For various reasons, the device in its current state will not allow a practical solution for the water purification assignments required in the developing world. Therefore, a more desirable solution to this problem is in need. To this end, the WAPI has been constructed from glass with the petroleum wax injected into the glass capsule sometime during the manufacturing process (Figure 2). It has been the task of this group to identify a way to take this redesigned WAPI and make a low cost reusable system for pasteurizing water in the developing world.

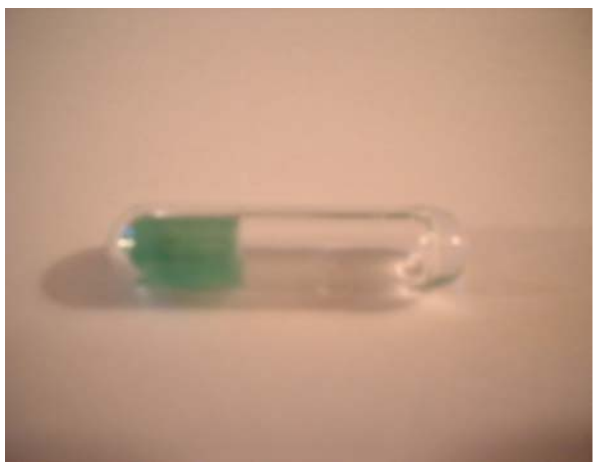


Figure 2: Redesigned Water Pasteurization Indicator.

The following report outlines the ten-week progress of the group with respect to this critical task. The report begins with a description of the project constraints, both the assigned constraints and the constraints imposed by the group. A summary of the background and literature search will highlight research conducted in order to educate the group to locations and potential uses for the system. Description of the design process which includes applicable codes and standards relating to the materials chosen for the device are included. Calculations with respect to stress analysis of the device are also included. In addition, a detailed economic analysis pertaining to the cost of the device is also highlighted within the report. This report concludes with a system analysis, highlighting the good and bad aspects of the design.

Design Specifications

Several design specifications were explicitly outlined when this project was initially assigned. The first is that the device must be reusable indefinitely. The device also must not impart any adverse taste to the water or impart any harmful chemicals. The device must be easy to use, even by illiterate people and must be inexpensive; about one dollar when made in the United States and even less if manufactured in a developing country. Finally, a method of semi-mass production is required using basic hand tools.

In addition to these specifications, the design group also outlined several additional specifications that were thought to be of some significance. The group concluded that the device must be usable in any container and with any heat source; either solar or flame. Also, the device must be positioned no more than one inch from the bottom of the container (in order to provide for the solar heating operations) and the capsule must never be allowed to fall on its side. This will ensure that the petroleum wax in the capsule will be in a position to fall to the bottom in a natural and free manner thus allowing positive indication of pasteurization. The device must also have a robust design and there should be some safe way in order to visualize the results of the processes.

Design Process and Design

Ideation Phase

During the ideation phase the design group used the design specifications and constraints defined in the Design Specifications section to synthesize the preliminary designs. Initially the group was able to narrow down the number of ideas derived into six viable options. Several ideas were abandoned as they were determined to be too complex for the assumed technology that would be available in parts of the world that this device would be utilized.

Utilizing the most important engineering specifications defined by the House of Quality, six preliminary designs were generated and ultimately a final design was accepted. The final design was chosen with Design for Manufacturability (DFM) and Design for Assembly (DFA) as secondary conditions to the characteristics determined from the House of Quality.

Final Design

The final design is highlighted by a wire wrap, manufactured in coil spring form, that the glass pasteurization indicator is fed. The coil spring, manufactured from #304 stainless steel wire, possesses a slightly smaller inside diameter than the outer diameter of the indicator (Table 3).

