



Tolerably Comfortable: A Field Trial of a Recreated Soldier Cabin at Valley Forge

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*"officers and men are chiefly in Hutts, which they say is tolerable comfortable,"
Martha Washington to Mercy Otis Warren, Camp Valley Forge, 7 March 1778.*



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I am indebted most to fellow park ranger Troy Shirley who worked at Valley Forge for eight years. Troy and I spent many enjoyable seasons striving to educate visitors about the Continental Army's accomplishments at the Valley Forge encampment. Ron Gimmillaro, another ranger at the park and one who has studied the American Revolution for over thirty years assured us that Valley Forge was so shrouded in myth that the real story of the encampment could only be revealed by reading the primary sources. As Troy and I combed through the first-hand accounts trying to piece our narrative together, one thing became clear to us – those soldiers and camp followers were a skilled and capable force. This conclusion ran counter to the common perception of the Continental Army at Valley Forge as a helpless and forlorn group. Nonetheless we felt compelled to paint an accurate picture of the camp. We reasoned that if we were really going to perform our duty and commemorate what took place here, then we were obligated to credit the men and women for what they actually accomplished. In practice we found that visitors enjoyed hearing that the soldiers and their camp followers had the skills to take care of themselves despite the obstacles thrown in their way. We often spoke of the log cabins as one of the primary examples of the army's self sufficiency. It then occurred to us that we could do more than talk about how well the cabins worked. We could test one against the winter elements ourselves and publish our findings.

HISTORICAL BACKGROUND

The Winter Encampment

Ask someone to think of Valley Forge and they will nearly always envision a scene of cold and misery. Artistic renderings of the camp often depict poorly clothed men situated against a backdrop of a cold and unforgiving landscape. Certainly, hardship did occur at Valley Forge, but the encampment experience could be characterized as "suffering as usual," for privation was the continental soldier's constant companion over the eight years of the war. Why then has Valley Forge been singled out as the pinnacle of distress? This is so because an early and romanticized version of the encampment story became a convenient parable to teach Americans about perseverance. As the story goes, this miserable suffering transformed the men so that they emerged in spring newly committed to the cause of liberty.

In contrast to this mythical narrative of the Valley Forge experience that depicts the encampment as a time of bitter cold and starvation, primary sources offer a different portrayal. The Valley Forge winter was not even a severe one. Meteorological records kept by local resident Thomas Coombe show that the average daily temperature in the Philadelphia area during the first month of the encampment, that is from December 20, 1777 to January 20, 1778, was 33 degrees.¹ The most severe winter of the war and concomitant suffering occurred in 1779-1780 when the army encamped at Morristown, New Jersey.² Ironically, some of the difficulties faced by the army at Valley Forge were due to the mildness of the weather. Thaws and rain prevented vital supplies from being shipped in as rivers become treacherously swollen and roads muddy and

impassable.

Disease, not cold or starvation was the true scourge of the camp. Army returns reveal that two-thirds of the nearly 2,000 men who perished died during the warmer months of March, April, and May, when supplies were more abundant. Army records and eyewitness accounts speak of a skilled and competent force in charge of its own destiny. Rather than wait for deliverance, the army uncovered sources of supplies, built log cabins to stay in, constructed makeshift clothing and gear, and cooked subsistence meals of their own concoction. Provisions, though never abundant in the early months of the encampment, were available. Shortages of clothing did cause severe hardship for a number of men, but many soldiers had a full uniform, and the well-equipped units patrolled, foraged, and defended the camp. Under the direction of engineers, the men built a city of 2,000-odd huts laid out in parallel lines along planned military avenues. In addition to the log shelters, the troops constructed miles of trenches, five earthen forts (redoubts), and a state-of-the-art bridge over the Schuylkill River.

It is with the log cabins built by the troops that this study is principally concerned. Although previous studies have revealed much about the variety, spatial arrangement, and construction of the huts, this research project will be the first to attempt to discover how well the cabins insulated Washington's men from the cold by using the principle of experimental archeology.³ In order to accomplish this, a team staffed a reproduction soldier cabin for six days and five nights from Tuesday, January 27 through Sunday, February 1, 2004. At the outset our hypothesis was that a heating period of six days, even during the typically very cold period picked for this experiment, would produce a significant differential between the outside environment and inside the cabin. Anecdotal evidence provided by Valley Forge state park rangers who stayed over in identical reconstructed cabins for several days on end in the winter reported that a significant heating occurred over such a period.⁴ In addition it has been the experience of current park staff that some warming takes place even over a single day. When we have lit a fire in a cold cabin in the morning, we have observed that frozen ground before the hearth begins to thaw by the afternoon hours even though the door is kept open to receive visitors. It is therefore predicted that once the cold and moisture in the dirt floor and log walls are removed through prolonged heating, the floor, and in particular the logs will begin to absorb and reflect heat and the temperature inside the hut will rise significantly.

Any evidence provided by this experiment that supports the premise that the cabins were good shelters will further bolster the already mounting evidence that the soldiers and the Continental Army at large were an organized, skilled, and capable group.⁵ In no way is it the intention of this author to downplay the privations suffered by the men and women of the Continental Army over the eight years of the war. It is rather my intent to publicize how skilled and accomplished the soldiers who wintered at Valley Forge were.

As the third year of the American Revolution (1777) drew to a close, General Washington and the Continental Army stood just outside Philadelphia. The British had captured the patriot capital earlier in the fall and the hard campaigning of the autumn left both armies exhausted and in something of a stalemate strategically speaking. As winter approached, armies in that time period often withdrew to fixed camps. Transportation problems of the day made large-scale winter operations infeasible. As he chose a site for quarters, Washington had to balance the congressional plea for a risky and unconventional foray aimed at dislodging the British from the capital against the needs of his weary and poorly supplied army. By mid-December Washington made his decision to encamp at Valley Forge. From this location twenty miles northwest of Philadelphia, the army was close enough to maintain pressure on the enemy, yet located far enough away to prevent a surprise attack.

The camp as laid out by army engineers would occupy a large triangle some seven miles along its sides. One edge ran along a ridgeline. This became the army's outer line of defense. The Valley Creek drainage, which is defined by two high hills, Mount Joy and Mount Misery, formed the second line. This was the inner line of defense. The last leg of the triangle followed the course of the Schuylkill River. Earthworks and trenches

would secure the inner and outer lines. The river itself served as a barrier to attack. The officers and engineers planned to have the huts built in lines along the defensive perimeter. In order to occupy the defense lines, the troops then built their cabins in three locations: along the top of the ridge along the outer line, about one-half of the way up the slope of Mount Joy and along the ridge above the Schuylkill. See Appendix, "Figure 1, Map of Valley Forge."

As the army came into camp on December 19, 1777 they would have found the greater expanse of the land within the interior cleared for crop and pastureland. Woodlots managed for charcoal production covered the slopes of Mount Joy and Mount Misery, and some timber grew along the banks of the Schuylkill. As the men marched in they may well have wondered, as did General Jeddediah Huntington, how well would this encampment site serve them?

Dear Family,

December 20, 1777

We are going to work with all our might and Diligence to House the Army in huts at this Place. General Washington seems resolved to concentrate our army here. Our Men are almost worn out with the constant Marches and Fatigues of the Campaign, but the army is well disposed and will try to make the best of it. I wish could tell you that I was coming home to see you, instead I am going to build me a House in the Woods.

Sincerely,

Jedediah⁶

The "houses in the woods" that General Washington directed the squads of men to build were to be 14 by 16 feet in size, with fireplaces made of wood and lined with 18 inches of clay.⁷ Since boards for roofs would have been hard to come by, Washington offered a reward of \$100 to the soldier or officer who suggested a better substitute.⁸

Accordingly the men went to work as Thomas Paine observed:

General Washington keeps his station at Valley Forge, I was there when the Army first began to build huts. They appeared to me like a family of beavers, everyone busy; some carrying logs, others mud, and the rest plastering them together. The whole was raised in a few days and it is a curious collection of buildings, in the true rustic order.⁹

Paine exercised hyperbole when he stated that the army raised the encampment in a few days. A general lack of tools and the diversion of skilled carpenters to the construction of a sturdy bridge spanning the Schuylkill River slowed hut building.¹⁰ The lateness of the season also pressed hard against the poorly clad troopers as they struggled to get under shelter.¹¹ Ironically, some of the troops who were better clothed and equipped spent more time on guard duty and were thus unable to concentrate on building their quarters. The well equipped, trained and led New Jersey soldiers who served under William Maxwell fell into the above category. Consequently they were among the last to move into quarters.¹² Despite the extra duty, these men took great pains to construct model huts. The total number of cabins built upon the landscape may have approached two thousand. Per orders cabins were to house either twelve enlisted men, six junior officers, three staff officers or one general. Half of Washington's generals lived in log cabins. These could be quite the commodious habitation.¹³ Washington himself entertained his dinner guests in a log cabin annexed to the stone home he used as headquarters.

