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# SET-BACK THERMOSTATS

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AN EXPERIMENT TO DETERMINE IF THEY  
SAVE ENERGY



# Set-Back Thermostats

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## THE PROBLEM

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There has been much debate about whether the use of set-back thermostats saves energy.

A standard thermostat is a device that controls heating (or cooling) equipment to maintain a specific temperature in the area of the thermostat. An automatic set-back thermostat performs the same function, but can also change the specific temperature up or down based upon a time and/or day. Typically, automatic set-back thermostats are used during the heating season to reduce the temperature in one or more rooms of a building part of the time for a number of reasons:

- Perhaps the occupants will not be there for that time (e.g., everyone leaves the home for school or work or the business is closed over night).
- Perhaps the occupants do not need the temperature to be quite as high (e.g., when they are sleeping and covered by blankets)

The argument in support of an energy savings is based upon the reduced difference between the outside temperature and inside temperature. Supporters of this argument claim that the heat transfer from within the building is slowed as the temperature inside the building goes down. Because the heat transfer is slowed, the heating equipment doesn't have to produce as much heat (i.e., use as much energy) to maintain the lower temperature and that savings more than makes up for the extra energy that will be needed when the thermostat calls for a higher temperature once the set-back (lower temperature) period is completed.

The argument against energy savings mot often hypothesizes that the amount of energy needed to bring the temperature in the building (and all the contents and interior surfaces) back up to the higher temperature once the set-back period is completed is either the same or greater. Therefore, any occupants must suffer with a colder environment without realizing any savings on their home energy bills. Proponents of this argument usually suggest simply picking a thermostat setting and leaving it on that setting 24 hours a day.

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## CLAIMS

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There are various claims made about the potential savings by using an automatic set-back thermostat. This experiment is not designed to verify or refute any of these claims. They are included to give the reader an idea of what others have written about the use of automatic set-back thermostats (with no supporting evidence).

The literature that accompanied the thermostat I am using in these experiments claims:

*Save up to 33%\* on your Energy Costs*

*\* if used as directed. Savings may vary depending on geographic region and usage.*

The calculator available at <http://www.warmair.net/html/thermostats.htm> claims:

*Based on a normal thermostat setting of 70° and a lowered thermostat setting of 62°, with an average outside temperature of 35°, you will use approximately 22% less energy for that time period.*

The U.S. Department of Energy  
([http://www.energysavers.gov/your\\_home/space\\_heating\\_cooling/index.cfm/mytopic=12720](http://www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12720))  
claims:

*You can save around 10% a year on your heating and cooling bills by simply turning your thermostat back 10°–15° for eight hours.*

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## THE EXPERIMENT

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There are too many variables to try to answer the question of automatic set-back thermostat savings using a building and the outside temperature. Among them:

- The outside air temperature is never stable enough to make successive trials meaningful.

It may be possible to use heating degree days<sup>1</sup> to try to normalize the data, but that becomes a problem when you set the temperature back for a portion of the day. You would need data that allowed you to normalize the data on the exact period that the thermostat was at each temperature. I suppose one could use a data logging device to keep track of both the inside and outside temperature and do calculations with the difference between the inside and outside temperature, but I developed and performed a simpler experiment.

- There are other sources of heat in the average building (cooking devices, solar gain from windows, even the number of warm bodies in the house ... more showers, etc.)
- Doors open and close causing additional heat loss requirements that may alter the results.
- Wind can cause an accelerated heat transfer from within the building.

I chose to simulate the problem on a smaller scale using the spare refrigerator in my basement. It would create an environment with a fairly stable temperature. Inside this environment, I could place a “building,” in this case, a Styrofoam cooler. Inside the box, I could place a thermostat and a heat source and I could run as many trials as I wanted without having to account for variations in the environment outside my “building.”

The equipment for my experiment includes:

- The refrigerator – for creating a cool exterior environment
- A Styrofoam cooler (saved from a major mail order beef company) – my “building”
- A line-voltage, set-back thermostat (LUX WIN100 Series Smart Temp®) to control the source of heat inside the box
- A light-bulb (25 watts) – the heat source

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<sup>1</sup> in United States usage, one heating degree-day is given for each degree that the daily mean temperature departs below the base of 65°F (where the Celsius scale is used, the base is usually 19°C).