Table 3: Parameters Relating to Required Parts

Component	Inside Diameter (in.)	Outside Diameter (in.)	Length (in.)
Indicator	*	0.236 (average)	1.022 (average)
Spring	0.210	0.247	13 coils
Steel Rod	*	0.071	18.00
Flex Wire	*	18 gauge	24.00

Considering this fact, when the indicator is inserted and the spring is released, the stored energy in the spring imparts a gripping action to the indicator which ensures that the indicator does not move freely through the spring. The test group has decided that the optimum number of coil wraps around the body of the indicator is seven. Another three coils will be placed at both ends, providing location for a stainless steel rod or flexible wire to slide (Figure 4). This feature allows the indicator to be fully and easily adjustable in order to maintain the critical distance of one inch from the bottom of the water vessel. Also, the indicator can be inverted easily allowing ease of reuse.

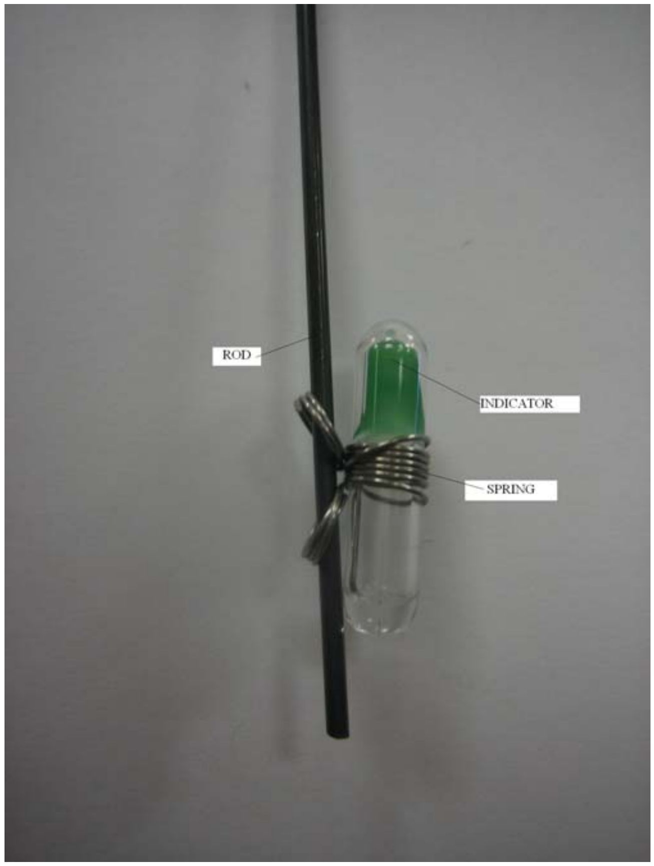


Figure 4: Pasteurization Indicator Design

However, this design comes with a minor drawback. The friction generated at the contact points between the spring and the rod, which is introduced to the parts at each pasteurization transition, apply adverse stresses to the steel coil. But these stresses are not high enough to cause any potential failure of the parts sometime during the life of the device. This is illustrated by the *Wöhler curve* (Figure 5), better known as S-N curve, in the following section.

Test Analysis

There are several specifications, outlined previously, that the group needs to satisfy in the development of these designs. For example, the design must be reusable indefinitely and also must not impart any taste or harmful chemicals to the water. Therefore, the design needs to be tested after it is constructed.

After obtaining expert consultation, the team decided to conduct two tests. The focus of these tests related specifically to temperature and stress. Since the design needs to be heated to a pre-determined temperature, the test that relates to the temperature is very important in determining whether the design imparts any taste and harmful chemical substances to the water. Furthermore, the stress tests were conducted in order to determine how long the design will perform before it fails.

The materials utilized in our design are comprised of the stainless steel spring and the pasteurization indicator. Temperature testing was conducted by boiling the device in water for about an hour and observations of the device were then conducted. In order to determine whether the device imparts any harmful chemical substances and/or taste to the water, a control batch of water was heated to a boiling point and then compared to the former. Results were compared to obtain the final conclusion.

