Design, Operation and Performance of a Commercial Scale Hot Water Treatment Facility to Control Coqui Frog on Potted Nursery Plants

Paul Singleton[1], William Durston[2] and Charles Nelson[1]
[1] CTAHR-University of Hawaii at Manoa, [2] Leailani Nuresry Waimanalo HI

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Summary.

We designed and tested new concepts in a commercial scale hot water treatment chamber that eliminates coqui frog and their eggs from potted nursery plants. New design features included:

- **a)** recovering heated water leaving the treatment chamber
- **b)** fine filtration of recycled water
- **c)** u.v. sterilization of recycled water
- **d)** elimination of storing large volumes of pre-heated water prior to treatment

We constructed a 20’ X 8’ X 8’ chamber fitted with equipment and controls to meet these design features and then tested its performance with commercial scale loads of nursery plants.

The heating, water recycling, heat recovery, fine filtration, water delivery system and heat characteristics within the chamber and treated plants worked well and met specifications to kill coqui frog on potted nursery plants. Our design was able to deliver 35 gpm of 120 F water into the treatment chamber through 48 cone nozzles that produced reasonably uniform heating of the plants and medium.

Heat recovery from recycling the treatment water averaged 81%. This represents an energy savings of nearly 600,000 Btu per hour of operation. With the boilers employed in our design the recycling system saves approximately $10 of propane per hour of operation.

We were unable to sterilize the recycled water with u.v. light. This is because as the hot water treatment progressed, the heated water became colored by soluble substances (probably polyphenolic compounds) leached from the peat moss based medium and u.v. transmission in the u.v. treatment chamber fell to levels well below efficacy. Since peat is the medium of choice for most growers this problem likely eliminates the possibility of sterilizing water as it is recycled during treatment operations.

Following is a presentation and discussion of all aspects of the design, construction, operation and performance of this hot water treatment chamber.

2) Recommended design changes.

- **a)** Eliminate u.v. sterilization or install u.v. equipment made to treat highly colored water e.g. equipment used to sterilize maple syrup or tertiary effluent.
- **b)** Increase opening in gravity filter from 200 mesh to 80 mesh.
- **c)** Reduce forward momentum of water at the recycled water outfall onto the 200 mesh screen. A plenum that drops water more vertically and spreads it widely onto the screen will reduce water loss when screen begins to plug.
- **d)** Eliminate bag filter or increase its pore size from 1.0 uM to 100 uM to reduce frequency of bag changes.
- **e)** Reduce volume of catchment reservoir and use a reservoir shape that is conical or has a sump on the bottom. This change will reduce cavitation at the pump intake.

3) Introduction

Coqui frogs (*Eleutherodactylus coqui)* were introduced to Hawaii through the horticultural industry around 1988, and have since become widespread pests affecting the plant industry, tourism, property values, insect populations and the quality of life of residents. These Puerto Rican natives were probably introduced to the Big Island via Florida as a stowaway in a single shipment of nursery plants.

Subsequent dispersal of the frog within and between islands was primarily the result of shipping infested nursery plants. Arnold Hara from The University of Hawaii College of Tropical Agriculture and Human Resources (CTHAR) developed a heated water treatment method to kill the frogs and their eggs on potted nursery products. His method identified the exposure time and temperatures required to kill the frogs and their eggs with minimum damage to plants.

4) Design evolution toward a commercial scale hot water treatment facility.

a) **Laboratory scale.** A small laboratory scale treatment unit was constructed at the Waiakea Research Station to evaluate the effectiveness of a hot water shower treatment to kill frogs on multiple potted plants. The initial treatment system used a small on-demand boiler to heat a large quantity of water held in a tank. The water was circulated between the holding tank and boiler with a pump until it reached the target temperature. Then, the heated water was pumped onto the plants in the experimental chamber via spray nozzles. The entire reservoir of heated water was pumped into the chamber and immediately drained from the chamber floor to waste.

b) **Pilot scale of a commercial hot water treatment unit.** With support from Leilani Nursery in Waimanalo we modified the laboratory concept and built a more commercial scale prototype. The treatment chamber was 8’ X 10’ with a floor lined with vinyl sheeting. The unit was designed to deliver 14 gpm of water into the chamber at 120 F. We eliminated the hot water reservoir by installing a two 199,000 btu/hour on-demand boilers that were plumbed in parallel. Each boiler could raise the temperature of approximately seven gallons of water per minute from 70 F to 120 F and deliver the heated water directly to the spray nozzle system in the treatment chamber. Various nozzle types and their configuration were tested in this phase to overcome problems with spray distribution when large numbers of plants were in the chamber and their foliage was close to the chamber walls. Industrial spray nozzles with a 120 degree cone pattern and spacing on 2’ centers along the sides and ceiling were determined to be the most effective. During this phase of development a data logger with a thermocouple was used that could reach various parts of the chamber, plants and potted medium during operation. In this way we determined where the thermocouple needed to be placed to ensure the entire load of plants met temperature and time criteria for killing the frog and its eggs. Heated water from this prototype chamber was also drained to waste. Eliminating the reservoir in favor of larger boiler capacity was more efficient for commercial use than the laboratory design since the operator did not have to wait until the reservoir water was raised to the target temperature to begin a new treatment cycle and avoided the need to retreat a load in case the heated reservoir water was not sufficient to meet the temperature and time specifications for effective treatment.

c) **Commercial scale design – this project**. With a grant of $22,675 from the Hawaii Department of Land and Natural Resources (S-05-314-522) through the Hawaii Invasive Species Committee and a cost share from Leilani Nursery of $28,500 we designed, constructed and tested a 8' X 8' X 20' commercial prototype hot water treatment facility.

Discussion with growers, the Hawaii Department of Agriculture and experience with the two previous designs led to a new design approach that is documented below with comments and reasoning for selected features. Our design aimed to reduce operating costs and reduce the potential of spreading disease between plants.

i) Prominent features of the new design include:
(1) Recycling heated water after it passes through the hot water chamber.
(2) Fine filtration of recycled water including 73 and 1.0 micron filtration
(3) Sterilization of recycled water by ultraviolet light treatment.
(4) Pressure, temperature and flow monitors in the supply and return portions of the water delivery and recovery systems

We tested the performance of the system and system components under commercial scale product throughput. Following the design description below we provide a detailed account of the system's performance, its operation and propose design changes to the system.

5) Design and construction of an 8' X 8" X 20" hot water shower treatment unit.

a) **Chamber.** We modified a 20 foot shipping container. The container had wooden floors that we coated with an epoxy paint impregnated with non-skid grit. Since one of the goals of this project is to recover as much heat as possible it is important that the floor be wooden or if a metal floor is used it is insulated otherwise a thick bare metal floor will create a large heat sink and significantly slow the temperature rise of plants and medium during operation (Image 1).

