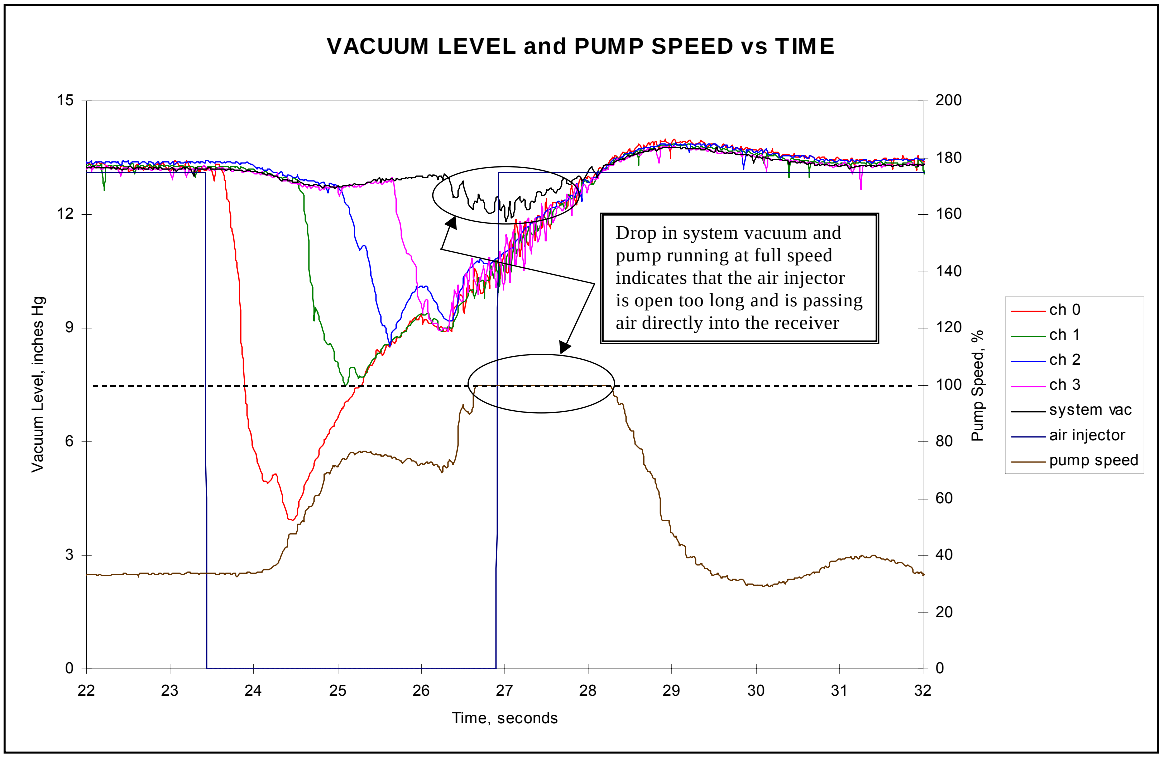

Figure 5-12. Air injector open too long

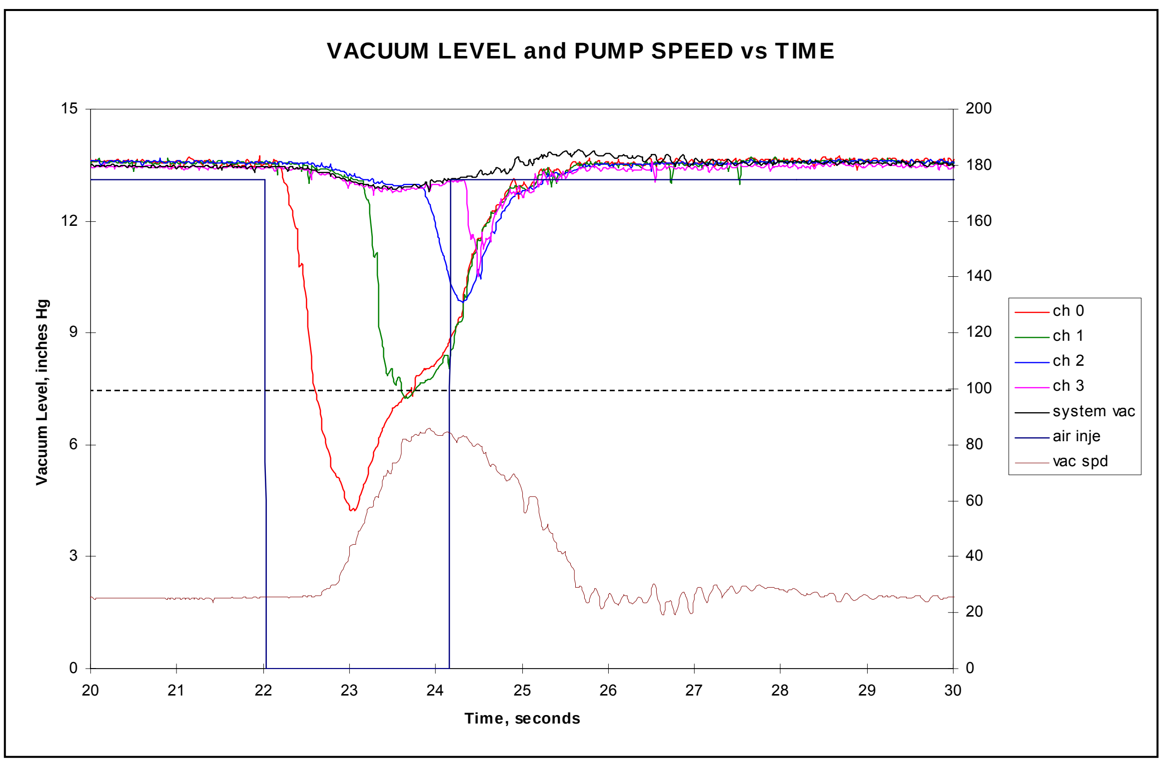

Figure 5-13. Air injector closing appropriately

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Operator Level Checks – Washing & Water Heating

Heat Recovery

- Add a small amount of oil to compressor – ID leaks from oil stains.
- Leak detector – (TIF or dye method) detect leaks to and from, and in heat recovery unit.
- If compressor is operating, check for temperature differential between in-flow and out-flow of refrigerant to heat recovery.
- If access is available to heat recovery water output, check temperature differential between water supply temperature and temperature out of unit. Should have temperatures of at least 90° F (100 -120°F after milking, before washing starts.)
- Electronic sight glass – check system refrigerant levels.

Wash cycle

- Slug action during the wash cycle can be observed at the receiver. At the end of each air injection cycle, there should be a forceful entry of water into the receiver. The force should be sufficient to splash sheets of water over the lid. The air injector should not remain open after this slug of water begins to enter the receiver.
- Unit cleaning can be observed by the shaking of the units. Units that do not shake when wash water passes through are not likely to be receiving enough high-speed water flow to clean effectively.
- The wash sink should not run out of water during the wash cycle. Only wash water should be drawn into the pick up tubes at the sink.