Although General Washington specified the style and dimension of the cabins, the necessity of getting out of the elements as quickly as possible and the disparity in command structure meant that the cabins were not

all identical. Limited archeological evidence and some primary sources bring this variety to light.¹⁴ However, many journal entries convey the impression that the camp and cabins were somewhat regular. For example Major William Hull stated that “the encampment was regularly laid out; the streets ran in parallel lines; neatness and order prevailed; and in viewing it from the hills, it had the appearance of a little city.”¹⁵ Ebenezer Crosby, surgeon of a Connecticut regiment concurred with Hull’s assessment when he said that “It would please you to see this Log-City, part of which is as regular as Phila.”¹⁶

Perhaps the greatest disparity was seen in the roofing material employed by the men due to shortages of tools and boards and General Washington’s encouragement to experiment with roofing materials. Soldiers constructed roofs of oak shakes, turf and dirt and a combination of all three.¹⁷ The well-built cabins of the Jersey line had wooden shingle roofs.¹⁸ As turf roofs leaked during the wet winter of 1777-1778, oak shingles turned out to be the best choice for roofing.¹⁹ In fact at the next winter encampment at Camp Middlebrook General Washington ordered wooden roofs used in all the huts.²⁰ Doors were generally placed in the south side to allow the sun to add its heat to the cabin during daylight hours.²¹

As part of this study aims to determine the comfort level of the huts it is well for us to consider the physiology of the men who lived in the cabins. Any examination of the living conditions of the time must take into account that a people who grew up with a harsh standard of living would likely have a hardy constitution as a result. It is widely recognized that humans can become accustomed to extreme temperature fluctuations. For example colonial era Europeans often commented on the toughness of the American Indians that they encountered.²² Recent studies carried out on the Aborigines of the central Australian desert offer more scientific evidence of the human ability to withstand temperature extremes.²³ In these experiments European scientists attempted to sleep through the cold desert nights in the same manner as the Pitjendjara peoples did. These indigenous tribesmen built a windbreak and then slept naked between two fires. When the scientists recreated the typical sleeping patterns, the Pitjendjara slept soundly while the scientists found the temperature extremes almost unbearable. From accounts and studies such as these, it is logical to assume that 18th century Americans who spent many hours working outdoors and living in homes without central heat and air conditioning would have a greater tolerance for extreme conditions than the average 21st century American who spends his/her life in a temperature-controlled environment. Due to their constant exposure to the elements, the continental soldiers possibly had an even greater forbearance for weather extremes than their civilian counterparts.²⁴

Keeping in mind that the soldiers had unique expectations about comfort, we can discern from their writings that the log cabins at Valley Forge served as favorable accommodations. The buzz about camp was that the shelters were “**tolerably comfortable**.”²⁵ Some officer cabins such as William Hull’s were spruced up as much as field conditions permitted.

The hut we occupied consisted of one room. This was dining-room, parlour, kitchen, and hall. On one side, shelves were put up for our books, having been so fortunate as to purchase a part of a circulating library that had been brought from Philadelphia. On another stood a row of Derby cheeses, sent from Connecticut by my mother; a luxury of which the camp could rarely boast, and with which visitors to the hut were often regaled. To give an air of greater comfort, we mixed some clay and water, and with this preparation painted the domicile, which our neighbors now declared to be quite an elegant mansion.²⁶

All of our knowledge of the cabins lies in the manuscript records and in the handful of archeological investigations as no original cabins remain. Most were torn down and salvaged by the local residents shortly after the army departed. When George Washington returned ten years later to visit the encampment site during a break from chairing the Constitutional Convention, he found most of the features of the camp in ruins.²⁷

Later tourists visiting the camp would have to imagine what the huts looked like until history enthusiasts built the first reproductions starting in 1905. The hut experiment took place in a reconstructed cabin that was the result of a Valley Forge State Park research project. In the 1940s Edwin E. Hollenbach constructed a series of cabins in the park based on a study conducted by architect G. Edwin Brumbaugh.²⁸ These reconstructions closely followed Washington's orders. In 1961-62 infestation and rot problems caused eighteen of these huts to be taken down and rebuilt on original footings including the two huts of Maxwell's Brigade where our experiment took place.²⁹ The reconstructed cabins lie on stone sills and are made of seven to thirteen inch diameter pressure-treated and creosoted oak logs saddle-notched together. They are roofed with modern-cut Western Red Cedar shingles. The spaces between the logs and the fireplaces are chinked with cement held in place by a matrix of wire mesh. There are four interior, three-tiered bunks of wood construction, enough sleeping space for the twelve enlisted men that were posted to each cabin. The wooden board door is placed opposite the chimney. There are three key differences in the reproduction cabin from the originals: cement, instead of clay was used for chinking material, cedar shingles were employed in place of hardwood ones, and the logs are much more seasoned than the fresh-cut ones used by the soldiers. Despite these variances the hut at Maxwell's Brigade offered us a close example of a hut built and lived in by the enlisted men of Washington's army with which to conduct our test.



The cabin used for the experiment measures 14 x 16 feet on the interior

Unlike the cabin described in Ewing's journal, in the hut selected for the experiment the door faces 337 degrees (north) and the fireplace opposite faces 151 degrees (south). The elevation of this cabin located on the mid-slope of Mount Joy is 230 feet above sea level. See Appendix, "Figure 1, Map of Valley Forge" and "Figure 2, Maxwell's Huts." We selected this particular hut because it is in fairly good condition and offered both easy access and proper security for the team.

Fundamental to the heating of the cabin was the fireplace and so it requires special mention. Colonial Americans based their fireplace design on the European model which was shallow and usually had a throat in the chimney that created a smoke eddy and a very strong draw.³⁰ Since fireplaces can be relatively

inefficient, losing nearly 90% of their heat up the chimney, colonials compensated for this by burning tremendous amounts of freely available wood and by bringing fires well out onto a stone or brick hearth.³¹ The chimney design of the Valley Forge soldier cabin was a mud and stick or catted design such as was built by the first colonists.³²



Hut chimney of one of the Brumbaugh reconstructions

Even a simplified catted chimney such as the ones built at Valley Forge will draw quite efficiently if the dimensions are correct. Certainly the soldiers used the principle of bringing the fire out onto the dirt "hearth" of their hut fireplaces as they were accustomed to doing at home in order to maximize heat efficiency. The wood required by the large population of soldiers far outpaced the locally available supply of seasoned wood and meant that the troops burnt green wood primarily.³³ A well drawing fireplace was therefore a must in a Valley Forge cabin. The fireplaces of the Brumbaugh-researched reconstructions including the one used for the experiment all draw extraordinarily well. In fact it was deemed both practical and historically correct to slow the draw down by tacking a piece of linen oilcloth over the door to reduce the draft from air flowing through the door slats. In previous experience we learned that once a fire was burning well in one of these fireplaces even large pieces of very green firewood were burned without difficulty. As part of the goal of this experiment was to estimate the amount of wood burnt by the troops to

warm their cabins, the team kept careful tabs on the fuel consumed.

Nearly as crucial to heating as the fireplace was the wood selected for the fire. The firewood available to the troops consisted primarily of oak, chestnut and hickory.³⁴ A finer group of woods for heat production and ease of splitting could not have been selected than these species.³⁵ The crew began the experiment with seventy cubic feet of nearly all oak wood, or just over one-half of a cord. A cord measures four by four by eight feet or one hundred twenty-eight cubic feet. This wood came from park storm-damaged trees and was aged from six months to a year. Nearly all of the wood was hand split to manageable sizes for burning. We stored most of the firewood inside the cabin located just across from the one used in the experiment. The team stored kindling and about a day's supply of larger split logs in the cabin with the fire.



Wood supply

A note on the heat efficiency of log walls should be included in this preliminary discussion. Log cabins served the inhabitants of the colder regions of Central and Northern Europe well for centuries. When the Swedes came to America in the middle of the seventeenth century they brought the technology of the log cabin with them. Though the later arriving English, Scotch-Irish, and Germans became the primary settlers of the Delaware Valley in Pennsylvania, it was the Swedes who proved the cabin's worth in the region, a structure which was to become synonymous with pioneer lifestyle on this side of the Atlantic.³⁶ By the time of the Revolution log structures were very commonly used for dwellings. Log cabins were practical for early Americans because timber was plentiful and for the reason that log walls offered good insulation against cold winters. Moreover, the heat efficiency of log walls rivals some modern insulation materials. In a study conducted by the National Bureau of Standards, a twenty by twenty foot square log building constructed of 7-inch squared logs was more efficient to heat and cool than an insulated wood frame structure of the same size.³⁷ This trial was of course done using modern heating methods, not a wood-burning fireplace.

The last factor to be considered is the weather. As has been already stated the winter of 1777-1778 was not particularly harsh. The period picked for the experiment, January, 27 to February 1, 2004 turned out to be much colder than the first month at Valley Forge when the men were constructing their huts. In fact January of 2004 was the coldest since 1982, and the fourteenth coldest on record.³⁸ The average January, 2004 temperature was 26.1 degrees, while the temperature recorded for the Philadelphia area during the first month of the encampment was 33 degrees.