In addition, I would need a few items to allow me to analyze the behavior during successive trials so as to come to a conclusion:

- A Kill A Watt (model P4400) device – this will measure the amount of electrical power consumed by the thermostat, light bulb, and clock<sup>2</sup> during each trial. I can use this information to compare trials.
- A clock – set to 12:00 at the start of each trial, it will measure how long the heat source was on during the trial. Primarily, this will be used to double check the Kill A Watt results.

The clock actually provides results with less error as the Kill A Watt meter can only measure to .01 Kilowatts. With my 25 watt light bulb, this is about 24 minutes of time for the light bulb to be lit.

- A temperature data logger (MicroLite LITE5008) – a small electronic device that will take periodic samples of the temperature that can be graphed to show the temperature inside the box during the trial. I set the unit to take one data sample each minute throughout the 24 hour test run.

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#### ASSUMPTIONS

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I am not an HVAC expert. I do not know the intricacies of the highest efficiency furnaces and boilers out there. Are there heating devices that operate more efficiently when only a little heat is called for (i.e., maintaining a temperature) but are less efficient when a lot of heat is called for (i.e., bringing a cold building up to temperature)? I don't know.

I am assuming that most heating devices consume little or no energy when they are not running and a particular, and constant, amount of energy when they are running (i.e., they are a simple on and off device). To put it more clearly, the thermostat calls for heat and the heating device tries its best to deliver as much heat as it can until the thermostat signals that no more heat is required. This assumption is modeled using a light bulb.

An incandescent light bulb converts electrical energy into other forms of energy, chiefly heat and light. Generally, we use the light bulb to generate light and the heat is the waste byproduct. In this experiment, the heat is the desired output and the light is the waste byproduct. When turned off, it uses no energy and when turned on, it uses a constant amount of power to generate a constant amount of heat.

I must add here that I know there are heating devices that don't fit this model.

Heat pumps, for example work best at raising the temperature slowly. If the temperature must be increased dramatically, they generally have back-up heat producing method (often electric resistance heat) that uses a different amount of energy than the normal mode of operation. Set-back thermostats are not recommended for this type of device as it will use more energy to return the

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<sup>2</sup> the clock and the thermostat each use a constant amount of power while on.

building to the higher temperature than if you had left the heating device try to keep it there steadily using the normal mode of operation.

Radiant floor heating may not fit this model either since it can take so long to return the floor's mass to the higher temperature. On the other hand, some bathroom radiant floor heating is meant to be used only when in the bathroom, so perhaps the recovery period is shorter than I imagine. On the other hand, the difference may not be in the energy efficiency of the heating method, but in the length of the recovery period.

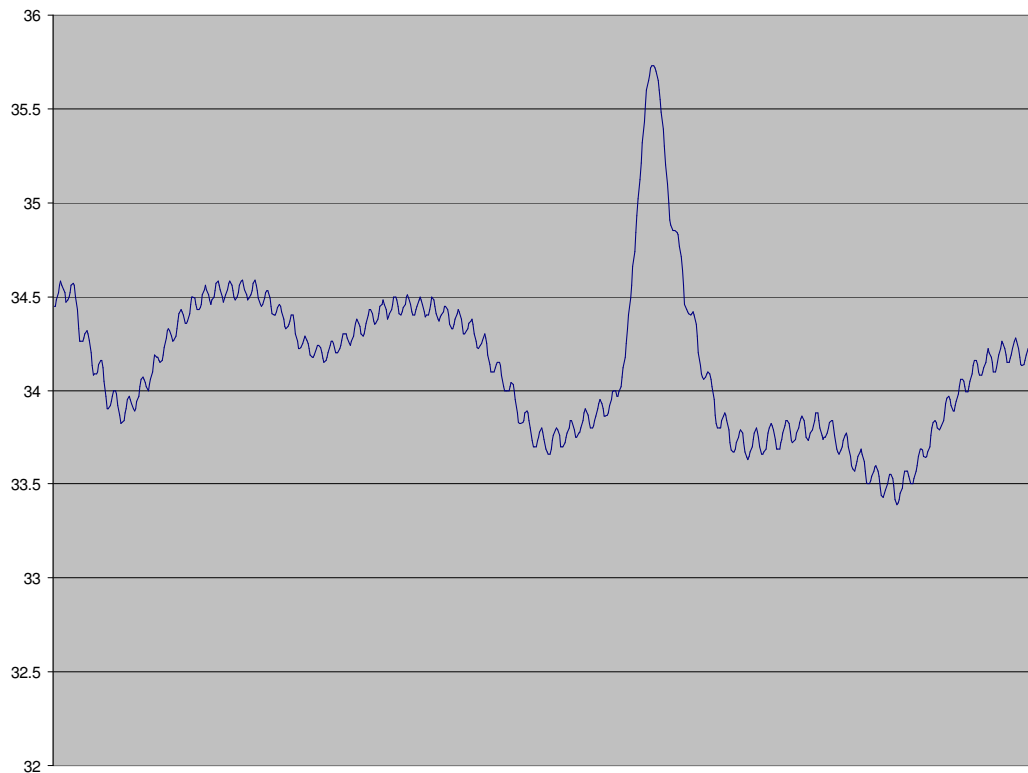
This experiment does not attempt to address the energy efficiency question for every kind of heating equipment. If you have questions about your specific situation, I suggest you contact your heating equipment manufacturer for more information about the use of automatic set-back thermostats.

