Senior Design Project: Design of a Heated Pet Washer

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Abstract

In accordance with recent ABET criteria, students should be able to "design and realize" a design project problem. The search for design problems that yield results that can be built is continuing. Constraints that should be observed in such designs include: safety, manufacturability, cost effectiveness, efficiency, reliability, and more. This paper describes the final design of an apparatus and steps in obtaining it is for a project. Included as well are descriptions of components used in the design process and their cost. The project was completed in a two semester senior design class and meets ABET criteria, making it suitable for a design problem.

Key Words: pet washer, senior design project

Senior Design

Senior Design at the University of Memphis is a two semester sequence. Students are given a project to work on and the first semester is devoted to obtaining background information on the subject. The students are required to design and realize the project. Realizing the project means that a working model or prototype will be produced. At the conclusion of the second semester, students summarize and present their work in an oral and in a written report. Faculty and the department Industrial Advisor Board are invited to grade the students on their work. The project described in this paper is the Design of a Dog Washer. The problem statement follows:

Problems Statement Provided to the Students

MMCA Dog Washer;†

Consider a dog washer that would be targeted for use by a pet owner. The dog would stand still, and the washer would actually merely rinse the dog's coat. The user would rinse the dog by moving the washer back and forth, then wash with soap, then rinse again.

The dog washer should be adaptable to any size of dog and minimize trauma to the animal. The device should optimally rinse all parts of the dog.

The dog washer should be reliable and rugged, as well as inexpensive. It should operate quietly and be easy to clean and maintain. Ideally, the device should operate automatically to minimize any actions required of an operator.

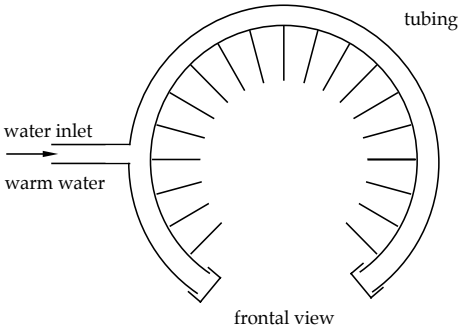
The device would be used outside and the water source is a garden hose. However, water from a domestic water tap might be uncomfortably cold. Therefore, a heating system must be used to warm the water before it is used to rinse the dog. If electricity is needed, the device should operate at 120 V AC. The washer must be safe for both the dog and the operator.

A preliminary design is shown in the figure. The dog would stand in the center, and the tubing sprays water on the animal. The user would move the tubing forward and backward.

To be designed, selected, or determined:

1. *What is a "comfortable" water temperature for the animal?*
2. *Design a device that can be used effectively for rinsing a dog, and for heating the water. Is a storage tank needed for a water heater?*
3. *Specify the fluid/thermal components of the entire apparatus.*
4. *How large should the unit be?*
5. *Determine the cost of the dog washer.*

†*From an idea submitted by Professor Julie Mathis.*



Introduction

Students were given the preceding problem statement and assigned the task of producing a device that can be used to wash a dog. The students formed a "company" named Puppy PAW-lisher Express, MMCA Inc. The group then elected a project leader, Michael Carlo. Other group members include Chad Albin, Mouhsin El-Chafei, and Andrew Webb; all 2016 BSME graduates.

Preliminary Instructions

To get the students started, they were directed to obtain some preliminary information such as: What water temperature(s) are suitable to bathe a dog? Would a veterinarian know this answer and would he/she use a dog washer? Are dog groomers equipped with such a device? What information is available on the internet? What pressures are delivered to a faucet of a standard home? What is the flow rate through a home system?

Design Evaluation Matrix/Brainstorming

Several decisions were made prior to sketching a design. These were electric storage hot water heater versus an electric heat exchanger, and more. The students did some brainstorming and put together a Design Evaluation Matrix, Table 1. The table shows various properties to consider and a weighting factor determined for each.

Constraints/Ethical Responsibilities

The apparatus must be safe, user friendly, manufacturable, cost effective, and reliable. Taking into account the constraints, and the relative importance of each factor in Table 1, a preliminary design was drawn.

Table 1. Performance Selection Process by Ranking. (Important = 1; Least important = 5)

		Cost	Weight	Size	Safety	Temperature	User Friendly
1	electric heater	1	3	2	2	3	2
2	heat exchanger	3	5	3	3	4	4
3	tankless heater	2	2	4	1	1	3
4	heated hose	5	1	1	4	5	1
5	weighting	0.3	0.04	0.06	0.3	0.2	0.1

See Figures 1 and 2 for the design.

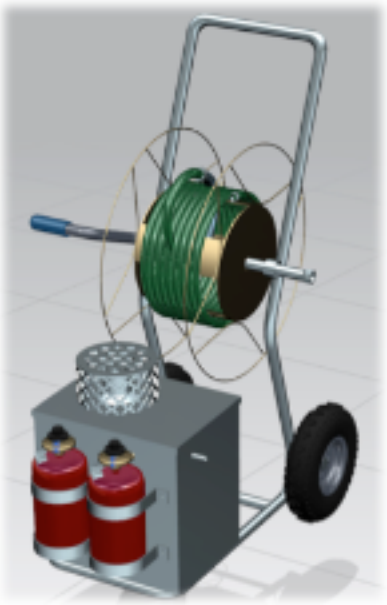


Figure 1. Preliminary design of the dog washer.