It snowed fairly heavily from December 27-28, eight days after the troops arrived.³⁹ This was one of only three snowstorms that occurred during the encampment. This snow cover stuck around for a little while as it turned cold for a few days at the end of December 1777.

A storm that came through at the beginning of the experiment began with a combination of light drizzle and freezing rain and ended as snow. Thus the experiment started as six inches of snow blanketed the ground and nearly as much covered the roof of the hut. Weather conditions, then, could be said to be very similar to those of the first week of the encampment. The ground temperature however may have been colder than it was in 1777-1778, as January of 2004 was colder than January 1778.

THE EXPERIMENT

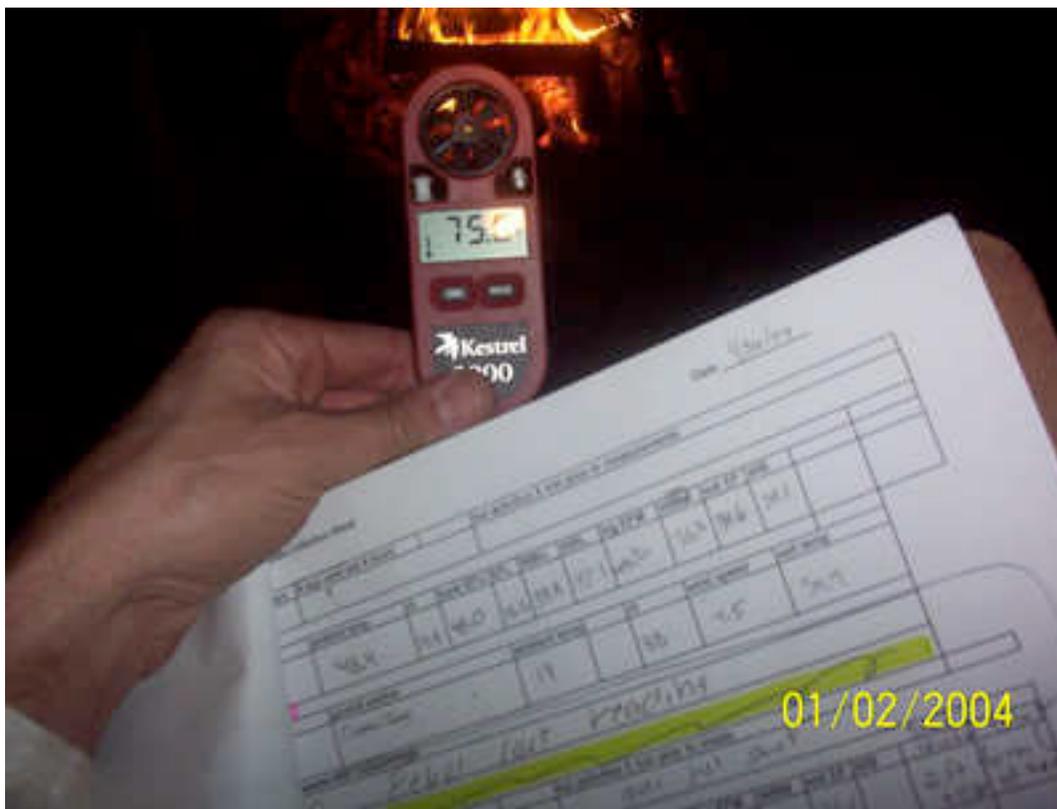
The data points

The basic premise of the experiment was to take readings that would allow us to compare key factors in how well the hut heated and provided comfort to the occupants as compared to outside conditions. The outside data thought to be important to measure were ambient temperature, relative humidity and wind speed, all of which the team measured at approximately chest height. We also monitored outside soil temperature at a depth of 6 in. Outside readings were taken at a location midway between the two huts. All temperature readings were measured in Fahrenheit.



Volunteer Chris Cassidy taking a reading of outside data

The inside readings thought to be determinative for comfort and heating were ambient temperature, relative humidity, soil temperature, log temperature and bunk temperature. The team took ambient temperature and relative humidity measurements in the center of the hut at approximately chest high level.



Taking the ambient temperature recording

Soil temperature was read at the front, just under the east bunk and in the back under the west bunk at a depth of 6 inches.



Recording ground temperature

The crew took readings of log temperatures at a 2 inch depth on logs located midway up the bunks at the east front and west back of the cabin.



Recording log temperature

In order to rate the comfort level of different bunks, bunk temperatures were recorded at the center of the following bunks: east front, upper and lower; west back, upper and lower.



Recording bunk temperature

A diagram of the data points and a sample data collection sheet ("Figures 3 and 4") are located in the Appendix.

The instrument used to measure the ambient temperatures, relative humidity, and wind speed was a Kestrel 3000 pocket weather meter. The Kestrel is capable of measuring temperature with +/- one degree centigrade accuracy, and relative humidity and wind speed within three percent accuracy. Ground temperature was measured with a Barnant Thermocouple Thermometer (Type K), capable of recording ground temperature within .5 degree centigrade. Two Oregon Scientific Jumbo Display Electronic Thermometers (model EM899) mounted at the front and back of the cabin walls allowed for instant references to outside and inside ambient temperature. General weather, ambient temperature, relative humidity and wind speed were checked daily against the data accessible from the park weather station, located about two and a half miles south east of where the experiment took place. The weather data from this station is available at <<http://www.skywatchweather.cc/valleyforge/index.htm>>.

A short workshop was held prior to the experiment to brief the rangers and park volunteers who staffed the cabin on their responsibilities. They generally worked in pairs as they fed the fire and took the readings. Some cooked period meals on the hearth during their stay. We planned to take readings every four hours and to staff the hut continuously throughout the six day period. Logistical difficulties brought on by a snow storm prevented the cabin from being staffed for some hours at the outset.

We began the experiment at 10:30 a.m. on January 27, 2004. At this time the outside ambient temperature read 22 degrees and there was 2.5 inches of snow on the roof and slightly less covering the ground. The door had to remain constantly open during set up. The fire was started well out onto the hearth with flint and steel. Initially, it was hard to keep it going due to the frozen earth of the hearth.



Initial conditions with frozen earth on the hearth

The fire was not burning robustly until 12 p.m. With the door open the fireplace drew so well that much of the heat was lost up the chimney. The door was shut at 1 p.m. and the inside temperature as measured by

the display thermometers in the cabin jumped almost immediately to 39 degrees in the front and 43 degrees in back. The fire was banked at 3 p.m., but due to the logistical troubles caused by the storm, no one was able to return until 8 p.m. when the team came in for the night. The fire was rebuilt and the ambient temperature on the display thermometer read 50 degrees. Snow continued during the night and the fire was kept burning continuously till morning.



Fire burning well out on the hearth

The snow accumulated 3.5 inches over night, which left a total of 6 inches on the ground and 5.5 on the cabin roof. The team built up the fire at 8 a.m., on Wednesday, January 28 and left. Due to poor driving conditions no one was able to return until 1 p.m. when the fire was rebuilt. There were some down drafts that afternoon that brought some smoke into the hut. The wind speed was recorded at 8 miles per hour at this time and was blowing from a westerly direction at 287 degrees. The fire was banked at 2 p.m. and the hut left vacant until the evening crew came in at 4 p.m. The hut remained occupied and the fire burned continuously until the end of the experiment on Sunday, February 1, at 4 p.m. The hut was opened so that visitors could tour the cabin at 1 and 3 p.m. on both Saturday and Sunday.

The Data

Ambient Temperature

One glance at "Figure 5, Ambient Temperature Inside Versus Outside," Appendix, shows how effective the fireplace was at heating the cabin. After the cabin door was shut for 1.5 hours, the ambient temperature differential between the outside and inside rose to 27 degrees. After the initial jump the graph shows a gradual gain in differential over the six day period. Peak temperature tended to occur in the late afternoon hours. For example the inside temperature highs for 1/29, 1/31, and 2/1 were all recorded at 4 p.m. On 1/30, it still was warm at 4 p.m., but the high for the day inside the cabin was recorded at 10 a.m. From the graph it can be seen that these high temperatures coincide with the outside ambient temperature highs for

the day. Some of the peak heating must then be related to the outside temperature. The other factor that should be considered was our natural inclination to tend and fuel the fire more during waking hours, which may have caused a build-up of heat.

The chart also shows that the cabin cooled down as the night wore on and outside temperatures fell. The inside ambient temperature consistently reached a low for the day during the early morning hours. In each case the lows inside very closely correspond with lows outside. Another pattern that emerges is that while outside declines consistently brought on a drop in the interior temperatures, the differential eventually became less. For example, on 1/28, the difference was 23 degrees, on 1/29, 20 degrees, on 1/30, 25 degrees, on 1/31, 31 degrees and on 2/1, 36 degrees. A similar pattern that surfaced was the net gain in high temperature. On 1/27, the difference in high temperature inside versus outside was 27 degrees, on 1/28, 20 degrees, on 1/29, 42 degrees, on 1/30, 43 degrees, on 1/31, 50 degrees and on 2/1, 41 degrees.