In addition, stress tests are conducted in order to determine, for a certain number of cycles, how long the spring coil will last. The team also decided to compare results between theoretical and experimental methods. With respect to the theoretical method, the team obtained material property values and applied them to formal stress formulas. These calculations resulted in the ability to obtain the estimated number of life cycles which in this case related to infinite.

Economic Analysis

Pani Works Inc.'s expectation is that several thousand water pasteurization indicator units can be manufactured by a method of semi mass-production using basic hand tools. The designs are fairly simple and the consensus is that they can be easily manufactured and utilized, even by illiterate people.

For our design the materials used are a coil spring (Figure 6), a pasteurization indicator (Figure 7), and a stainless steel rod (Figure 8) or simple bendable wire (Figure 9). The design requires thirteen spring coils at a cost of $0.12 per unit. The cost of each indicator has been estimated to be approximately $0.10 U.S., assuming that the indicators could be manufactured outside of the United States, potentially in a developing country. In addition, the cost of 1.5 feet of stainless steel rod, required to complete the device, amounts to $0.59 U.S.. We are assuming that the average water container would not exceed 1.5 feet in height, so that the users can use the rod provided. If a container would exceed 1.5 feet in height, the customer could use most any rod of appropriate length and diameter. Placing the rod through the spring coils is very easy, and additional instruction will be provided outlining the kinds of rods that are safe to use if they choose to use their own rods instead of the ones supplied. The total cost in producing this design is about $0.81 cents per unit, assuming that the devices are assembled by the user or other non-profit organizations within these regions. This total cost per unit is well within the limitations imposed at the start of the project.

Figure 6: Coil spring

Figure 7: Pasteurization Indicator

Figure 8: Stainless steel rod

With respect to production, one unit of this design can be produced very rapidly. Pani Works. Inc determined through testing that for this design, one unit can be produced in approximately one minute, which correlates to about 60 units per hour. However, after further consideration we estimate that in one hour, the average number of units that can be produced is about 45, due to defective products, break hours and so on. These devices can be easily manufactured in a semi-mass production environment where basic hand tools can be used in order to complete the assembly process. All the required materials could be exported to the developing countries, and assembly can be accomplished in field. This product would be distributed with a user's manual. The manuals will be translated in a number of different languages. Volunteers could be incorporated to aid in the assembly and distribution process, therefore allowing the products to be distributed at a much lower cost.

Conclusion

The final design that the group produced adheres to all of the imposed design parameters that were assigned at the start of the project. Some of the aspects of this design that the group is most proud of are the simplicity of the device with respect to the limited number of parts and its ease of operation or use. The material chosen for this device allows for a theoretical infinite life, which is beneficial for the individuals utilizing this product. And, the device will perform very well in most any container and condition.

Cost of the device is within the specified guidelines, if it could be produced in a third world country. However, if this device is manufactured in the United States, the cost would be increased significantly and this parameter would not be realized. Material choice was a factor that contributed significantly to the cost of the device but this material will not impart taste to the water or leave harmful chemicals that could be potentially worse than the organisms the device indicates it eliminates.

Some other drawbacks of this design relate to the ease with which the Water Pasteurization Indicator could be lost when not in use. However the group feels that the individual users could convert the device to a necklace charm with little effort in order that loss could potentially be minimized.

The entire group is very proud of the work that has been put into this project. The group hopes that this device could help to minimize the amount of disease that threatens the population in these third world countries. Pani Works is honored to have had the opportunity to make the world a better place for these people.

I. English Manual

Instructions for Assembly and Use of Water Pasteurization Indicator

Instructions for Assembly:

Required Items:

1) Section of Stainless Steel Spring (at least 13 coils)
2) Glass Water Pasteurization Indicator
3) Stainless Steel Rod (1.5 feet length)

Required Tools:

4) Needle Nosed Pliers
5) Diagonal Cutters

Drawings/Pictures of Required Items and Tools:

1. Stainless Steel Spring

1. Water Pasteurization Indicator

1. Stainless Steel Rod

1. Needle Nosed Pliers

1. Diagonal Cutters

Assembly:

Step 1) Obtain section of spring (Item 1).
Verify that there are at least 13 coils present in the spring.