Figure 2. Final design of the Dog Washer.

The entire assembly consists of a 2-Wheel Heavy Duty Hose Truck, two 16.4 oz. Coleman propane tanks, a 5/8 inch diameter garden hose, a custom fabricated double-wall 24-guage stainless steel exhaust flume, ten feet of 3/8 inch diameter copper tubing, custom fabricated brackets for the propane tank holder and exhaust flume that are made from stainless steel, a 1ft. x 3/4 ft. x 1ft. sheet metal box, and a cast iron single propane burner. Once the items needed were identified, and component prices were determined, Table 2.

Description of Components

Yard Butler 2-Wheel Heavy-Duty Hose Truck made from heavy-duty powder coated steel to resist weathering. Holds up to 200-feet of 5/8 inch hose.

Table 2. Component Prices

Components	Supplier	Cost (US $)
Double wall stove pipe	Southern Pipe	60
Push button igniter	True Value	10
Gas valve	Southern Pipe	50
Insulated sheet metal box	Trane HVAC & Sheet Metal	75
Assorted copper	True Value	90
Transport cart	True Value	120
Miscellaneous hardware	True Value	35
25 ft Garden hose	True Value	20
Burner	AgriSupply.com	20
	Total	480

12 x 9 x 12 sheet metal box with 25 1-inch holes that increase airflow for the propane burner. The sheet metal box's only purpose is to allow air into the system.

Single burner, cast iron stove capable of 15,650 BTU/hr. This burner can be used only with propane or liquefied petroleum gas. A cast iron burner was selected because of its impressive thermal properties. Cast iron retains heat over a long period of time.

The exhaust flume is constructed from double-wall 24-guage steel with a diameter of 6 inches. The inner wall is made up of stainless steel. The coil that the water flows through is made up of copper that is 3/8 inch in diameter.

Custom stainless steel bracket that mounts on the steel metal box and holds the exhaust flume stationary 1 inch wide, 1 inch from edge to edge, and each tab is 1 inch in length.

Custom stainless steel bracket that hold the propane tanks in place. These brackets retain the propane tanks on the sheet metal box. The dimensions of this holding bracket is: 1 inch in height, 10.75 inches in width, and 4.25 inches in length with an internal radius of the bracket of 2 inches. Our assembly contains 2 of these brackets.

A Coleman propane tank was selected that is 16.4 fluid ounces. 2 propane tanks were used for this assembly. Another option is to use a larger propane tank from a typical gas grill.

Students produced a preliminary design that was refined and modified to produce the final design.

Figure 1 shows the preliminary design of the dog washer and its components. Shown is a tank containing the water to be used. Attached to the tank are two propane heaters, and inside the tank are propane burners. A water hose attached to the frame is used to deliver water to a hand held wand that the user moves over the dog to effect the cleaning.

The system contains a copper helical coil used with the propane burners to warm the water. Alternatively, the heater can use household power to heat the water.

After a series of refinements, practice runs and modifications, a final design was agreed upon and

built. See Figure 2. This required energy is supplied by a two-pass heat exchanger shown in Figure 3.

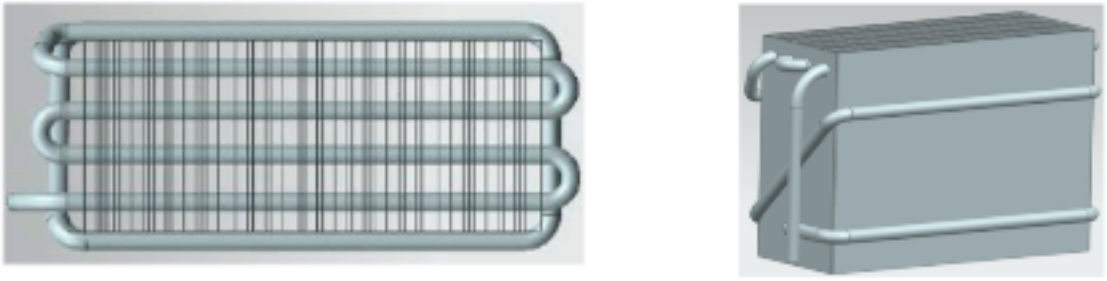


Figure 3. Heat exchanger and sheet metal tank.

The components of this design include:

- 2 x Coleman 16.4 oz propane tanks
- 10,800 Joules/second (37000 BTU/hr) Propane Burner
- Copper tube and Sheet Metal Finned Heat Exchanger.
- Custom Furnace Box.
- Hose Reel Cart.
- Custom Spray Handle with Soap Dispenser

Sample Calculations

Heating the water is done by using propane burners of the type found in an outdoor grille. The flow rate of water delivered to the hand held sprayer is 1.5 gpm (9.46×10^{-5} m^3/s).