The one outstanding anomaly on the ambient temperature chart is the precipitous drop in inside temperature from 70 degrees to 50 degrees that occurred at 12 p.m. on 1/30. This took place without a commensurate major drop in outside temperature. This is easily explained by the fact that the crew manning the hut for that period had the door open for an extended time. Once the door was shut, the temperature shot back up to 66 degrees by 4 p.m.

Wind Speed

The east slope of Mount Joy where the cabins are located is a sheltered area. As measured over the course of the experiment, wind speed ranged from 0 to 8 mph. At many times it was quite calm, often in the 0-3 mph range. At only two points did speed top out at 8 miles per hour. The wind speed measured by the park weather station just below the outer line where the troops built many of the huts often was higher than the Mount Joy area. Readings here topped out at 12 mph and were nearly always above 6 mph. Just how much a higher wind speed would affect the heating of the cabin and the comfort level of the men inside is open to question, and certainly bears investigation.

Relative Humidity

It should be noted that for some reason, the initial reading inside the cabin was a much drier 53% than the outside measurement of 78%. This measurement should probably be checked on another occasion under similar conditions to help to understand why this occurred. The general weather at this time was cloudy with a light drizzle. "Figure 6, Relative Humidity Inside Versus Outside," Appendix, shows evidence of a steady decrease in inside humidity over the course of the experiment. This decrease followed the outside drop early on as a front passed through and the outside air became cooler and drier. By the evening of the fourth day, 1/31, however, there was a significant and permanent departure between the drier air of the cabin, which stabilized in the range of 15 to 20 % rh, and the outside rh, which ranged between 31% and 43%. The inside rh then rose to 28% on the sixth day (2/1) as the outside rh increased to 60%. The one anomaly in this graph, where the outside rh dropped lower (41%) than the inside (47%) is probably explained by the fact that as the front passed through the outside air's drop in humidity outpaced the drying phenomenon taking place inside.

A trend that was observed during the course of the experiment may partially account for the rise in temperature and decrease in relative humidity within the cabin. The event that may be responsible for the warmer, drier hut was the thawing of the earth within the walls. It was first observed that the frozen ground inside the cabin began to thaw shortly after the fire was lit. At the outset the hearth area thawed out and then slowly, in an outward path from the hearth towards the door the ground defrosted. The teams discerned that the ground first turned from frozen to muddy and then became dry. On 1/31 at 12:30 p.m. we noted that the earth had thawed out 9 feet back from fireplace towards the door and by 2:30 p.m. on 2/1, the line (seen as a darker color in the following photograph) had spread to a point 11.5 feet back from fireplace, nearly to the door.



The thaw line nears the door

Certainly the drier and warmer ground would make it easier for the fire build heat inside the cabin. Does "Figure 7, Soil Temperature Inside Versus Outside," Appendix, show any empirical evidence of the thawing?

Soil Temperature

On examining Figure 7, the first piece that must be accounted for is the initial temperature of the soil inside the cabin reading that was lower at both the front (soil EF) and back (soil WB) than the outside. Perhaps the snow that covered the ground helped to insulate the outside soil from fluctuations. The outside earth also had the advantage of being heated by the sun and air more readily than the ground inside the cabin which was covered. Again, additional testing could determine if the inside hut floor would be colder than the outside soil under a series of winter conditions [with snow cover and without for instance].

One general observation that can be made from the chart is that there was very little difference between both front and back soil temperature as compared to outside soil condition. At most the difference was about 5 degrees. However, a small change in temperature could have had a great effect on the total inside conditions of the cabin, particularly if the shift brought the average inside soil temperature above the 32

degree freezing mark, indicating that the ground was no longer frozen. Did this occur according to our measurements? At the beginning of the third day (1/29), the temperature of both front and back soil inside the hut climbed above the outside and remained there for the course of the experiment. At 8:30 p.m., on the second day (1/28) the soil temperature both front and back rose above freezing for the first time. Soil temperature inside remained above freezing, while the outside soil remained near or below the freezing mark, for the remainder of the test, except for a short dip below the 32 degree mark on the morning of the last day. This dip may be explained by the sharp drop in outside ambient temperature to 9 degrees and soil temperature to 26 degrees that occurred at that time. The rise above freezing and continued maintenance over the 32 degree mark of the soil temperature that we recorded does offer empirical evidence for the thawing and drying of the earth that took place within the hut.

It would seem reasonable to suppose that the front soil which was closer to the fire would become warmer faster than the earth at the back of the cabin. Did this occur? There is some evidence that this took place, but the difference was slight. The first time was the period that began at 4 p.m. on 1/29 when soil EF was a degree or two warmer than WB. The second occurrence was at 4 a.m. on 1/31, when EF became warmer and then remained so for most of the rest of the test.

Figure 7 does exhibit several anomalies. On 1/29 at 4:30 p.m., both inside soil measurements fell below the outside soil temperature. This drop was not accompanied by a sharp decrease in either outside ambient or soil temperature and remains unexplained. Perhaps an error in measurement is to blame or maybe the thawing of the ground was stopped for some reason. The next incongruity transpired on 1/30 at 12 p.m. when the back temperature was 3 degrees warmer than the front, reversing the major trend in which the front had been warmer than the back. The last irregularity to be accounted for was the relatively sharp rise in both front and back soil temperature while the outside ground temperature actually dropped. This took place on 1/31 at 4 a.m. Once again perhaps an error in measurement is to blame in both of these cases.

The spike in temperature to 36 degrees at the end of the test may indicate that the soil would continue to warm up if the experiment were continued. The only way to attempt to prove this would be to carry the test on for more days, perhaps for as long as two weeks. A difference between the test conditions and those on the ground in 1777 that should be noted is the fact that the soldiers would have built their cabins on exposed ground and then started to heat the hut. In the experiment the existing cabin of course stood over the ground the entire fall and part of the winter before the test started. Soil temperature may have been warmer than historic winter as well since the preceding weeks were warmer than they were in 2004. In theory then, the soldiers may have been able to warm their huts faster than what we experienced in the test cabin.

Log Temperature

Interior log temperatures may also hold a clue in accounting for the rise in temperature and drop in humidity inside the hut. "Figure 8, Log Temperature Versus Outside," Appendix, shows that both logs EFM (East Front Middle) and WBM (West Back Middle) warmed up over the course of the experiment. As with inside ambient temperature the high and low temperatures of the logs corresponded with the highs and lows in outside temperature. The front log warmed faster and stayed warmer than the back log for the entire course of the trial. One of the main premises that we wished to test was to determine if the logs would gain and hold enough heat to bring permanent warmth to the interior of the cabin.

One clue to see if this was taking place would be to see if there was a significant and continual gain in one or both of the logs. At their peak warm readings, at 4:30 p.m. on 1/28, 12 a.m. on 1/30, and at 12 a.m. on 2/1, there did seem to be a progressive gain in log temperature. Log EFM showed the most gain at these times, reading, 17, 35 and 35 degrees above the outside ambient temperature. Log WBM showed only a gain of 7, 16, and 14 degrees at the same times. There was also a precipitous drop in both logs on 2/1 at 12 pm. when EFM fell to 31 degrees and WBM to 30. The only apparent clue as to why this occurred is that it

took place 8 hours after the outside ambient temperature plummeted to 9 degrees, the lowest reading in the entire test.

Could this great fall in outside temperature have brought on a delayed drop in the amount of heat contained in the logs? Perhaps, but it should be noted that the temperature of both logs sprung back up at the end of the trial at 4 p.m. on 2/1 when EFM reached 54 degrees and WBM 34. While the successive gain in the amount of heat held in the front log offers some evidence that the logs would continue to gain and hold heat, the test would have to be run for more days to determine if log temperatures would not drop off repeatedly when the outside temperatures fell significantly. Another question that might be asked is how much moisture would have been lost from the logs during the course of the heating, and whether this would have assisted in heat retention. A more sophisticated monitoring method would have to be employed to resolve this question.

Bunk Temperature

The last set of data recorded in the hut test was bunk temperature. Bunks were tested to attempt to answer a question often asked by park visitors: Which bunk was warmest? Measurements were taken for the upper and lower bunks on the east side (Bunks EFU and EFL), and west side (Bunks WFU and WFL) of the cabin. A quick look at "Figure 9, Bunk Temperature Versus Outside," Appendix, shows that the two familiar trends reappear. As was the case with inside ambient and log temperature, the highs and lows in all the bunk temperatures follow the highs and lows in outside ambient temperature. Bunk temperatures also plummeted when the outside temperature reached the low for the test at 9 degrees.