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### THE ENVIRONMENT

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My basement refrigerator is operated by an external thermostat control (Johnson Controls A19 series control) which is intended to allow the refrigerator to operate at a wider range of temperatures required for beer making. The temperature differential with this controller is 4° F (to save wear and tear on the refrigerator. I set the thermostat at 29° which keeps the internal environment between 33.39° F and 35.73° F (34.14° F average, Std Dev 0.40° F). See the graph below for a 12 hour slice from the inside of the refrigerator:



I do not have an explanation for the temperature spike. This increase in the inside temperature of the refrigerator occurred at about 3:00 am, so no one mistakenly opened the door. Since this spike is still only about 1° F from the previous high temperature, I don't believe this invalidates the data obtained from the various tests.

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## LEARNING ATTEMPTS

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My initial attempt used a simple cardboard box as my “building.” Unfortunately, I found that there was too little insulation in my cardboard “building.” Put another way, the 25 watt light bulb “furnace” was not enough to keep the internal environment at the temperature requested by the thermostat and the light bulb “furnace” ran continually.

I considered increasing the size of the light bulb, but rejected that out of concern that the escaping heat would adversely impact the temperature inside the refrigerator. That is, if the refrigerator has to run continuously in try to keep the environment surrounding my “building” constant; it will negate the advantage of having a relatively consistent air temperature outside my “building.” As luck would have it, my mother had saved a Styrofoam cooler that had brought some frozen beef to her home and I was able to recycle this cooler as my new, better insulated, building.

The selection of my “building’s” construction was not the only hiccup before running my experiment. I had reused an old analog kitchen clock as a timer, but quickly found out why we were no longer using it as a clock. The motor in the clock could get “stuck” and not move the hands at all. This is, of course, useless for my purposes, so it had to be replaced with a new timing device.