The chamber was raised approximately 4' above ground level and tilted along its length to create a slope between the doors and opposite end of approximately 2%.

i) Chamber drain. To prevent pooled water from developing a heat sink in the container we designed a drain that would rapidly evacuate water from the floor. We cut a 4" X 7' slit in the floor at a distance 4" from the end wall of the container. The entire floor drain was fitted with an 'L" shaped strip of aluminum flashing that extended 2" onto the floor surface and 2" below the outside bottom edge of the floor. The flashing was caulked and secured to the floor with stainless screws. The flashing ensured a clean vertical drop of drain water into return water collection plenum immediately below the floor slit. We used plastic auto body filler to build a slope between the foam sheeted back wall (see below) and the remaining 4" of floor left between the wall and the back side of the drain slit to prevent any pooling of water.

The drain slit was lined with a 1/8"mesh wire hardware cloth to trap large trash or fauna from exiting the chamber (Image 2).

ii) **Chamber insulation**. The metal walls of the chamber are large heat sinks but, when un-insulated, can also radiate a large amount of heat during operation. We insulated the walls and ceiling with 1/8" pvc sheet foam. A matrix of 1" X 2" treated lumber on 2' horizontal and vertical centers was screwed to the walls and to the ceiling of the container. The pvc foam sheet was then attached to the wood lattice with stainless steel screws and washers. Seams of the sheeting were caulked (Image 3). This pvc foam is very light weight and easy to cut and even bend with a heat gun but it cannot easily withstand blows or punctures. There are other materials such as thin corrugated hard pvc sheeting that may prove to be more durable.

iii) **Drain plenum**. A drain plenum, made of a 6" i.d. pvc pipe cut longitudinally, was fitted below the entire drain slit. The plenum was installed with a slope of approximately 10% from one side of the drain to the other. The drain plenum was flush with the bottom of the container so that the vertical side of the aluminum drain flashing terminated below the lip of the pipe. The pipe was capped on one end and we used a 90 degree pvc elbow also cut in half longitudinally to direct the drained water out the end of the container for return to the reservoir.

b) **Reservoir.** We used a 300 gal Rubbermaid stock tank as a water reservoir (Image 5). One goal of this project was to determine criteria to develop an understanding of how to specify the size the return water tank. We used an excessively large capacity tank so the system could be run without additional water input. This allowed us to measure water use under different loads. We covered the reservoir with ¾" plywood coated it with epoxy paint, made a water tight seal with the tank edge with caulk and secured the cover with bolts through the plywood and tank lip. We cut an opening of 22.5" X 22.5" in the top of the tank in line with the drain outfall on the side of the tank most distant from the end of the container.

i) **Initial filtration of return water**. We installed a self cleaning gravity filtration system for the drain water. In this system, drain water falls with a significant horizontal velocity onto a large area of nearly horizontal fine mesh screen. The forward water velocity pushes debris outward onto the screen which keeps the screen from plugging Image 6 and Image 7).

The outfall from the 6” pvc drain pipe was placed 1.5” above a 2’ X 2’ stainless steel screen with 200 mesh/in (73 uM opening) (TWP Inc. www.twpinc.com Part 200X200S0021W48T). The screen was supported by a 22.5” X 22.5” piece of flat (¾” opening) piece of expanded metal that was welded to a frame of ¾” angle steel along three sides (Image 7). The weld seam between expanded metal and angle steel was at the bottom of the vertical side of the angle steel. The three-sided angle steel frame faced outward from the expanded metal. We installed 3” stainless steel bolts through the four corners of the horizontal side of the angle steel to serve as slope adjustments for the screen (see corners of frame in Image 4).

ii) **Float valve.** A 1” float valve was installed through the cover and along one side of the tank. The float valve was adjustable from levels near the bottom of the tank to within 5” of the top of the tank (Image 8).

iii) **Water level gauge and volume determination**. A 24” flexible sight-liquid level gauge made of aluminum tank fittings and clear vinyl tubing was installed on the side of the tank (McMaster-Carr http://www.mcmaster.com item #32880K44) (Image 9). We calibrated the tank volume in 25 gallon increments using a precision water meter connected to a hose. Volume data was recorded on a white foam sheet fixed behind the sight tube.

c) **Pump system**. The hot water delivery system was driven by a 5.0 h.p. 3-phase Meyers QuickPrime self priming centrifugal pump (OP50B-3) rated at 70 gpm @ 60 psi (Image 10).

i) **Intake.** The pump intake was through a 2” bung fitting at the bottom side of the tank. A swing check valve was installed in the suction pipe to maintain pump prime when not in use. A 2” 100 mesh filter was installed after the check valve to trap any debris inadvertently entering the tank.

ii) **Drain valve.** A 2” tank drain valve was installed in the intake pipe to aid cleaning the tank

iii) **Priming pump.** The pump was primed with fresh water via a valve controlled ½” pvc pipe plumbed into the 2” output at the pump head. This prime filled the entire water intake and delivery system prior to pump activation.

iv) **Pump by-pass.** We installed a 1 ½” valve and pipe into the 2” pump output pipe. This pipe can return provide pressure relief when pressures at the pump head become too great or regulate flow through the system. This manual by-pass valve is not necessary and pump head pressures never exceeded maximum specification unless the bag filter (see below) became clogged and was not replaced early enough. We suggest operators protect the pump from overload with overload protection as we did and as an extra precaution use a automatic adjustable pressure relief valve.

d) **Pressure, temperature and flow gauges.**

i) **Pressure**. We installed glycerin filled pressure gauges (McMaster-Carr www.mcmaster.com) at the following points in the water delivery system: a) before the 1.0 uM bag filter housing, b) after the 1.0 uM bag filter housing, and c) in the 2" pipe used to aggregate the flow from the five boilers. The pressure gauges before and after the 1.0 uM bag filter are needed to detect rapid changes in pressure differential across the filter which indicates the need change the filter. See Table 1 below for dynamic pressures in the system duringoperation.