Common sense would dictate that the front bunks would warm first and most since they are nearer the fire. The bunk temperatures that we recorded confirm this. The front two bunks became warmer by the beginning of the second day, at 6 a.m. on 1/28. The front bunks stayed warmer for the rest of the experiment. While it was evident that the front bunks were cozier than the back, was there a difference between the upper and lower in each pair? In the case of the front bunks, the upper bunk (EFU) was just slightly warmer at the beginning, and the lower (EFL) was only somewhat warmer at the end. In each case the difference was a mere couple of degrees. The lower back bunk was the warmer one by 3 degrees in the first part of the trial, then on the morning of the third day (1/29) the upper heated up 6 degrees more than the lower. The back bunks then repeated this flip flop with WFL again becoming warmer on the evening of the next day and WFU overtaking WFL on the afternoon of the next day. The difference between the back upper and lower bunks was slightly greater than the variation recorded between the upper and lower bunks in the front, but not enough to state that one was much more preferable than the other in this trial. It certainly could be said that the front bunks were the more desirable place to sleep at least over the course of the five nights spent in the cabin. As with inside ambient temperature it would be interesting to track the differences between the bunks and the outside temperature for a longer period.

Wood Consumption

It was part of the experiment's purpose to suggest how much wood Washington's men might have burnt while heating the cabins during the encampment. During the test we burned nearly all of our wood supply. This wood pile consisted of one-half of a cord. If one reasons that the men burnt fires in the cabins from just after they built them in late December until later in the spring when temperatures moderated, the heating season was about 20 weeks long. It would have required approximately 10 cords of wood to heat one cabin for the season and about 10,000 cords to heat all the huts. The army would have consumed even more wood than this in the fires built for cooking, laundry and other uses.

CONCLUSION



"April Inside:" temperature reading at front of hut near the end of the experiment

One of the most important statements that can be made about our experiment in heating the cabin is that we were able to create a most comfortable environment despite the quite harsh conditions that existed on the outside. The 40-50 degree difference that we were able to gain over the outside temperature during the daytime and the 25-35 gain that we were able to achieve overnight indicates that in a properly constructed hut the soldiers could have survived quite well even during the coldest spells. In effect we were able to make it April inside while it was January outside. The fact that the experiment took place during a period when it was actually colder than it was during the first month of the encampment adds further creditability to our results.

The steady decrease in relative humidity inside the cabin as measured during the trial was probably a result of the observed thawing of the frozen earth of the hut floor. Our soil temperature readings offered additional proof of this phenomenon when we observed that they climbed over and remained above the freezing mark. As the logs in the cabin warmed and possibly lost moisture, their drying may also have helped reduce the humidity within. An additional benefit of the lower relative humidity was the added comfort that a drier cabin provides for the inhabitants.

The observed difference in the bunk temperatures, notably the fact that the front bunks were warmer may have ramifications for how officers or sergeants assigned enlisted men bunks. Sergeants, corporals and privates with more seniority may have been given preference.⁴⁰ The men may also have given over warmer berths to soldiers who were ill or coming off of hard duty.

The main recommendation of this study is that in order to reach any further conclusions about how well the cabins at Valley Forge worked the experiment would have to be carried out over a longer period and expanded to include more variables. For example it would be interesting to determine if the temperature difference between the front and rear bunks would have lessened if the test was carried forward for perhaps two weeks under similar cold outside conditions. A longer test would almost certainly help us learn if the

drop offs that we witnessed in inside ambient, log, soil and bunk temperatures would have modulated when the hut was heated for an extended period. The rise in all the inside data temperatures at the end of the experiment is possibly an indication that this would take place. Repetitive gains in daytime inside temperatures as well as continued drying and warming of the hut soil and logs would possibly create a cumulative effect that would override the drops in outside temperatures that seemed to bring on commensurate declines in interior conditions.

A technique for measuring the amount of moisture in the soil, log cabin walls and even the roofing material would be helpful in determining how much the fire would reduce moisture levels in these materials. Any empirical evidence of this drying out of the hut fabric would assist in proving that the drop in interior relative humidity was related to this phenomenon.

Another potential field for discovery would be to increase the amount of variables. For example readings could be taken of a cabin that was not heated and compared against measurements taken of an identical heated cabin. Another option would be to test one of the cabins that is of similar construction to the Maxwell's Brigade huts, but located on the exposed outer line of the camp occupied by many of the troops to see if higher wind speed and possibly colder temperatures would affect the heating of the cabins there. Since soldiers at the Valley Forge encampment apparently built huts that varied from the model proposed by Washington and experimented with roofing materials it would be edifying to try out the experiment on cabins built with such variations as sunken basements, different chimney orientations, and roofs of turf, leaves, and hand-split oak shingles. It would also perhaps be instructive to build a cabin or set of cabins from scratch using fresh-cut logs, hand-split shingles, and locally obtained clay chinking and then heat the structure(s) up using only the greenest of wood to see if any of these materials provided better or lesser heating qualities than those of the cabin used for the test.

Another variation on the experiment would be to add in some realistic military detail. It is well to note that there would have been as many as 8-12 soldiers living in the majority of the huts. We rarely had more than two occupying the test cabin. Would placing more people in the cabin affect the heating in a significant way? Even if many of the squad was outside on other duty during the day and perhaps even over the course of the night, the soldiers would have rotated the duty of tending the fire so that it would have been kept burning strong for 24 hours a day.⁴¹ Because of our inability to get to the cabin during the early part of the storm our fire went out at the outset. In addition, our small crew and the demands of work and personal life meant that we sometimes let the fire burn down as we tried to catch up on much needed sleep. Attempting to duplicate such details as storing gear and hanging wet clothes to dry inside the cabin may also help to add to our understanding of how life was for the men in the huts. Of course any expansion of the experiment would require more staff support and time; something that will be hard to come by as park budgets are not likely to grow. Perhaps a grant or other special funding could be obtained to assist in carrying the test forward.

If the experiment was to be continued and expanded, a more sophisticated monitoring system should be developed. Continuous monitoring with computerized data loggers and other instrumentation would help reduce human error in measurement and detect important events that might have been lost because we only were able to record data at 4-hour intervals.

All conclusions reached must be tempered with the knowledge that any attempt to duplicate the original conditions of the camp must ultimately fail at some level since we cannot possibly recreate the situation, mindset and folkways of the period. Our different outlook and the disparity that exists between our environmental tolerance and theirs must be taken into account. To cite just one instance, there is evidence that period backwoodsmen fared extremely well in the winter in three-sided shelters built with a fireplace facing the open end.⁴² Soldiers acclimated to the extremes may have not minded airy huts and may have left their doors open to let in light and air without much concern.

In spite of these possible sources of bias we did infer from this experiment that the huts probably worked better to shelter the men than has been commonly supposed. Another satisfying result of the experiment was the realization that the team that manned the cabin was as much as is possible in the modern world, self-sufficient. After a period of days the body seemed to acclimate a little bit to the period clothing worn and to the lower temperatures than we were used to at home. The comfort level and "survival" of the crew depended not on some unseen gas pipeline or electrical grid, but on our own pile of split firewood located only a short walk away. The days and nights were spent in agreeable company, the fire burned cheerily, and the hut was indeed found in the end to be tolerably comfortable.

NOTES

¹ Thomas Coombe, "Meteorological Observations near Philadelphia," American Philosophical Society, Philadelphia, PA. 551.5, M56, III.

² Here the Continental Army suffered through one of the worst winters in American history. Severe cold bit at the men and massive snows prevented food from being brought in. On January 11, 1780, General Nathanael Greene reported that "Such weather as we have had, never did I feel. For six or eight days it has been so extremely cold, that there was no living abroad; the snow it is also very deep, and much drifted; it is so much so, that we drive over the tops of the fences." Nathanael Greene to an Unidentified Person, 11 January 1780, Nathanael Greene, *The Papers of Nathanael Greene*, ed. Richard K. Showman (Chapel Hill: The University of North Carolina Press, 1989), 253; General Johann Kalb believed that "Those who have been in Valley Forge or Middlebrook during the last two winters, but have not tasted the cruelties of this one, know not what it is to suffer." Major General John Kalb, Camp Morristown, 12 February 1780, in Friedrich Kapp, *The Life of John Kalb: Major General in the Revolutionary Army* (New York: pvt. ptd., 1870), 183.

³ Experimental archeology is the process of learning about some event or activity by imitating or reenacting the activity. Jay Anders, *Time Machines: The World of Living History* (Nashville, TN: American Association for State and Local History, 1984), 87.

⁴ Ronald W. Gimmillaro, Interview by the author, 14 July 2003, Valley Forge, PA. Transcript.

⁵ Wayne Bodle, *The Valley Forge Winter: Civilians and Soldiers in War* (University Park, PA: Penn State Press, 2002); Wayne K. Bodle and Jaqueline Thibaut, "The Valley Forge Report" (Valley Forge, PA: Valley Forge National Historical Park, 1982); Barbara Pollarine, *Great and Capital Changes: An Account of the Valley Forge Encampment* (Gettysburg, PA: Thomas Publications, 1993); Charles W. Royster, *A Revolutionary People at War: The Continental Army and American Character, 1775-1783* (Chapel Hill: University of North Carolina Press, 1980). See especially pages 190-254.

⁶ General Jedediah Huntington to Relatives, 20 December 1777, Jedediah Huntington Papers, Chicago Historical Society.