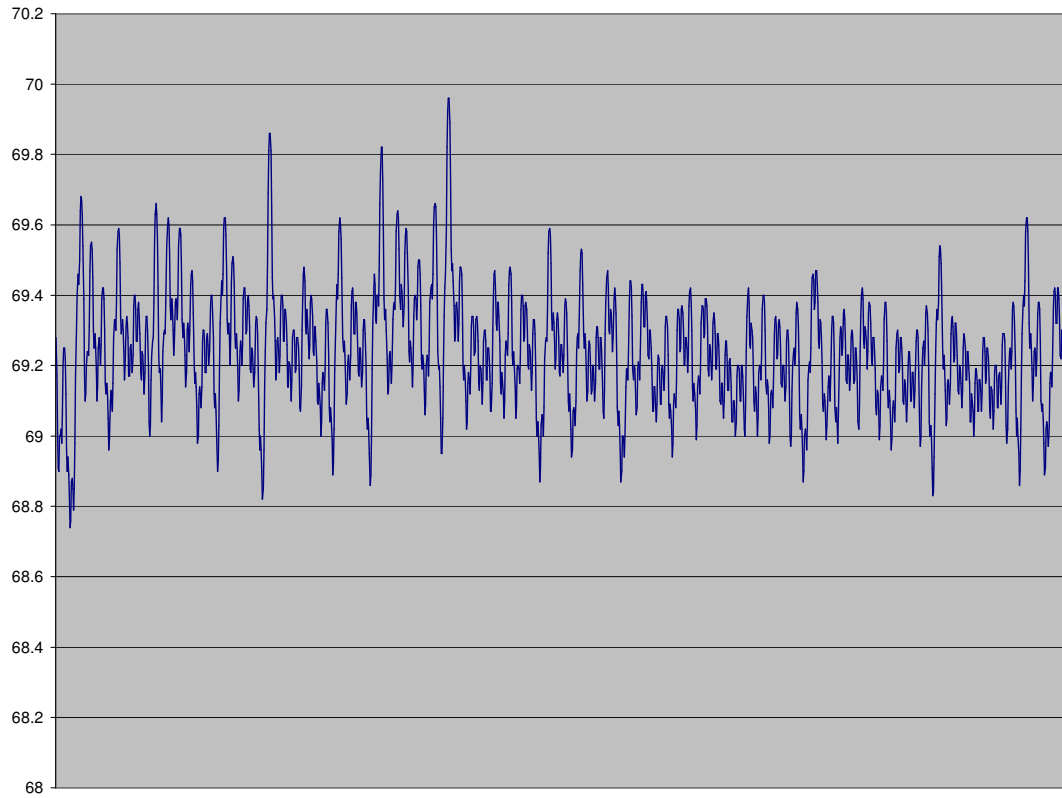
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**STEADY TEMPERATURE RUN #1**

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This is the non set-back test. The thermostat was set to keep my Styrofoam “building” at a constant 70° F.

Here is the diagram of this 24 hour test (8:27 am to 8:27 am):



Energy consumption for this test amounted to .21 Kilowatts (i.e., 210 Watts) as measured on the Kill A Watt meter and 8 hours 32 minutes 40 seconds (8.544 hours) as measured on the clock.

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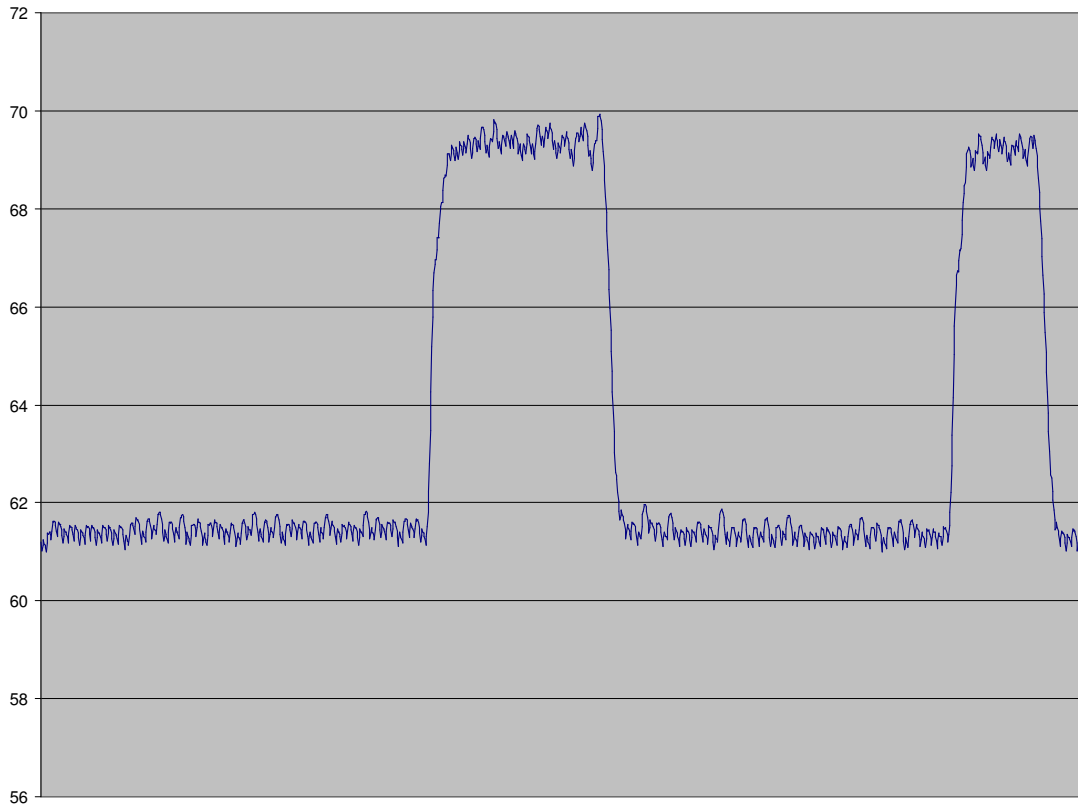
### SET-BACK TEST #1