Table1. Mean line pressures at various points in water delivery system

Gauge location	psi	Comments
Between pump & bag filter	68	
Between bag filter & boilers	67	Specified pressure drop after filter = 0.5 psi
Between bag filter & boilers after three runs with 1.0 uM bag filter	58	Pressure drop was sudden and indicated filter bag was plugged.
Between boilers & nozzles	44	

ii) Temperature. Glycerin filled gauges (McMaster-Carr www.mcmaster.com) were installed: a) just before the boilers, and b) in the 2" pipe used to aggregate the output of the five boilers. These gauges were not only used to monitor the system but to calculate potential energy savings from the recycle system.

iii) Flow gauge. We installed a battery operated digital ¾' paddlewheel flow meter/totalizer in the feed line to one of the five boilers (McMaster-Carr www.mcmaster.com – item 3562k33) (Image 10). Flow data was used to monitor the system to determine energy savings with the recycling system.

iv) Chamber and medium temperature. A printing data logger (Omega Engineering) with four 15 ft thermocouples was used to monitor internal temperatures. Thermocouples were passed through a small hole in the middle of the side wall of the container. The data logger was used to develop data presented in this report and is useful to operators to document treatment specifications.

e) Water filtration and ultraviolet treatment. Our water recycling system was designed to a) recover hot water with an aim toward energy conservation and reducing operating costs, and, b) kill potential pathogens introduced to the recycled water from treated plants. The later purpose has not only obvious value to reduce cross contamination of plants but could obviate the need to treat used water in the reservoir before disposal.

i) The filtration and disinfection of water by ultraviolet light treatment (u.v.) are linked. Suspended particulate matter, soluble compounds coloring the water and high temperature all adversely affect the effectiveness of u.v. light treatment of water. **Filtration.** Recycled water was first filtered through a 100 mesh (73 uM) gravity filtration system as described above. We further treated the water to improve u.v. light performance with a 2" stainless steel upright Flowline filter housing with extended life polypropylene 1.0 uM filters. The unit is rated at 80 gpm.

ii) **One micron bag Filter.** After the pump by-pass tee and valve our pump output was connected to a 2" swing check valve then a high capacity bag filter (Image 12 and Image 13) followed by another check valve, a sample port and a ultraviolet light (u.v.) The outflow from the u.v. light was fed immediately into the boilers.

iii) **U.V. light treatment.** We installed a WEDECO 2", 80 gpm dual bulb u.v. light (GLI-15) fitted with a u.v. intensity sensor (Big Brand Water Filter - http://www.bigbrandwater.com). The u.v. light was installed immediately following the 1.0 uM bag filter and just before the boilers. A ½" sample port was installed before and after the u.v. light to evaluate water turbidity, color, sterility, salinity and pH.

f) **Boilers.** Five Paloma boilers (model Waiwela PH28ROF Residential Outdoor Tankless Water Heater - rated at 199,900 btu/h anf a flow rate of 7.45 gpm at a 45 F temperature rise) (http://www.tanklesswaterheaters.com) were installed in parallel by connecting them to 2" main supply and product water lines . Each boiler has its own digital thermostat.

g) **Water delivery system to treatment chamber.** Water exiting the boilers was 120 F and entered a 2" mainline to the chamber where it was split into 2 1" sub-mains and ½" sub-sub mains that supplied the nozzles. We installed 48 Promax QuickJet spray nozzles (Spraying Systems Co., P.O. Box 7900 Wheaton Il 60189-07900, 630-665-5000) on the container walls and ceiling (see Images 1& 3 in appendix). Dynamic pressure in the nozzle supply line was 45 psi (Table 1).

6) Performance Evaluation

a) **Water consumption.** One objective of this research water to specify the amount of water consumed by the system from leakage and that absorbed by the plant media, The later determination is important to select the proper size reservoir and needed fresh water flow through the float valve.

We operated the system without plants and with the float valve off to determine the amount of leakage we had. Most leakage was through the container doors. Gaskets on those doors are meat to keep water from entering the container but not to seal internal water form leaking out. The Table below shows a leakage rate of less than 0.5 gpm and that about 16 gallons retained in all parts of the water delivery and return systems.

Table 2. Test 1. Water retention in system plumbing and water loss from system without plants

Time from Pump Start (min)	Pump or Tank Status	Water Volume in Tank (gal)	Water Leakage While System is Running gal/minute	Putative Water Volume in Delivery/Recycle System While in Operation (gal)
00	Start	255	0.39 *	15.66 **
06	Running	237		
11	Running	235		
13	Stopped	235		
20	Final Volume	250		

* Difference between Start Volume and Final Volume divided by minutes pump was running

** Includes, pipes, filters and water on floor and in return outfall. Difference between Start Volume and Dynamic Volume while pump was running less water loss rate times the minutes pump was running at point of evaluation.

b) **Determination of water retention by rooting medium of treated plants**. We measured total water consumption of different treatment loads over time. In this way we estimated the amount of water retained by treated plants (primarily due to retention by the rooting medium). All treated plants had been watered to day before and their medium consisted of 4 parts sphagnum peat moss and 1 part perlite.

The four tables below show that while total water retention by the potted plants had a relatively large range (17.6 – 35.2 gallons) if we accounted for the volume of media being treated the relative range was nearly cut in half. Water retention ranged from 8% to 14% of the volume of media being treated (see Tables 2-5) with a mean of 11%.

Table 3. Plant Test 2. Water retention in system and water loss when system is run with plants – 2400 Areca palms in 3.25" square pots filled with 350 mL peat/perlite medium

Time from Pump Start (min)	Water Volume in Tank (gal)	Estimated Water Retention by Pots Adjusted for Leak Losses gal. (liters)	Water Retention per Unit Media (v. water retained / v. media)
00	250	17.6 (66.5)	0.08
02	212		
04	207		
07	203		
12	201		
15	200		
18	198		
21	195		
27	194		
Final Volume	222		

* assumes each 3.25" square pot had 350 mL of media

Table 4. Plant Test 3. Water retention in system and water loss when system is run with plants – 1200 Areca Palms in 3.25" square pots filled with 350 mL peat/perlite medium and 32 Areca palms in 7 gallon pots filled with 22.5 L of peat/perlite medium

Time from Pump Start (min)	Water Volume in Tank (gal)	Estimated Water Retention by Pots Adjusted for Leak Losses gal. (liters)	Water Retention per Unit Media (v. water retained / v. media)
00	220	35.2 (133.1)	0.12
01	182		
02	172		
05	163		
07	160		
08	158		
11	156		
14	153		
18	150		
23	149		
Final Volume	176		

* assumes each 3.25" square pot had 350 mL of media and 7 gallons pots are 85% filled.