⁷ George Washington, *The Writings of George Washington, Vol. X*, ed. John C. Fitzpatrick (Washington, DC: United States Government Printing Office, 1933), 170-71.

⁸ *Ibid.*, 170.

⁹ "Military Operations Near Philadelphia in the Campaign of 1777-78. Described in a letter from Thomas Paine to Dr. Franklin," *Pennsylvania Magazine of History and Biography* 2 (1878): 294.

¹⁰ "We are now about to build Hutts for shelter this winter Expect in a few days to be comfortable, tho we have nothing convenion to work with - Axes are very scarece - ...we have but one dull ax to build a Logg Hutt When it will be done knows not. . . ." Jonathan Todd to Timothy Todd, 25 December 1777, Roll 1561, M806, RG 15, National Archives, Washington, DC.

¹¹ As the army prepared to go into quarters the year after Valley Forge at Camp Middlebrook, New Jersey, George Washington reflected upon the difficulty of raising camp Valley Forge: "the Troops must again have recourse to the expedient of hutting, as they did last Year, but as they are now well clad, and we have had more leisure to make some little preparation, for Winter quarters, I hope they will be in a more comfortable situation than they were in the preceding winter." *Writings of Washington, Vol. XIII*, 352.

¹² George Ewing did not occupy his hut until January 10. Thomas Ewing, ed. *Military Journal of George Ewing (1754-1824), A Soldier at Valley Forge* (Yonkers, NY: priv. prt., 1928), 26; William Gifford, also of the New Jersey brigade was not able to move into his cabin until January 24. William Gifford to Benjamin Holme, 24 January 1778, Roll 1561, M806, RG 15, National Archives, Washington, DC.

¹³ “He went on to state that his rather grandiose structure would be 32 feet in length, and would have three fireplaces. It would also have a kitchen, a dormitory for servants, and a stable.” Baron Kalb to the Vocomte de Maruroy, December 1777, K1364. No. 170, Archives Nationale, Paris, France. trans. by Jaqueline Thibaut in Wayne K. Bodle and Jaqueline Thibaut, “The Valley Forge Report, Vol. III” (Valley Forge, PA: Valley Forge National Historical Park, 1982), 29, 109.

¹⁴ Bodle and Thibaut, “The Valley Forge Report, Vol. III,” 60-61. For example, the conclusion of the archeologists who excavated the four huts on the outer line found the overall size, alignment, and chimney placement varied considerably from Washington’s orders. B. J. Egloff, V. Packard, and J. de Ramsay, *The Excavation of Four Hut Sites at the Outer Defensive Line of Valley Forge* (Valley Forge, PA: Valley State Park, 1975), 8-9.

¹⁵ William Hull, *Revolutionary Services and Civil Life of General William Hull*, ed. Maria Campbell, (New York: D. Appleton & Co., 1814), 116.

¹⁶ Ebenezer Crosby to ?. 14 April 1778. Houghton Library, University, New Haven, CT.

¹⁷ Bodle and Thibaut, “The Valley Forge Report, Vol. III,” 61.

¹⁸ “our men are in huts 16 by 18 covered with Oak Shingles, and now are pretty comfortable – Since we have got to live in ‘em, we lay in tents untill the 20 instant, an instance of the kind hardly known in any Country whatever, but what can’t brave Americans endure” William Gifford to Benjamin Holme, 24 January 1778, Revolutionary Era Documents, Newark, New Jersey: New Jersey Historical Society.

¹⁹ “the roof is not the best in wet weather oak slabs Cover’d with Turf & Earth - Our Inards work is not yet completed.” Jonathon Todd to Timothy Todd, 25 December 1777.

²⁰ “Much of the sickness among the Troops seems to have been occasioned by the improper method adopted in forming many of the Hutts last Winter; Some being sunk in the ground and others covered with Earth; To avoid consequences of a similar nature as far as is in our power from occurring again the Commander in Chief directs, that all the officers on the ground see that their men observe the Instructions of the Quarter Master General in the formation of their huts. That they be roofed with boards, slabs or large shingles. That the men be not suffered to dig into the ground (except so far as to level the surface) or to cover their huts with earth or turf. The officers will likewise see that their men erect bunks or births to keep them off the ground and proper conveniences in their huts for the purpose of preserving their Arms and Accoutrements from being damaged.” *The Writings of Washington, Vol. XII*, 395.

²¹ *Journal of George Ewing*, 25.

²² “. . . they [American Indians] have been inured to bear the extremes of heat and cold; and from their infancy, in winter and summer, to plunge themselves in cold streams, and to go almost naked, exposed to the scorching sun or nipping frosts, till they arrive to the state of manhood.” Henry Bouquet, *An Historical Account of the Expedition Against the Ohio Indians in the Year MDCCLXIV Under the Command of Henry Bouquet Esq.* (Dublin, Ireland: John Milliken, 1769; repr., Bargersville, IN: Dresslar Publishing, 1997), 49, 50.

²³ David M. Gates, *Man and his Environment: Climate* (New York: Harper and Row, 1972), 84-85.

²⁴ “A Soldier’s Life is such that no one can have a true idea of without the Trial. It is such that I am convinc’d will suit no Man except he have a Constitution like Iron.” William Weeks to Clement Weeks, 6 August 1777, William Weeks, “Letters,” in Hiram Bingham, Jr. *Five Straws Gathered from Revolutionary Fields* (Cambridge MA: pvt. ptd., 1901), 13-14.

²⁵ Martha Washington to Mercy Otis Warren, 7 March 1778, Adams Warren Papers, Massachusetts Historical Society.

²⁶ *Life of Hull*, 116-17.

²⁷ George Washington, *The Diaries of George Washington*, ed. Donald Jackson and Dorothy Twohig, Vol 5. (Charlottesville: University Press of Virginia, 1979), 179.

²⁸ John and Cherry Dodd, *List of Classified Structures, Vol. IV: Log Structures* (Valley Forge, PA: Valley Forge National Historical Park, 1981), 3.

²⁹ *Ibid.*, 3.

³⁰ John Vivian, *Wood Heat* (Emmaus, PA: Rodale Press, 1976, repr. 1978), 10, 225-229.

³¹ Vivian, *Wood Heat*, 10; Elliot Wigginton, ed., *The Foxfire Book*, (Garden City, NY: Anchor Books, 1972), 111.

³² Vivian, *Wood Heat*, 91; Wigginton, *Foxfire*, 108-113.

³³ If Brumbaugh’s calculation of the timber required to build the 74 cabins built in the 1940s is extrapolated to full scale, it would have required approximately 127,575 trees between three to twelve inches in diameter to construct the total number of huts at the encampment. Dodd, *List of Classified Structures, Vol. IV: Log Structures*, Worksheet 1A. Fuel consumption probably exceeded the amount of timber used to construct the huts. The British Army estimated that it utilized about 100 cords a week in heating log huts, barracks and homes for 15,000 troops during their occupation of

Philadelphia in 1777-1778. John W. Jackson, *With the British Army in Philadelphia* (San Rafael, CA: Presidio Press, 1979), 171. The British Army occupied New York City and its environs from 1776-1783. Their demand for timber for firewood and other uses was tremendous. Nearly the entire expanse of Long Island's post glacial forest of chestnuts and oaks was cut to supply the needs of the British. Tony Hiss, *The Experience of Place: A New Way of Looking at and Dealing with Our Radically Changing Cities and Countryside* (New York, Vintage Books, 1990), 111.

³⁴“That the timber prevalent about Valley Forge, previously to its being fallen for the use of the American army, in the autumn of 1777, and winter and spring of 1778, consisted of white oak, black oak, spanish oak, rarely interspersed with scrubby chestnut and hickory.” “On Timber at Valley Forge,” Letter from Isaac Wayne, Esq., Easttown, Chester County (PA) to Richard Peters, Philadelphia, 4 March 1814, in “Memoirs of the Philadelphia Society for Promoting Agriculture, Containing Communications on Various Subjects in Husbandry and Rural Affairs,” Vol III. (Philadelphia: Johnson and Warner, 1814), 376.

³⁵ Vivian, *Wood Heat*, 305.

³⁶ Terry Jordan, *American Log Buildings: An Old World Heritage* (Chapel Hill, NC: University of North Carolina Press, 1985), 146; Henry C. Mercer, “The Origin of Log Houses in the United States,” Doylestown, PA: Paper Read before the Bucks County Historical Society, January 19, 1924, 6, 21-23, 30.

³⁷North American Log Homes Council of the National Association of Home Builders, “Research Report on Energy Efficiency of Log Buildings,” Washington, DC: 1982, 1-4.

³⁸ “A January to Forget,” *The Philadelphia Inquirer*, B1, Sunday, February 1, 2004.

³⁹ Joseph Lee Boyle, “Up to Our Knees in Mud for Four Days Past”, Valley Forge National Historical Park, 1998.