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The first set-back experiment used the thermostat's default setting (these are consistent with the settings necessary for a thermostat to be ENERGY STAR qualified – see [http://www.energystar.gov/index.cfm?c=thermostats.pr\\_thermostats](http://www.energystar.gov/index.cfm?c=thermostats.pr_thermostats) form more information):

- 6:00 am to 7:59 am (2 hours) - 70° F
- 8:00 am to 5:59 pm (10 hours) - 62° F
- 6:00 pm to 9:59 pm (4 hours) - 70° F
- 10:00 pm to 5:59 am (8 hours) - 62° F

This amounts to 6 hours at 70° F and 18 hours at 62° F. Here is the diagram of this 24 hour test (9:08 am to 9:08 am):



Energy consumption for this test amounted to .17 Kilowatts (i.e., 170 Watts) as measured on the Kill A Watt meter and 6 hours 45 minutes 29 seconds (6.758 hours) as measured on the clock.

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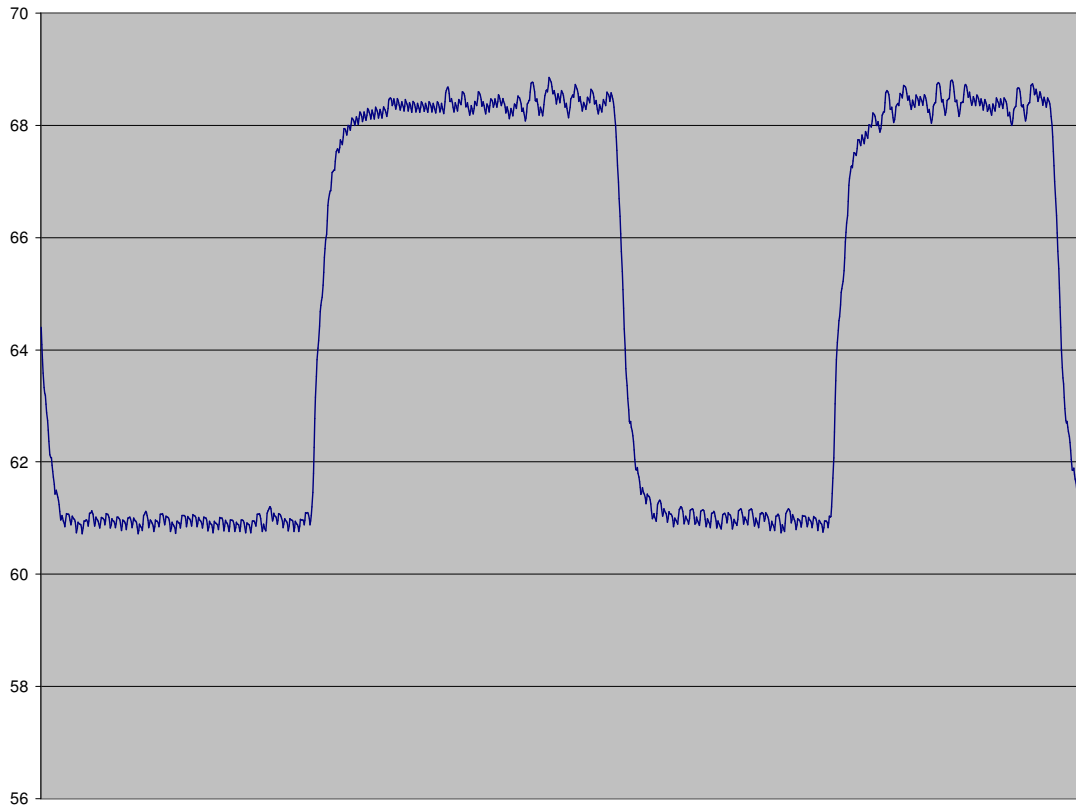
## SET-BACK TEST #2