Table 5. Plant Test 4. Water retention in system and water loss when system is run with plants – 2400 Areca Palms in 3.25" square pots filled with 350 mL peat/perlite medium

Time from Pump Start (min)	Water Volume in Tank (gal)	Estimated Water Retention by Pots Adjusted for Leak Losses gal. (liters)	Water Retention per Unit Media (v. water retained / v. media)
00	150	22.7 (85.8)	0.10
01	120		
02	113		
04	110		
05	108		
19	95		
24	95		
28	90		
32	88		
Final Volume	115		

* assumes each 3.25" square pot had 350 mL of media

Table 6. Plant Test 6. Water retention in system and water loss when system is run with plants – 2400 Areca Palms in 3.25" square pots filled with 350 mL peat/perlite medium

Time from Pump Start (min)	Water Volume in Tank (gal)	Estimated Water Retention by Pots Adjusted for Leak Losses gal. (liters)	Water Retention per Unit Media (v. water retained / v. media)
00	175	31.2 (117.7)	0.14
01	135		
03	125		
08	118		
10	113		
14	110		
20	110		
24	110		
28**	110		
32	105		
36	100		
Final Volume	130		

* assumes each 3.25" square pot had 350 mL of media
** 1 uM bag filter changed at 22 minutes after outlet pressure dropped to 50 psi

c) **Dynamics of return water temperature during operation**. The five figures below show how the recycle system affects the temperature of the water re-entering the boilers. Generally, by the mid time point of the treatment the water re-entering the boilers is within a few degress of the boiler exit temperature. In most cases there is a continual upward rise in return water temperature as the treatment operation continues. In batches where the volume of potted medium is particularly large (Test 5) the return water temperature can initially fall significantly as the treated water is cooled by the chamber contents. The very large flow of water through this system other wise prevents a large temperature drop at when he system is started.

The following graphs (Figure 1-5) show the efficiency of the heat recovery system. For calculations on how much heat was recovered in these treatment runs see the next section.

Figure 1.