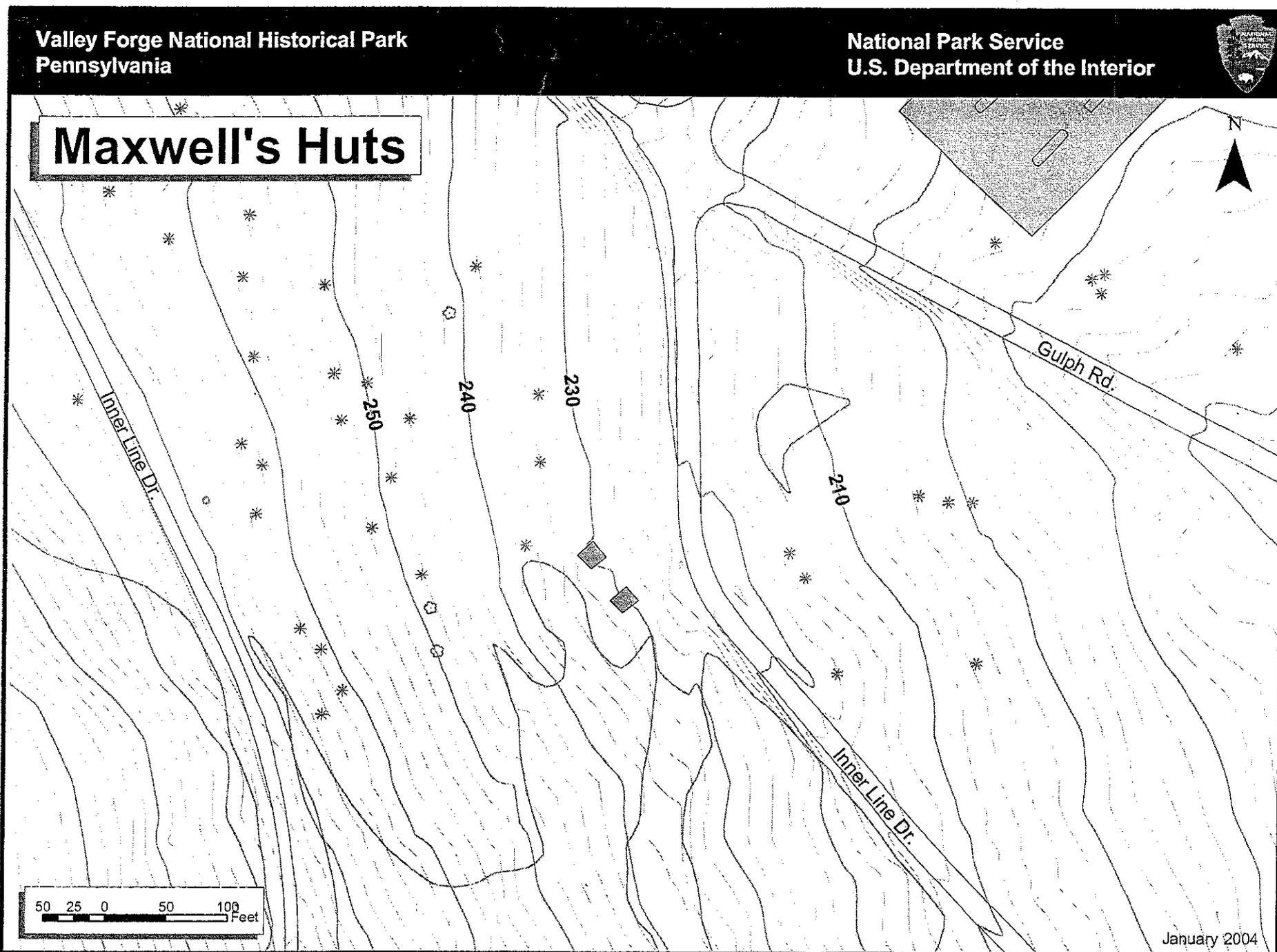
⁴⁰ Officers and non-commissioned officers used seniority as a basis for making tent sleeping assignments. The newest enlistees sometimes had to sleep near the front door of the tent where the other men would step over them in the night as they made their nocturnal visits to the latrine. It is logical to assume that rank also had its privilege when it came to assigning bunks. Howard Lewis Applegate, “Constitutions Like Iron: The Life of the American Revolutionary War Soldiers in the Middle Department, 1775-1783,” (PH.D. diss., Syracuse University, 1966), 367, 394-95.

⁴¹ *Ibid.*, 353.

⁴² Gary S. Zamboly, “A Lodging for the Night: A Brief Study of Some Types of Wilderness Shelters Used During the French and Indian War,” *Muzzleloader* March/April 1989, 47, 50-51.