Step 2) Using Needle Nose Pliers and focusing attention at the third coil of the stainless steel spring, make a 70 to 85 degree bend in the wire such that the spring resembles the following Figure.
Note: the three coil loop, created by this bending process, will be referred to as a 'Tension Loop' in further instruction.

Step 3) Obtain the glass Water Pasteurization Indicator (Item 2) and insert the indicator 'wax end first' into the inner diameter of the spring using a constant twisting motion. Discontinue insertion when the indicator has passed through 7 coils of the stainless steel spring.

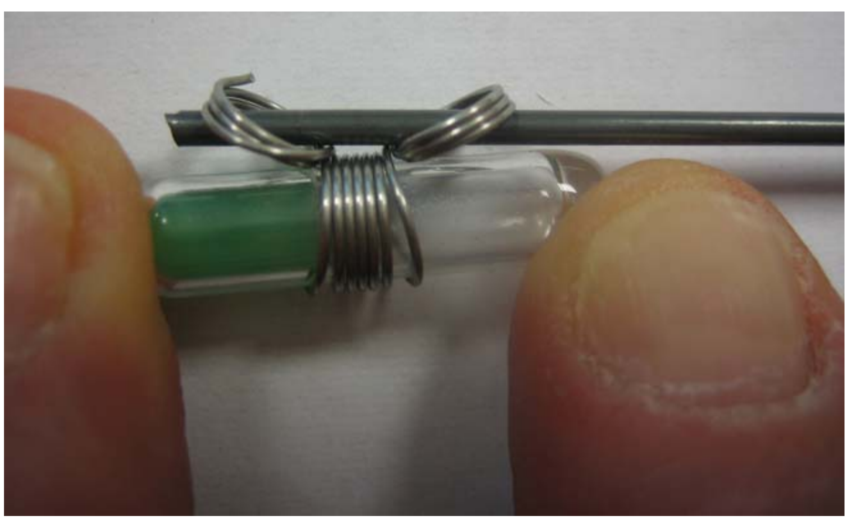
Step 4) Using Needle Nose Pliers, make another 75 to 85 degree bend in the wire at the end of the seventh coil that is wrapped around the glass capsule.
NOTE: The spring coil loop formed in this step should be oriented on the same side of the Water Pasteurization Indicator as the tension loop created in Step 2. At the completion of this step, the device should resemble the following drawing.

Step 5) Count an additional three coils of spring and using a set of diagonal cutters, snip the remaining portion of the spring at the end of this third coil.
NOTE: This step may not be necessary if exactly thirteen coils of spring were included in the kit.

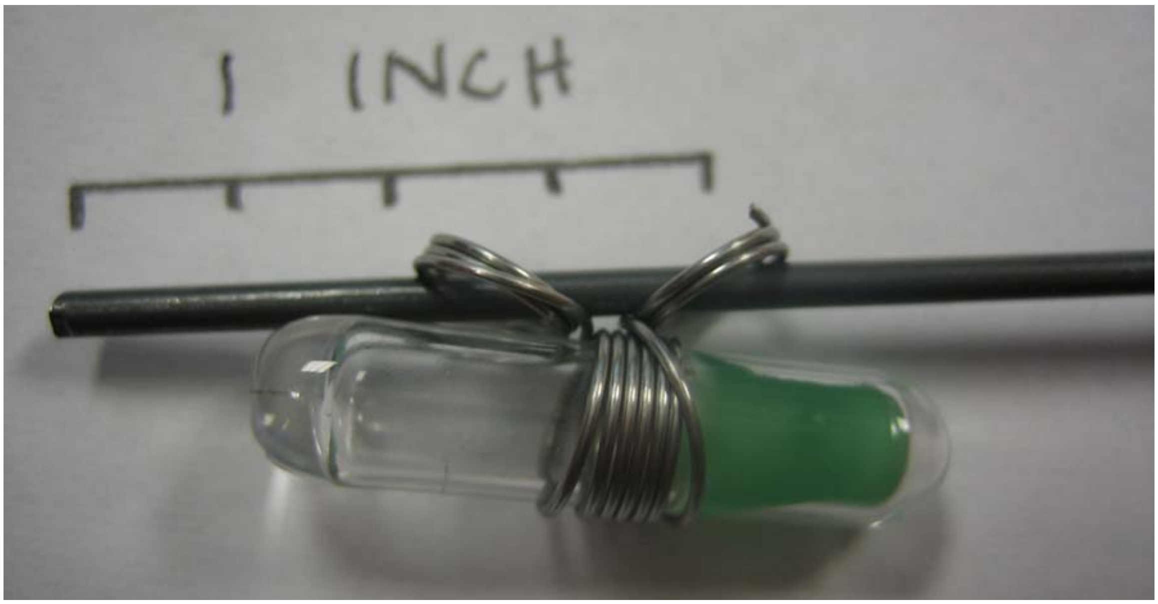
Step 6) Feed the glass Water Pasteurization Indicator further into the spring until the 7 inner spring coils are wrapped firmly around the center of the WAPI as shown.