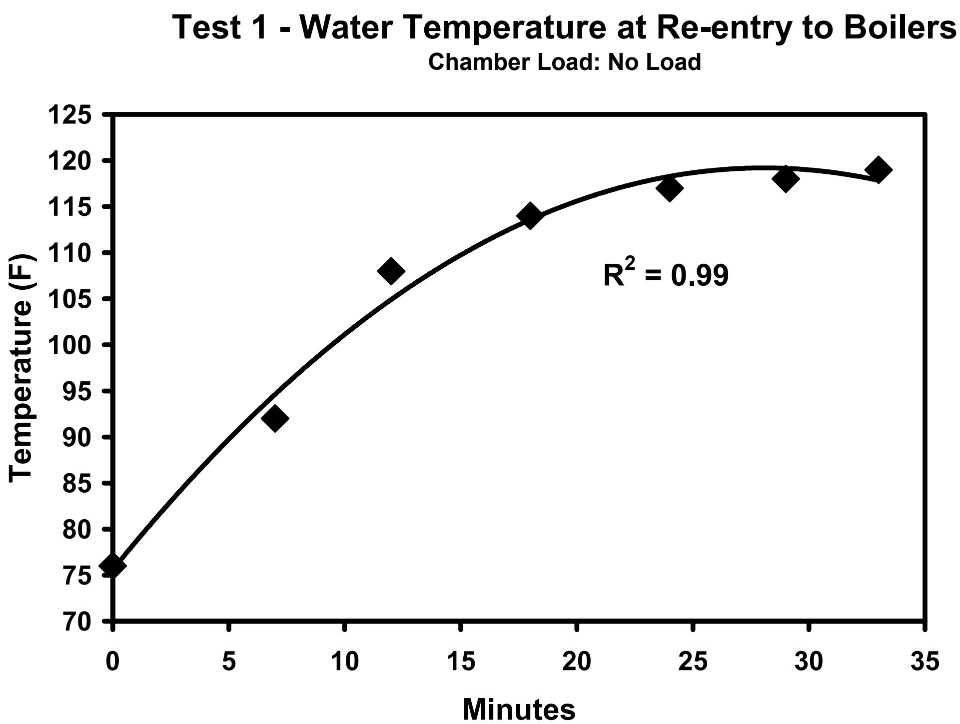


Figure 2

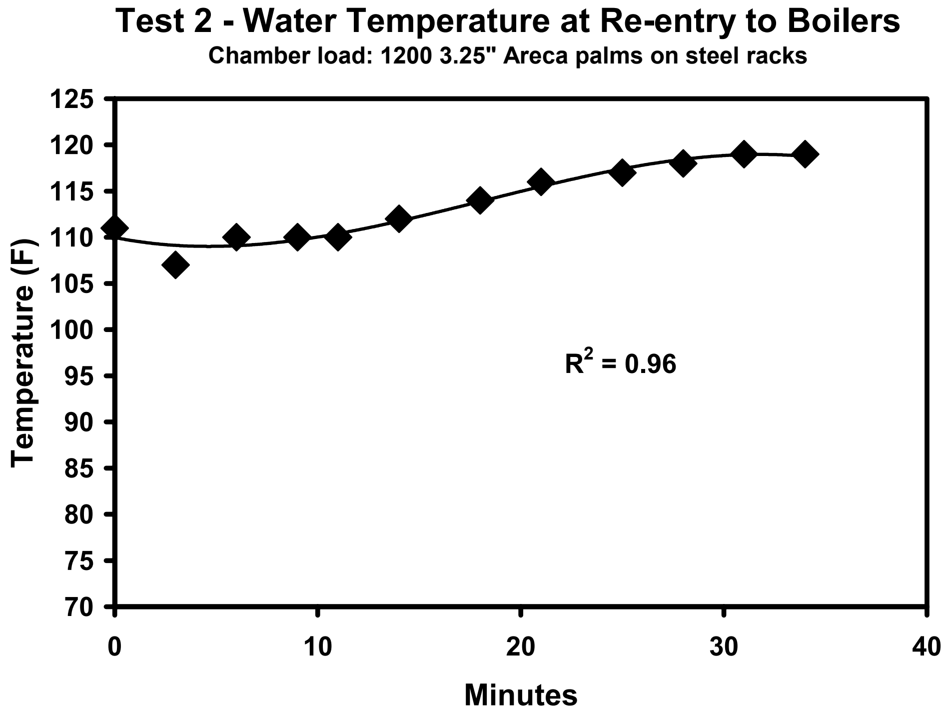


Figure 3

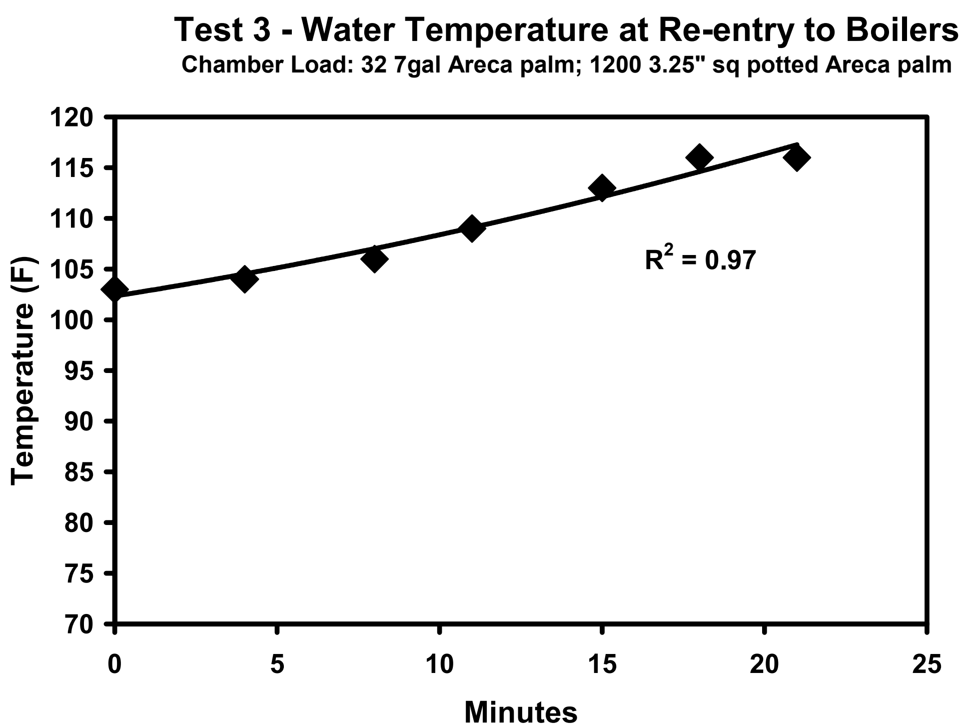


Figure 4

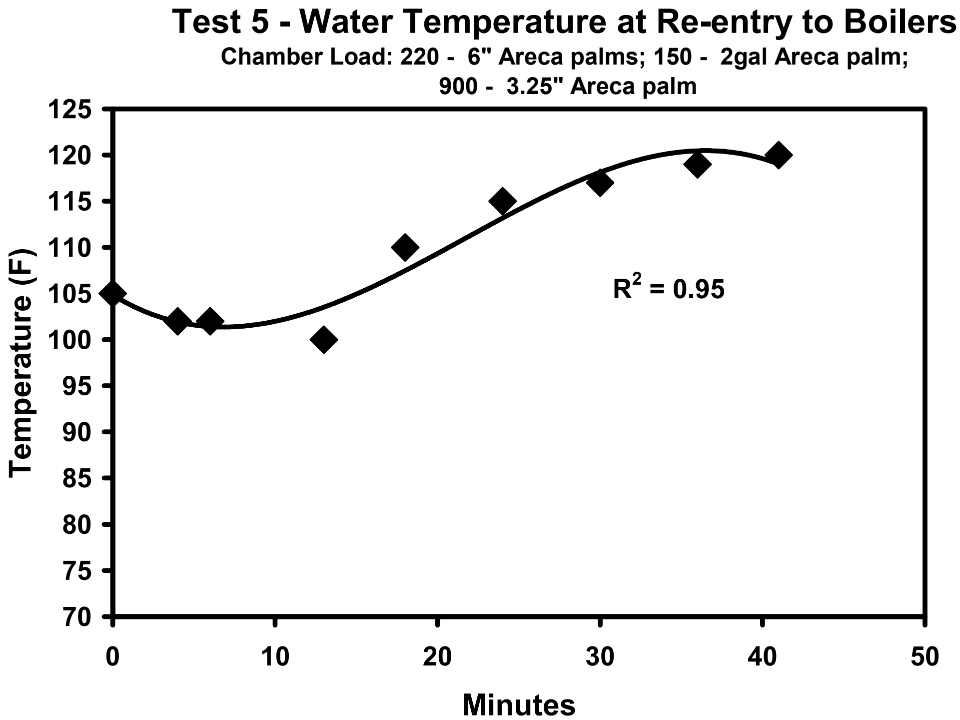
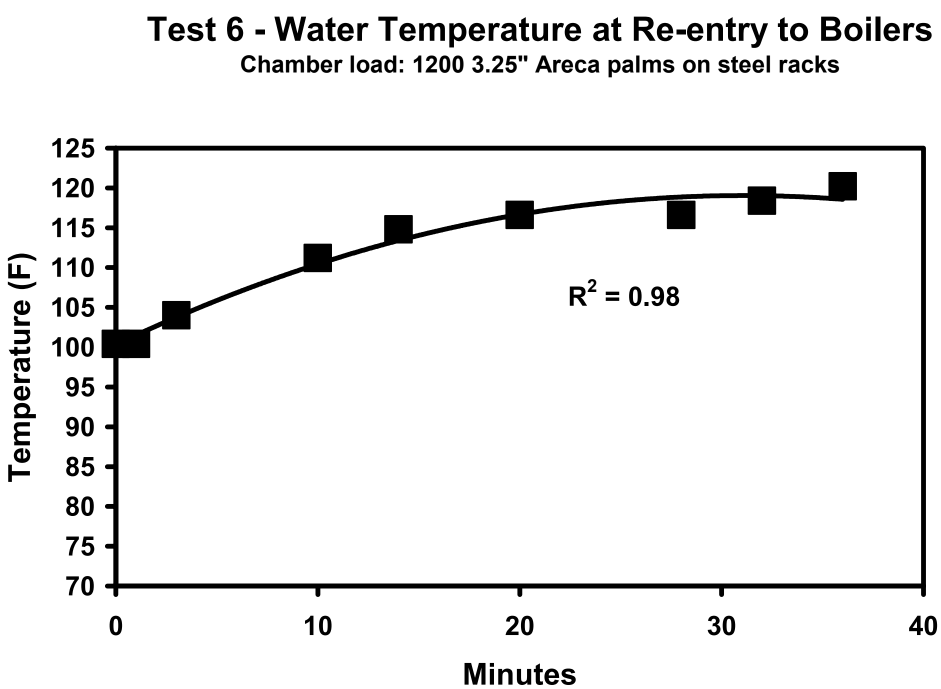


Figure 5



d) **Calculating efficiency of water recycling system - conservation of heat energy.** We estimated the amount of heat energy that the water recycling system conserved during operation with container full loads of various plants for various times. We derived these estimates by subtracting (b) cumulative heat energy added to the water flow in the recycling system from (a) the cumulative heat energy in the same flow when its temperature is raised from 77 F (average temperature of fresh water at the site) to 120 F (temperature of water leaving boilers) and eh water flow is sent to waste as in earlier designs.