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The second set-back experiment used the following schedule (each time is set to 15 minutes before an hour because the thermostat can only be set on the 0, 15, 30, or 45 minute mark and seemed to have trouble being set to midnight):

- 4:45 am to 9:44 am (5 hours) - 70° F
- 9:45 am to 4:44 pm (7 hours) - 62° F
- 4:45 pm to 11:44 pm (7 hours) - 70° F
- 11:45 pm to 4:44 am (5 hours) - 62° F

This amounts to 12 hours at 70° F and 12 hours at 62° F. Here is the diagram of this 24 hour test (10:33 am to 10:33 am):



Energy consumption for this test amounted to .19 Kilowatts (i.e., 190 Watts) as measured on the Kill A Watt meter and 7 hours 35 minutes 10 seconds (7.586 hours) as measured on the clock.

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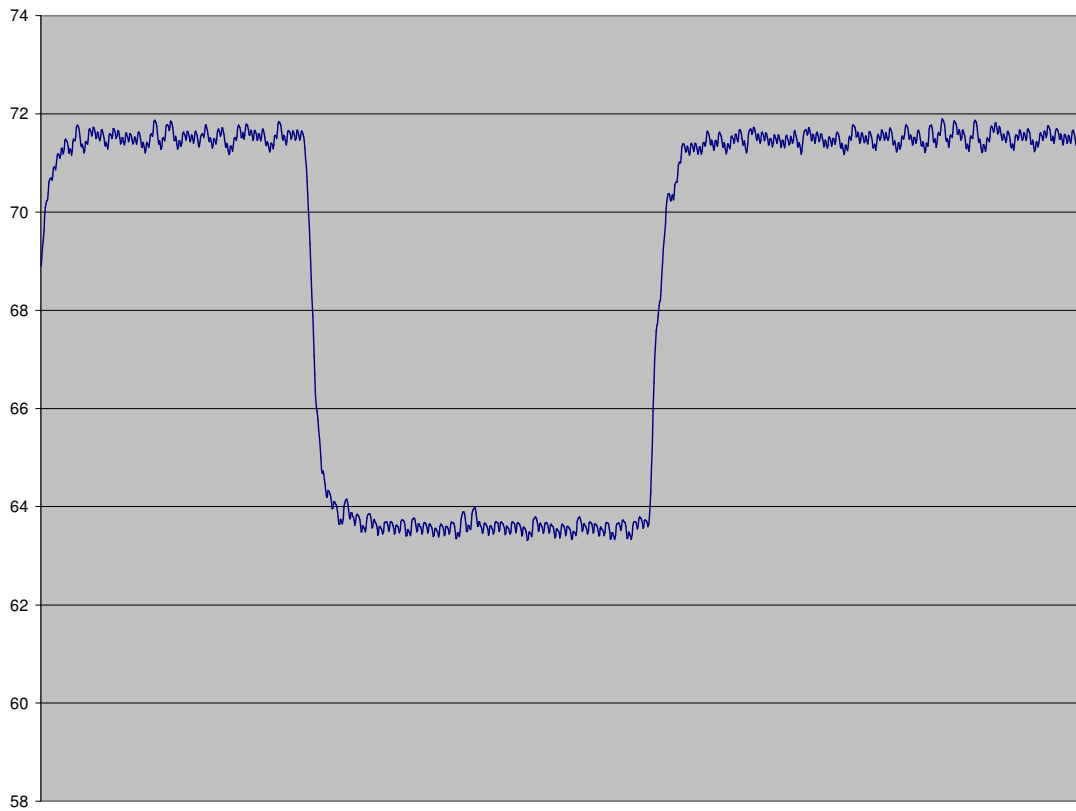
### SET-BACK TEST #3

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The third set-back experiment used the following schedule:

- 7:00 am to 10:59 pm (16 hours) - 70° F
- 11:00 pm to 6:59 am (8 hours) - 62° F

This amounts to 16 hours at 70° F and 8 hours at 62° F. Here is the diagram of this 24 hour test (5:00 pm to 5:00 pm):



Energy consumption for this test amounted to .19 Kilowatts (i.e., 190 Watts) as measured on the Kill A Watt meter and 7 hours 44 minutes 11 seconds (7.736 hours) as measured on the clock.