Step 7) Obtain the Stainless Steel Rod and insert one end of the rod into the center of either Tension Loop, as shown in the drawing.

Step 8) Insert the rod into the second Tension Loop by slightly bending the second tension loop in an upright manner. The Water Pasteurization Indicator should now be held snuggly on the Stainless steel rod as shown in the figure.



Step 9) Orient the Water Pasteurization Indicator on the rod such that the wax in the indicator is at the top and the indicator is one inch from the bottom of the stainless steel rod as shown in the figure.
NOTE: Use the one inch scale (included in the figure) to orient the indicator properly on the rod.



Instructions for Use of the Water Pasteurization Indicator

Introduction:

In order that various contaminants in water supplies are eliminated, the water sample must be heated to a temperature of 65 degrees Celsius in order to kill bacteria that could be potentially present. This heating process could be administered through the introduction of flame or through solar heating processes. The Water Pasteurization Indicator (WAPI) is designed to indicate that the water sample has reached this critical temperature of 65 degrees Celsius.

There exists inside the glass capsule a sample of soy bean fat that will melt at approximately 69 degrees Celsius. If the un-melted soy bean fat is positioned at the top of the capsule when the device is placed in the water heating device, the soy bean fat will drop to the bottom of the capsule when melted. This will give positive indication that the critical temperature of 65 degrees Celsius has been reached. Therefore, it is important to ensure the orientation of the Water Pasteurization Indicator is correct (capsule oriented with the un-melted soy bean fat at the top of the capsule) at the start of the pasteurization process. The verification of correct orientation before use will ensure that the indicator will give correct indication that this critical temperature of 65 degrees C was reached.

The indicator can be reused indefinitely. Simply flip the rod, or the indicator, in order to orient the un-melted soy bean fat sample properly and then ensure that the indicator is positioned one inch from the bottom of the water vessel. The Water Pasteurization Indicator is then ready for another use.

Simplified Instruction

Step 1) Orient the WAPI on the rod such that the WAPI is one inch from the bottom of the rod and that the wax in the capsule is in an upright position (Figure 1).

Step 2) Insert the rod, WAPI side first, into container holding water (Figure 2).

Step 3) Allow water container to sit until heated to proper temperature.

Step 4) Remove rod and check progress of pasteurization.
NOTE: If wax has transferred to the bottom of the capsule, the water is safe to consume.