i) **(a) Cummulative heat energy sent to waste (Btu)** = (120 F – 77 F) X 280 pints/min X total minutes run time

ii) **(b) Cumulative heat energy added to recycle system (Btu)** = $\sum(120 - F_i)$ X $(t_{i+1} - t_i)$ X 280 where: F = temperature of water entering boilers, t – time in minutes between temperature readings. Time increments between temperature readings averaged 5 minutes. Calculations assume temperature rise in reading interval is the same throughout the interval and is based on the temperature at the beginning of the interval. We did not adjust Btu estimates for heat lsot in leaks since these would be the same for both a recycled and non-recycling system.

e) **Heat energy recovery.** Heat conservation from recycling water drained form the treatment chamber was highly successful. The proportion of heat recovered compared to the hot water treatment flow going to waste ranged from 69% to 93% (Table 6). The amount of energy savings is dependent on the starting temperature of the water and on the total time the chamber is operated for a batch. When batches were run back-to-back water temperature in the reservoir at the start of operation was, on average, 38 F higher than at the start of the first run. Run time also affects potential energy savings with the water recycling system. Toward the end of each batch the return water is within a few degrees of the temperature target of 120 F so the differential between recovered water temperature and a system with no heat recovery in increases with time.

Table 6. Energy and water recovered by the water recycling system

Test	Starting water temperature	Run time	Heat energy recovered	Heat recovery per hour	Relative energy recovery	Water conserved
	F	min	Btu	Btu/h	%	gallons
1	76	33	280,140	509,294	69	1142
2	111	34	361,060	637,720	88	1177
3	103	21	189,000	539,973	75	727
5	105	41	383,460	561,001	78	1419
6	100	36	403,564	672,741	93	1246
Mean	**99**	**33**	**323445**	**584,145**	**81**	**1142**

f) **Potting medium temperature during treatment**. We monitored the changes in temperature of the potted medium (1 perlite : 1sphagnum peat moss, v:v) during operation. Samples of the this temperature response are presented in Figures 6-10 below. The present standard for treatment to rid potted plants of coqui frog and their eggs is to have the surface of the potted medium reach 113 F and remain at that temperature for 5 minutes.

In all tests we maintained the hot water treatment well beyond this standard. For example see Figure 8 below. Figure 8 shows treatment was required for nearly 40 minutes for the potting medium to reach 115 F at a depth of 1" below the surface. In figure 9 we placed thermocouples at different location in a pot and different sections of the container. A thermocouple placed on the surface of potting medium in a 7 gallon reached 115 F in only about 10 minutes.

Figures 9 and 10 show that whether the thermocouple is placed on the medium surface on the top of the pot or on the surface on the medium at the drain hole the temperature rise to 13 F is relatively rapid compared to the time to raise temperature beneath the surface.

Our results demonstrate that if the treatment standards to kill coqui frog and its eggs are raised the design of the treatment facility presented here can meet higher standards.

Figure 6.

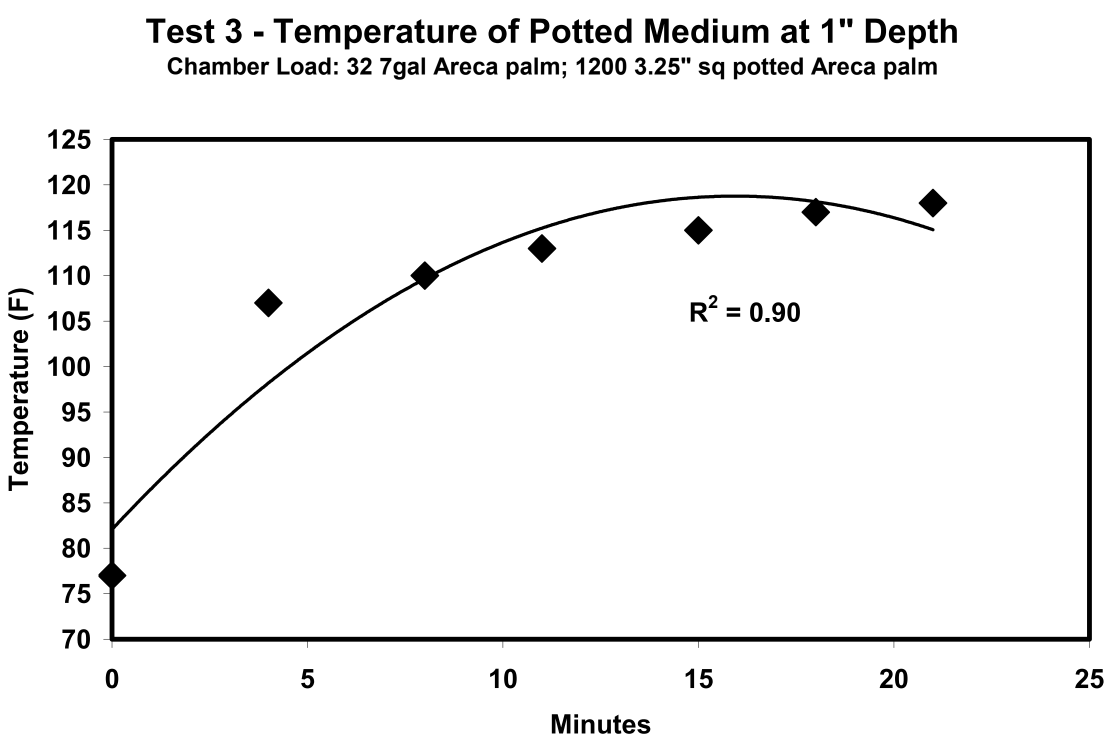


Figure 7.