- Wash water temperature should be checked periodically to ensure that the temperature is correct for each cycle. Prerinse water that is too hot not only uses more energy, but also increases the risk of a cleaning failure. Infrared thermometers do not accurately measure water temperature.

Water Heating

Common Water Heater Conditions and Solutions

Table 5-4. Common Water Heater Conditions & Solutions

SYMPTOMS	CONDITIONS	SOLUTIONS
Lime deposits in tank; Scale; Popping sounds.	Water Hardness Above 7 grains	Water treatment; Softener; etc.
Rust staining; bad taste and odor in water	Iron Deposits	Filtration
Rotten egg odor;	Hydrogen Sulfide	Flush tank with Chlorine solution & Install Aluminum anode rods.
Air from hot water fixtures	Electrolysis (Stray Current) or Air introduced by water supply	Properly ground heater & replace anode rods. Check well pump system.
Reduction in recovery	Dip Tube	Replace, dip tube
Inlet / Outlet fitting corrosion	Galvanic corrosion Dissimilar metals	Install dielectric unions
Temperature & Pressure gushing water	Excessive water temp. - 200 F deg.	Adjust or replace Aquastat & T/P valve
Temperature & Pressure dripping	Excessive pressure (above 150 psi)	Check Incoming supply press.; Closed system requires expansion device.

(Bock Water Heating, Inc.)

Reduction of Hot Water Leaks and Waste

A leak as small as one quart per hour can waste 2200 gallons of hot water and 1.3 million Btu per year. Identifying and elimination of leaks is can be done with minimal effort, simply repaired at minimal costs and offer real energy savings.