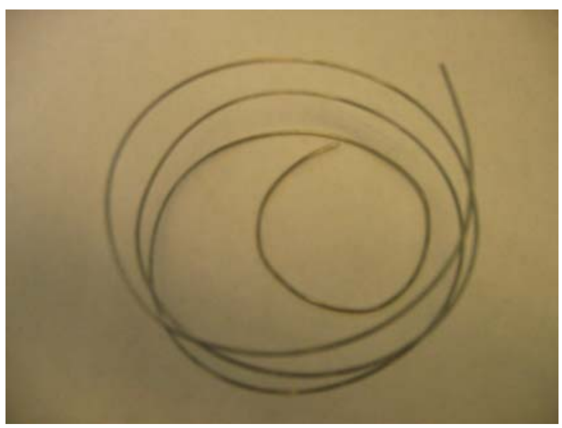
Step 5) Position WAPI for another use (Figure 3) and follow the prior outlined steps.

ADDENDUM A:

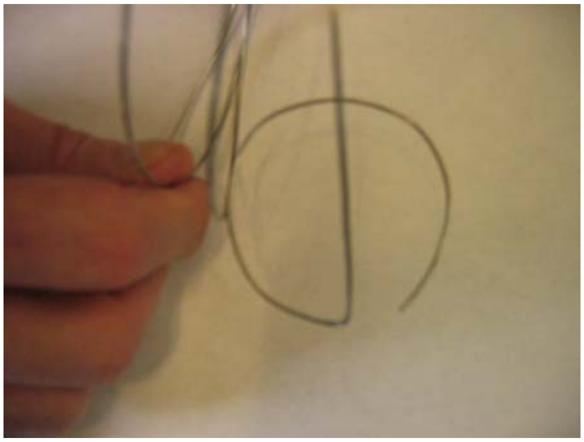
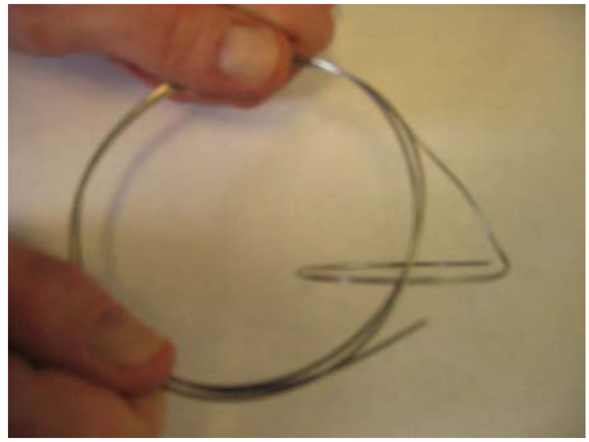
Instructions for use of Flexible Wire instead of Solid Rod for Application:

Step 1) Obtain approximately 2 feet of Type 304 (18 Gauge) Stainless Steel wire.

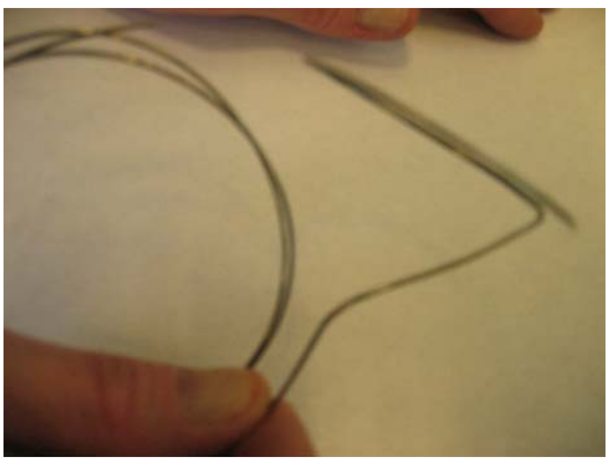
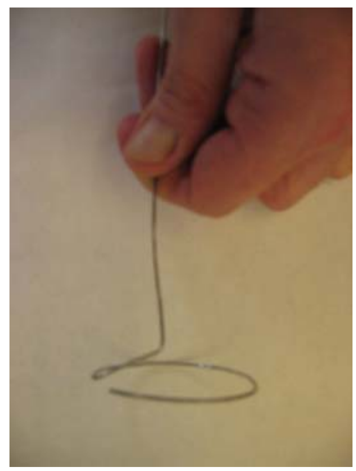
Step 2) On one end of the wire, create a loop that is approximately 2 inches (5 cm) in diameter. NOTE: If the water container used for the water heating process has an opening of less than 2 inches in diameter, adjust the loop diameter appropriately.