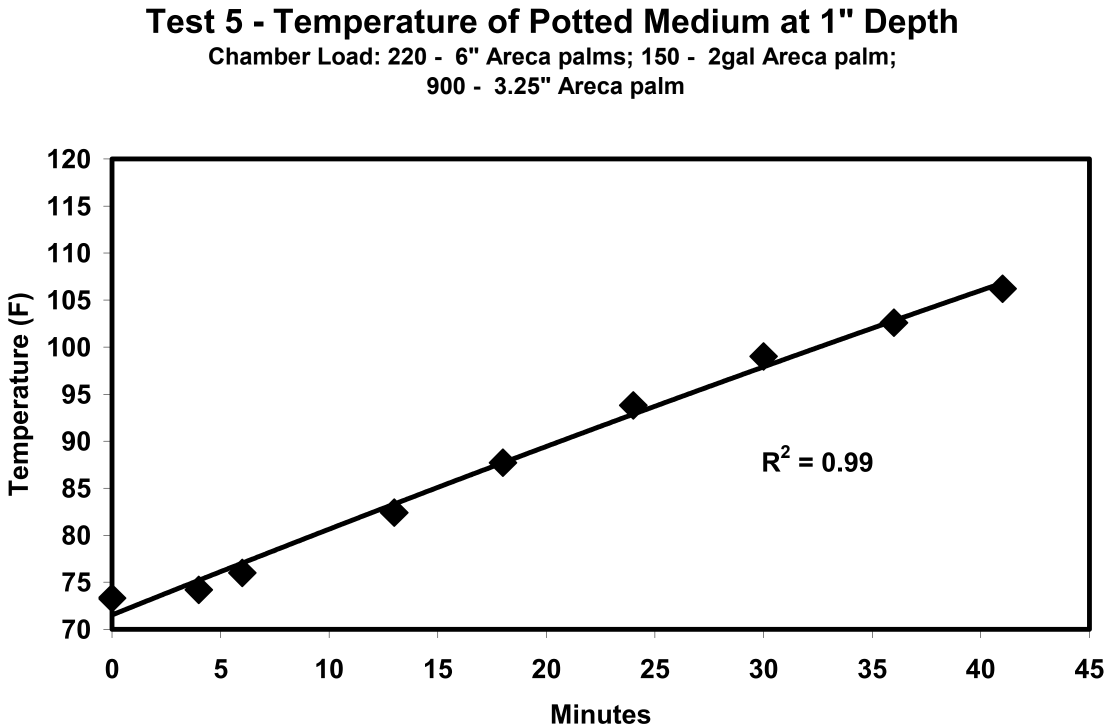


Figure 8

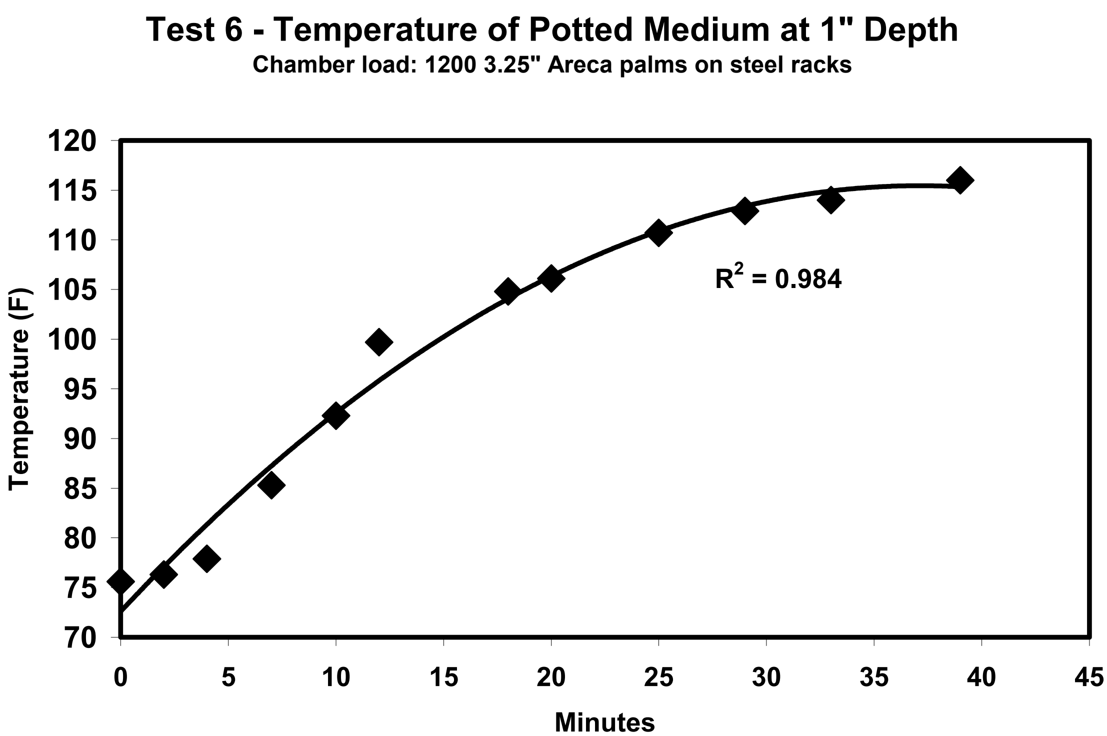


Figure 9.

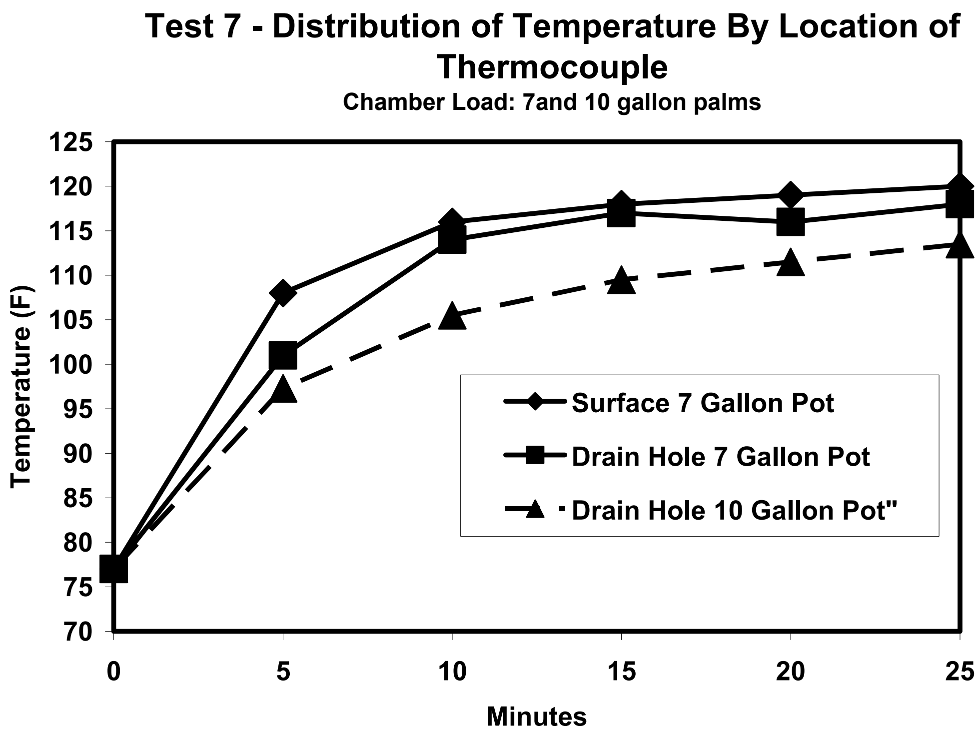
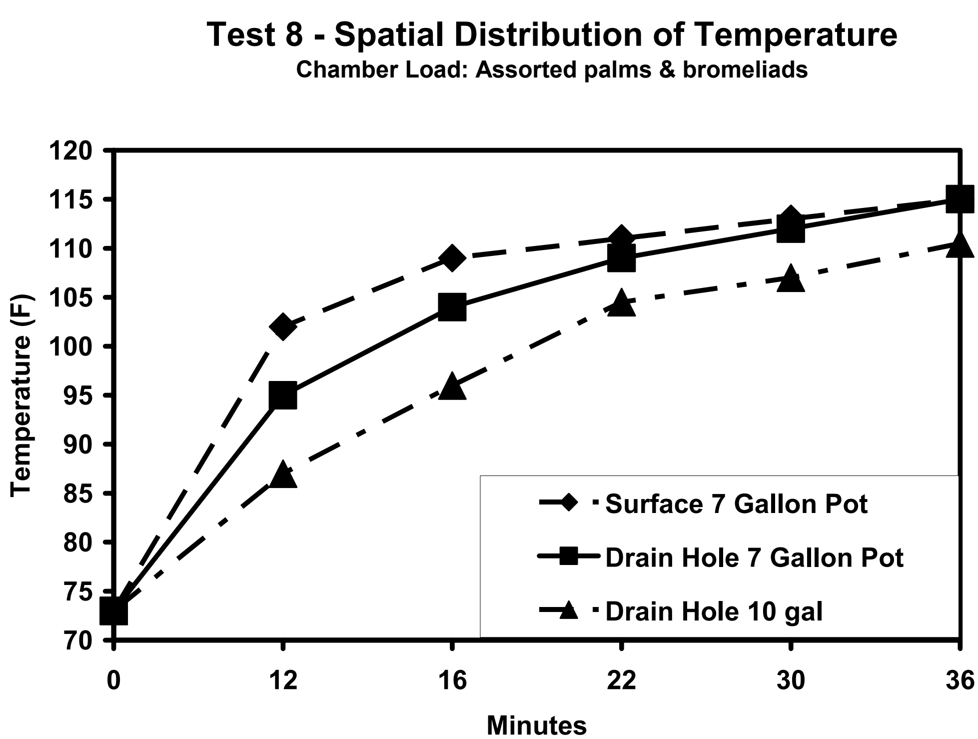