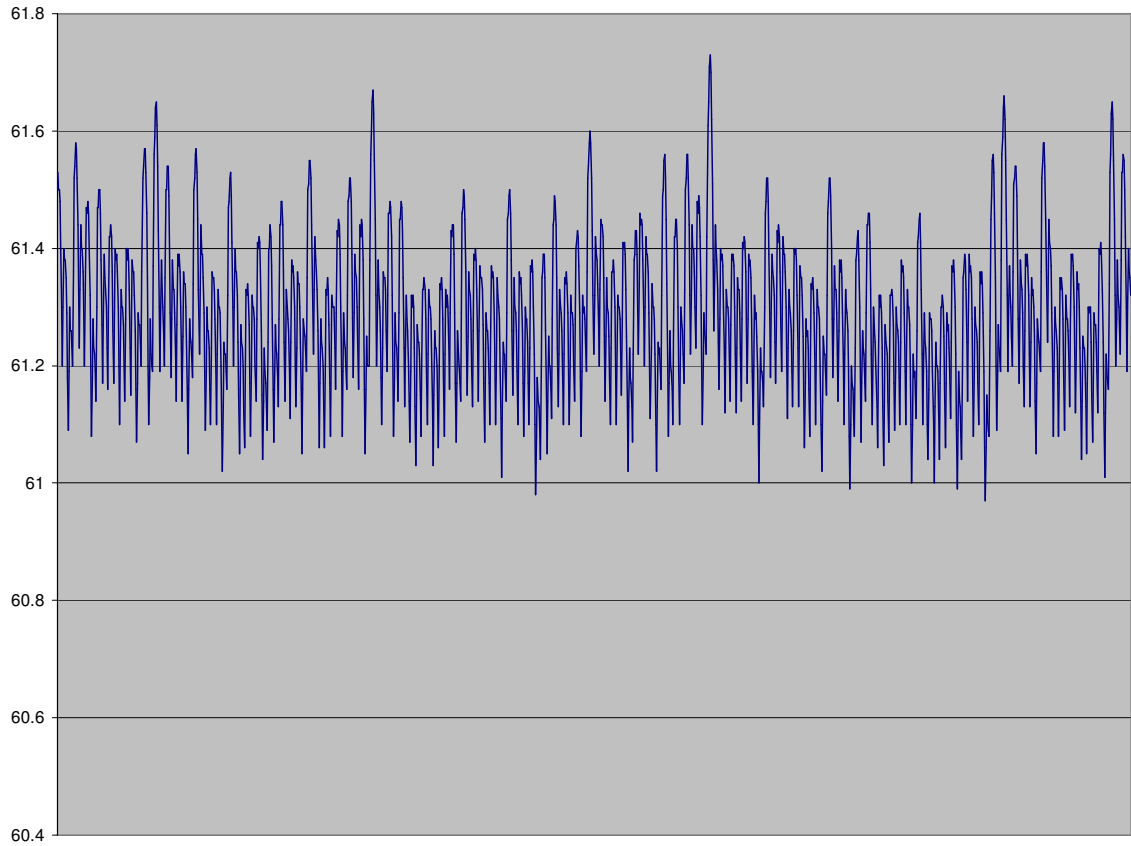
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**STEADY TEMPERATURE RUN #2**

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This is the “all” set-back test. The thermostat was set to keep my Styrofoam “building” at a constant 62° F.

Here is the diagram of this 24 hour test (5:20 pm to 5:20 pm):



Energy consumption for this test amounted to .16 Kilowatts (i.e., 160 Watts) as measured on the Kill A Watt meter and 6 hours 21 minutes 2 seconds (6.351 hours) as measured on the clock.