The desired temperature increase is 10°F. The energy required to increase the water temperature at the required flow rate is:

$$Q = mC_p\Delta T = 9.46 \times 10^{-2} \text{ kg/s}(4.19 \text{ kJ/(kg·°C)})(5.6°C)$$

or $Q = 2\,200$ W or 7500 BTU/hr

These numbers are prelimary estimates to show a sample calculation. (i.e., 1.5 gpm, $\Delta T = 5.6°C$).

The heat exchanger and burner (Figure 4) can supply as much as 37 kW. The burner is placed under the heat exchanger in the tank. A propane regulator is also part of the completed design. The regulator contains a solenoid valve that is engaged when the water flows through the system.

Water is directed at the dog by using a multi directional spray handle, Figure 5. A length of pvc tubing is heated and bent into the semicircular shape.

A desired spray pattern is effected by holes drilled into the tubing. Small diameter holes maximize spraying pressure at low flow rates.

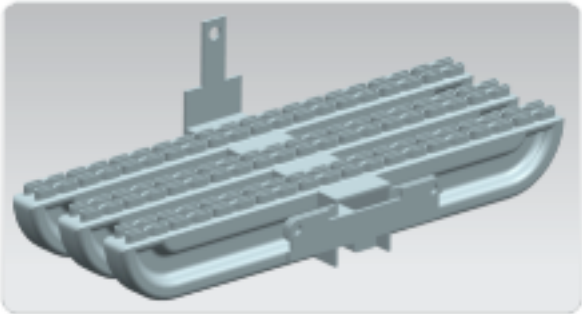


Figure 4. Propane burner.

Figure 5. Multi directional spray handle.

Soap injector is used to mix the dog shampoo with water.

This design allows for single hand rinsing.

Measurements indicate that the pressure loss through the heat exchanger is 3.7 psi.

Custom PVC spray handle assembled with 3 straight 6 inch pieces of PVC along with a piece bent into an 18 inch diameter half circle. One T joint, one coupler and two end caps complete the assembly. This spray configuration allows powerful deep rinsing allowing for nearly every bit of soap to be removed on just one pass.

Narrative

The cost of parts and materials could put a strain on the imposed deadling. After consulting various hardware stores in the greater Memphis area, we obtained a sponsor from True Value©. Parts were received and used to obtain experimental data such as, flow rate and pressure drop. The initial plan was to use a 2 kW immersion heater to warm the water flowing throw a helix-like copper piping. After conducting an analysis on the amount of power needed to achieve a ten-degree temperature, we concluded that a 13 kW immersion heater was needed. There were two faults in this process. First, an immersion heater with that much power is very costly and would not be economically efficient to manufacture. The second problem is that most immersion heaters larger than 4 kW require 220 V of power. For the design to be user-friendly, 110 V was preferable. A ten-degree difference would require a fuel heater (propane).

In order to achieve a desirable flow rate similar to that of a shower head, it was necessary to limit the flow rate coming out of the handle. First, the flow rate coming through the tap was measured by timing how long it took to fill two gallons. The same method was used for the flow rate through the garden hose and the PVC handle with 9 holes that were 3/32 inch in diameter. For the flow rate across the hose, the flow rate was measured at 9.2 gallons per minute. As for the flow rate across the hose and through the handle, the flow rate was 9.12 gallons per minute. From these results, it was determined that the pressure loss due to the friction of the garden hose was negligible.

Safety

A circuit board with an automated kill switch is positioned on the spray handle. This is a solenoid operated control valve. Two temperature sensors and one flame sensor are positioned near the burners. A written warning on the top of the tank boldly states “Caution Hot.” All sharp edges of sheet metal are covered with metal duct tape.

Operating using propane is very risky. There are many safety features embedded within this design to help protect anyone that uses this product. As of April 1, 2002, the U.S. Consumer Product Safety Commission (CPSC) requires every propane tank manufacture to upgrade its devices by placing an over-fill prevention device in all of their tanks. Our dual propane assembly incorporates this feature. We also have propane a flow regulator that regulates the amount of propane needed to heat the copper piping to achieve a certain water temperature coming out of the handle.

Video

The students produced a video of the dog washer while in use; presented here.

Conclusions

The project is one that can be designed and realized, making it suitable for a Mechanical Engineering study. The design may be deemed effective, as it met all the requirements for safety, and in being able to wash a dog. The system produces soapy water which is used to spray the dog. The dog is then washed by hand, and subsequently rinsed with the same device.

The dog (it is believed) would not have appreciated cold water from a water hose attached to a household spigot. When the water was warmed, the video shows that the dog more or less did not feel uncomfortable.

Lessons Learned (students self evaluation):

- How to work together effectively as a group.
- Important safety features of this design.
- How to size and select a heating system to produce warmed water.

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