Figure 10



g) **Recycled water quality - sterilization**. We were unable to sterilize the recycled water with u.v. light. The fine filtration system worked well and exceeded the u.v. light manufacturer's specifications for input water to the u.v. light chamber. However, as the hot water treatment progressed, the recycled water became colored soluble substances leached from the peat moss based medium. These substances are likely polyphenolic compounds. U.V. transmission in the u.v. treatment chamber fell to levels well below treatment efficacy before the run could be completed

h) **Recycled water – salinity and pH.** There was little effect from water recycling on water pH and salinity. For the most part only negligible amounts of soluble salts accumulated in the recycled water even when it was sued for multiple runs. The pH of the water remained at or near neutrality. Both characteristics meet the boiler manufacturer's specification for input water.

i) We highly recommend that after use, the entire system be flushed with fresh water. When water is left in the reservoir or hot water delivery system microbial growth occurs, the system develops a strong odor and there is the likelihood that bio-films could develop and affect gauges and controls.

Image 1 Interior of shipping container & loading dock.

Image 2. Slit drain in floor lined with wire mesh

Image 3. PVC sheet lining container walls with spray nozzle and thermocouple

Image 4. Outfall of drain plenum exiting chamber onto gravity screen filter

Image 5. 300 gallon return water tank

Image 6. 35 gpm flow onto 200 mesh (72uM) stainless screen

Image 7. Debris and potting medium collected on 200 mesh screen after operation

Image 8. Flexible PVC supply pipe adjusts height of 1" float valve. Cover for gravity screen and outfall is at rear of image.

Image 9. Flexible sight liquid level gauge and water volume calibration

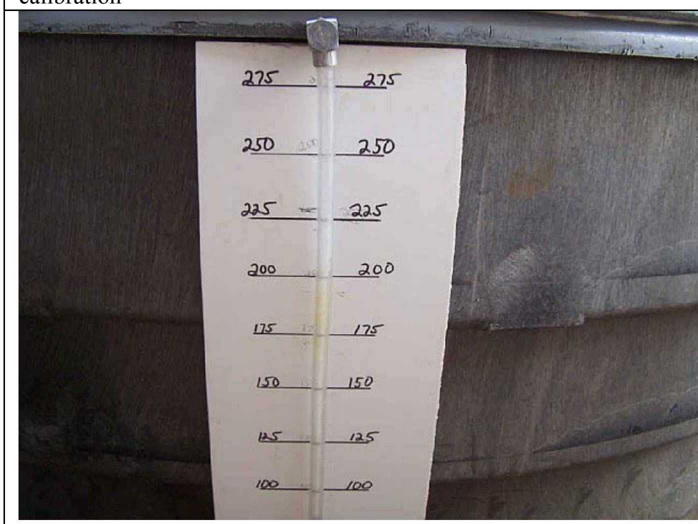


Image 10. Five horse power 3 phase brass impeller pump.

Image 11. Pressure and temperature gauges for monitoring performance

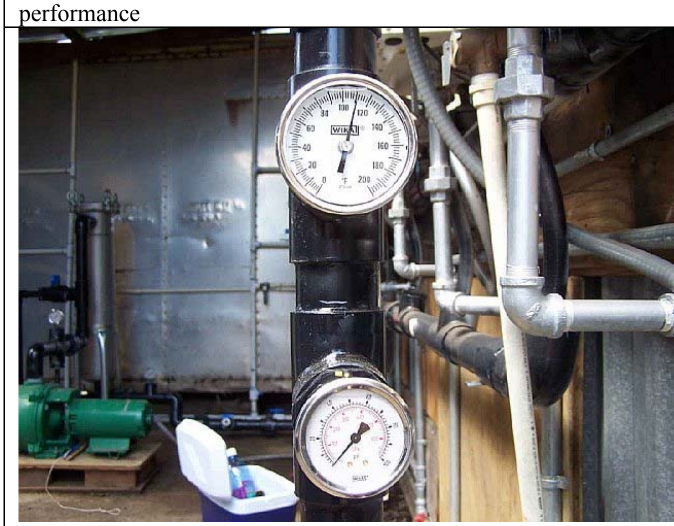


Image 12. Flow/totalizer meter installed on a boiler supply pipe.

Image 12. Haywood 2" bag filter rated at 80 gpm	Image 13. 1.0 uM nominal pore size polypropylene filter inside filter basket that has been removed the from filter housing
	
Image 14. 80 gpm WEDCO ultraviolet light sterilizing unit	Image 15. Thermocouple inserted 1" into peat medium