Reduction of Standby Heat Loss

Standby heat loss occurs in storage tanks and piping and can be reduced with:

- Additional insulation to storage tanks if appropriate
- Insulation of hot and cold water piping within three to five feet of water heater.
- Install heat traps on storage tank hot and cold piping connections.

Corrosion Protection

Corrosion in water heating equipment is inevitable. High water temperatures, dissolved oxygen in water, use of dissimilar metals in plumping, softened water, and poor maintenance increase corrosion problems. Periodic inspection and replacement of anode rods can dramatically extend the life of a water heater.

Scale and Sludge Formation

When water is heated, calcium carbonate and other minerals are forced out of solution and accumulate as sludge on the tank bottom or scale on tank and piping surfaces. The insulating effects of scale and sludge reduces heat transfer to water, decreases efficiency and capacity. The following method can be used for removal.

Tank Flushing Procedure

1. Shut off electrical power to the heater and disconnect the cold water supply.
2. Completely drain the heater and remove the drain valve.
3. Install a 3/4" x 6" nipple with a garden hose adapter into the drain valve spud (opening) and run it to the floor drain, a bucket, or another method of removing water from the work area.
4. Use a straight adjustable spray nozzle (set for wide angle) attached to a garden hose. Insert the nozzle into the cold water inlet spud and wash down the interior sides of the tank. This will remove any particles that have adhered to the sides of the tank. Slowly begin to lower the nozzle into the tank until it reaches the bottom. Repeat this process several times to be sure the interior walls are clean.
5. Close the drain valve, refill the heater, and return it to service.

(From: Bock Water Heating, Inc.)

Periodic Burner Maintenance

Fossil fuel combustion burners should be inspected, cleaned, serviced, adjusted and performance tested annually to maintain system efficiency.

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Glossary of Washing and Water Heating Terms

Anode Protection – A means of protecting a surface from corrosion using a naturally occurring current, derived from an anode of more reactive material to maintain the surface at a negative potential. The anode acts as a sacrificial element to protect the surface.

Aquastat – A thermostat which senses water temperature.

British Thermal Unit (Btu) – The amount of heat [energy] required to raise the temperature of one pound of water one (1) degree Fahrenheit, ie from 62 to 63ºF.

Coefficient of Performance (COP) – The ratio of total useful work output by a machine to the net energy input. Units must be consistent.

Conduction – The transmission of heat energy through solids and liquids by interaction of adjacent molecules.

Convection – The transfer heat by the motion of a liquid or gas. This motion may occur naturally or it may be forced by mechanical means such as pumps or fans.

Desuperheater – A refrigeration heat reclaim device designed to heat water using heat recovered from a refrigerant stream which is superheated above the saturated vapor temperature.

Energy Factor – A rating for water heater efficiency defined by U.S.D.O.E. and published in the GAMA *Consumer's Directory of Certified Water Heater Efficiency Ratings.* A measure of a water heater's overall efficiency, based on the recovery efficiency, standby loss, and energy input.

Energy Efficiency Ration (EER) – The ratio of cooling effect [Btu/hr] to the power input [Watts]. The units are Btu/W-hr.

Gas Appliance Manufacturers Association (GAMA) – is a national trade association whose members manufacture appliances, components and related products used in connection with space heating, water heating and commercial food service.

Hard Water – Water that has a high concentration of dissolved minerals.

Heat Pump Water Heater (HPWH) – A device that uses the vapor compression refrigeration cycle to extract heat form a source and deliver it to the domestic hot water system at a higher temperature.

Pressure Relief Valve – A safety valve that opens when pressure exceeds a preset level.

Recovery Rate – The amount of water in gallons per hour that can be heated by a water heater based on a specified temperature rise (usually 80 or 100º F).

Resistance Heating - A heating process that involves conversion of electricity into heat energy by a resistance element, and the subsequent transfer of that heat into a target object or fluid

Scaling – The formation of mineral deposits, primarily calcium carbonate, in a water heating system. Scale reduces the efficiency of fossil fuel-fired water heaters by insulating the heat transfer surfaces in the tank.

Standby Loss – The heat loss from a water heating system that results from maintaining water at a require temperature.

Temperature and Pressure Relief Valve - A safety valve that opens when pressure or temperature exceeds preset limits.

Thermostat – Adjustable temperature actuated switch.

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