Step 3) Bend the wire, at the outside of the created loop, to approximately 45 degrees toward the center of the 2 inch loop created in the prior step. The wire should now resemble that of the included photos.
Note: Adjust the length and angle of bend to allow the 1 inch distance from the base of the loop.

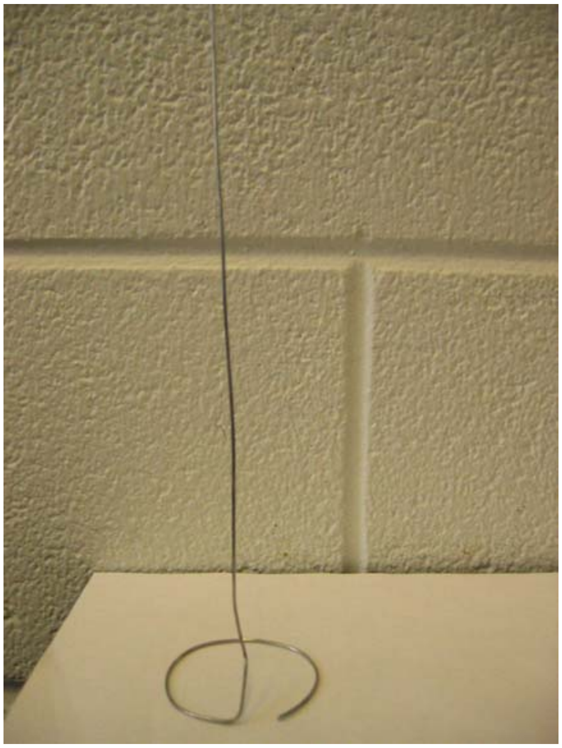
 

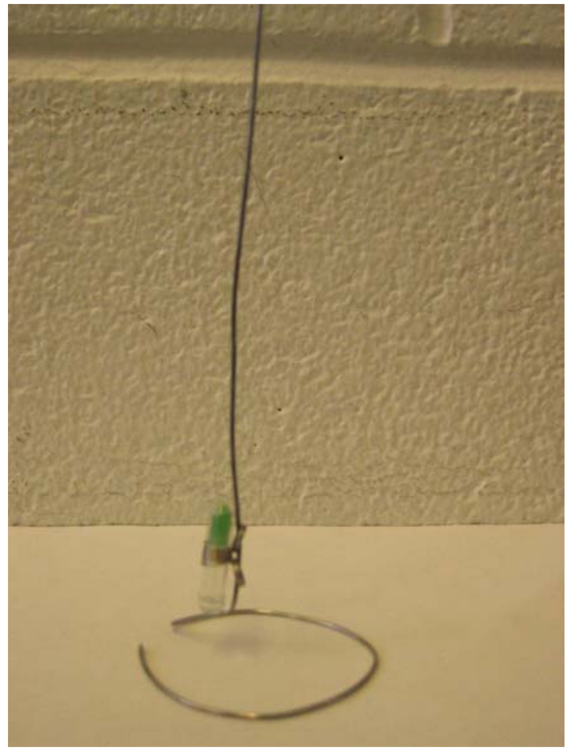
Step 4) Bend the remaining wire in a straight fashion such that it emanates from the center of the created loop as in the figure.

Step 5) Straighten the remaining portion of the wire such that the device will stand on its own, the base being the 2 inch loop created in Step 2. The WAPI can now be installed on the wire stand.

NOTE: The WAPI should be positioned at approximately 1 inch from the base. If this is not the case, adjust the angle of bend created in Step 3 to ensure that this distance is realized.





Step 6) Follow 'Instructions for Use of the Water Pasteurization Indicator' included in this manual.