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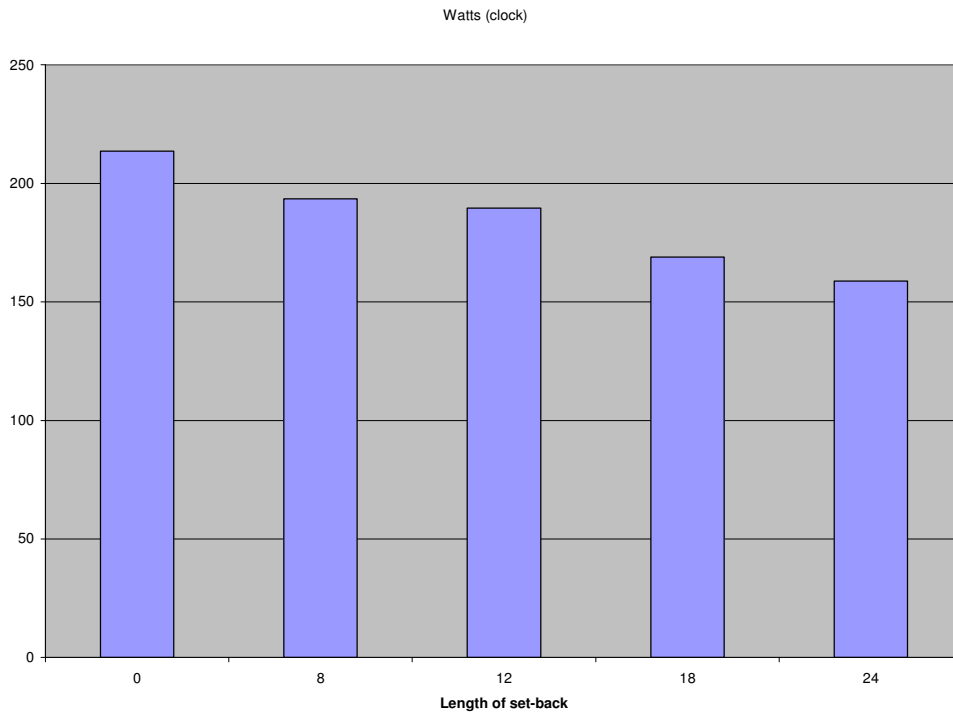
**RESULTS**

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Below is the spreadsheet comparing the results from each test (Clock Watts = 25W \* Clock):

Test	Length of set-back (Hours)	Clock (Hours)	Clock Watts (Watts)	Kill A Watt (Watts)
Steady Temperature Run #1	0	8.544	213.6	210
Set-back test #1	18	6.758	168.95	170
Set-back test #2	12	7.586	189.65	190
Set-back test #3	8	7.763	193.41	190
Steady Temperature Run #2	24	6.351	158.76	160

Below is the graph of the amount of energy used for the various set-back periods:



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## CONCLUSIONS

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It is quite clear that lowering your thermostat for a certain period each day results in a measurable savings over leaving the thermostat at a particular temperature 24 hours a day. My data shows no support for the theory that it takes the same amount of energy to return the environment to the higher temperature following the set-back period. Setting the temperature lower, even for a period as short as 8 hours yielded an energy savings of over 9%. Although I did not specifically test a period of less than 8 hours, with level of energy savings I recorded, even a shorter period should result in noticeable energy savings.

It must be noted that the results I recorded in my tests are difficult, if not impossible, to apply to any other situation. Most exterior environments are not nearly as uniform as the interior of my refrigerator. My experimental home was sealed for the duration of the test and had no other heat sources. Your home has a much more dynamic heating environment than my experiment.

This experiment was designed to respond to those individuals who have avoided the use of an automatic set-back thermostat as not being worth the expense and loss of comfort. Each home owner must continually evaluate the “heating equation” in his/her home. There are many things that could be altered in an attempt to save on utility bills, such as:

- Servicing or replacing the heating equipment (to increase its efficiency).
- Improving the energy efficiency of the envelope of the house (e.g., insulation, windows, caulking, weather stripping, window treatments, etc.)
- Changing the energy needs of the home (e.g., shutting off lesser used rooms).
- Changing the thermostat settings, either lowering the setting across the board or changing the settings (either manually or automatically)

Each homeowner (or more accurately, utility bill payer) must evaluate each energy saving idea and answer for themselves whether the expense, inconvenience, and potential discomfort are worth the savings to be gained.

What I take away from the results of this experiment is this: Even if you only use an automatic set-back thermostat to set your home’s temperature back for a few hours while you are asleep, you are likely to save enough money on your utility bill to pay for the new thermostat quickly and you will never even notice the difference in your home’s environment.

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## ACKNOWLEDGEMENTS

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I want to thank the following people for reviewing this document and providing a huge number of helpful comments: Richard Bergeron, Maryann Geiser, James Kumorek, John Peyton.

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## FEEDBACK

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If you have any comments (including suggestions for further experiments), please send them via e-mail to: [info@MyPowerCouple.com](mailto:info@MyPowerCouple.com)