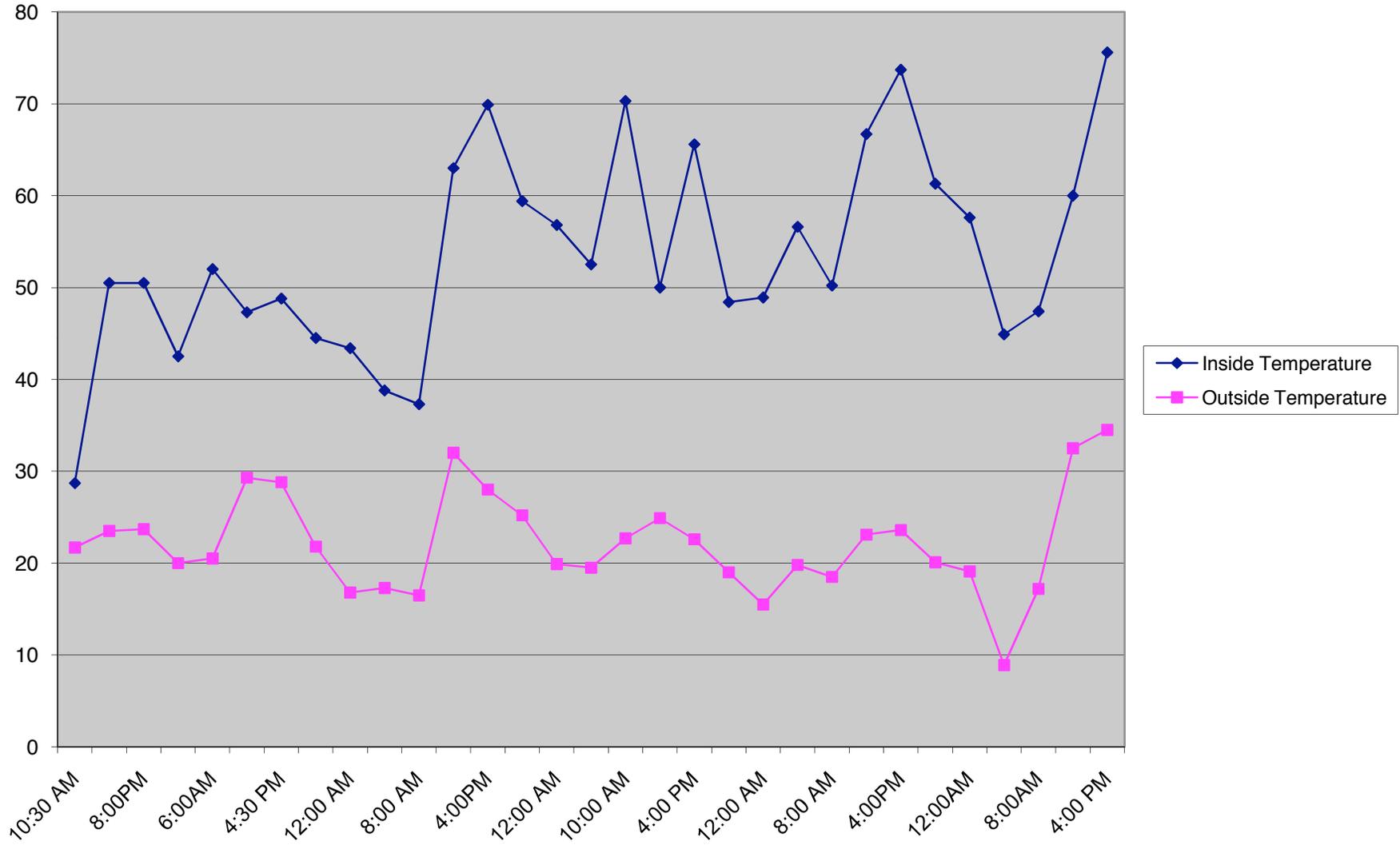
APPENDIX

Figure 2--Maxwell's Huts

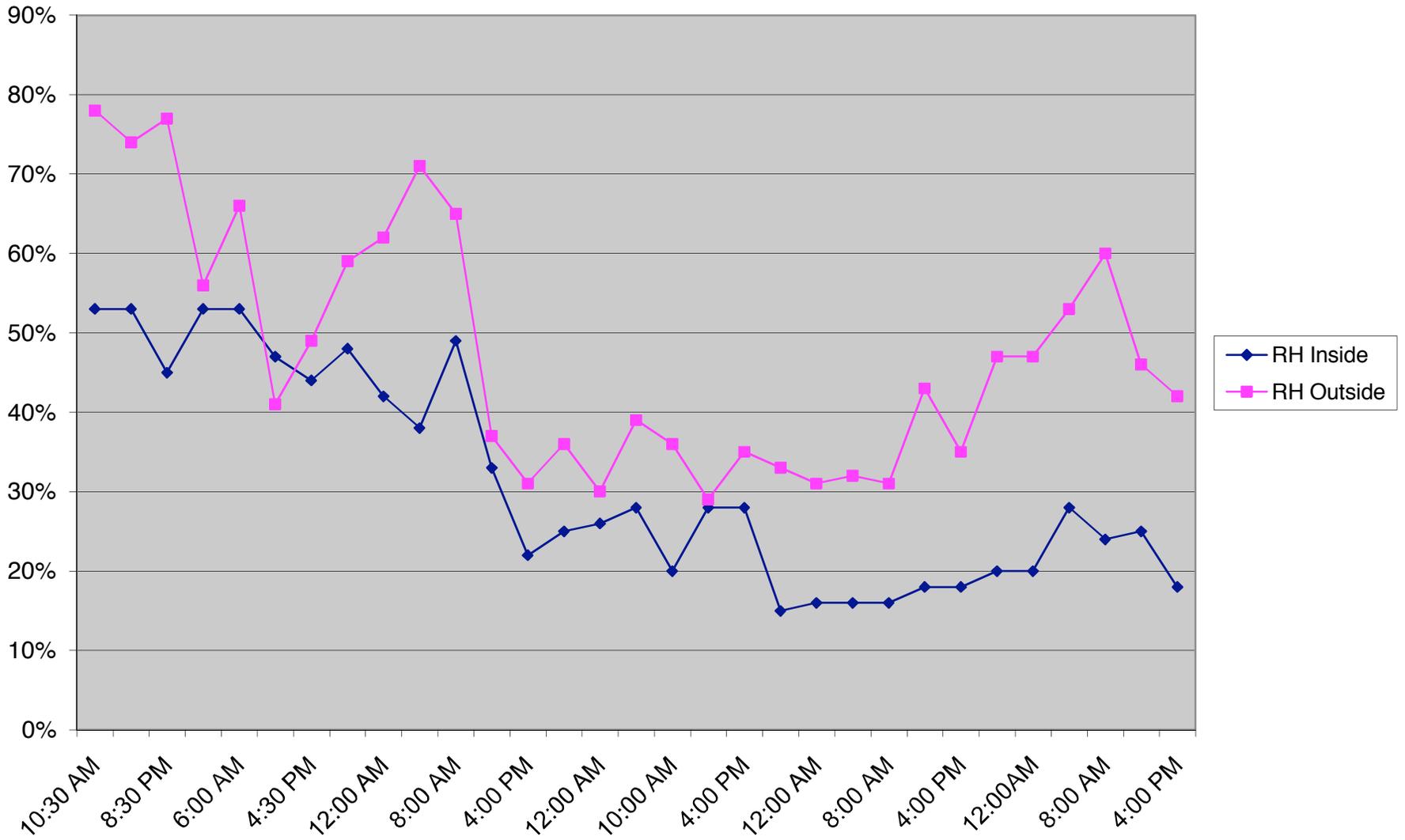


hut activities last 4 hours		# logs used last 4 hours		hut activities 5 min prior to measurements							
Hut Empty 2 PM - 4 PM		Whatever Mags used to re-stoke fire 2 PM		Hut Crew Assembled Tom M., Bob K., G.M. Brought in Gear							
inside conditions											
time	ambient temp	rh	bunk EFU	EFL	WBU	WBL	log EFM	WBM	soil EF	WB	
4:30 PM	48.8	44 %	54.8	$\frac{26.4}{52.3}$	$\frac{35.8}{49.5}$	47.6	46.2	30.2	31.6	32.6	
outside conditions											
general weather			ambient temp		rh		wind speed		soil temp		
Sunny, Breezy			28.8		49%		Max 8.8 Av. .7		34.		
hut activities 5 minutes after measurements											
Tom Mck., Bob K Commenced Cooking											
hut activities last 4 hours		# logs used last 4 hours		hut activities 5 min prior to meas.							
Cooked, Ate Talked		= 8 tot.		were cleaning up Put stuff away							
inside conditions											
time	ambient temp	rh	bunk EFU	EFL	WBU	WBL	log EFM	WBM	soil EF	WB	
8:30 PM	44.5	48 %	44.7	$\frac{22.3}{44.1}$	$\frac{24.5}{41.6}$	39.9	44.6	34.9	33.8	35.7	
outside conditions											
general weather			ambient temp		rh		wind speed		soil temp		
Clear Sky, Stars Not as Breezy			21.8		59%		Max 4.8 Av .5		34.2		
hut activities 5 minutes after measurements											
Tom Mck. Packed Up Left, Bob K Hung Out, G.M.											
notes		readings should be taken at 8 a.m., 12 p.m., 4 p.m., 8 p.m., 12 a.m. and 4 a.m.									
Wind speed outside measured for 2 min, then record Max. + Av.											

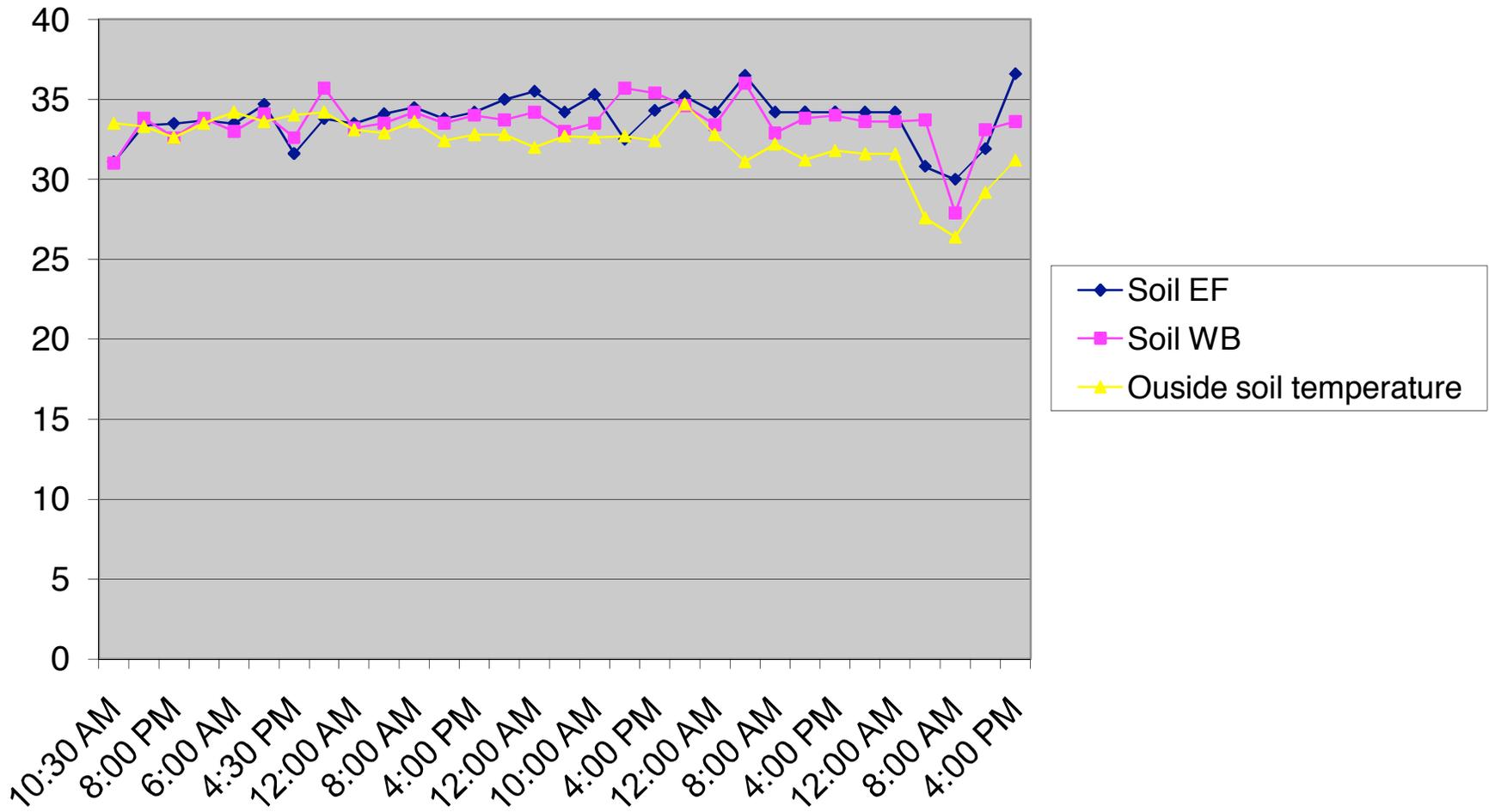
Ambient Temperature Inside Versus Outside



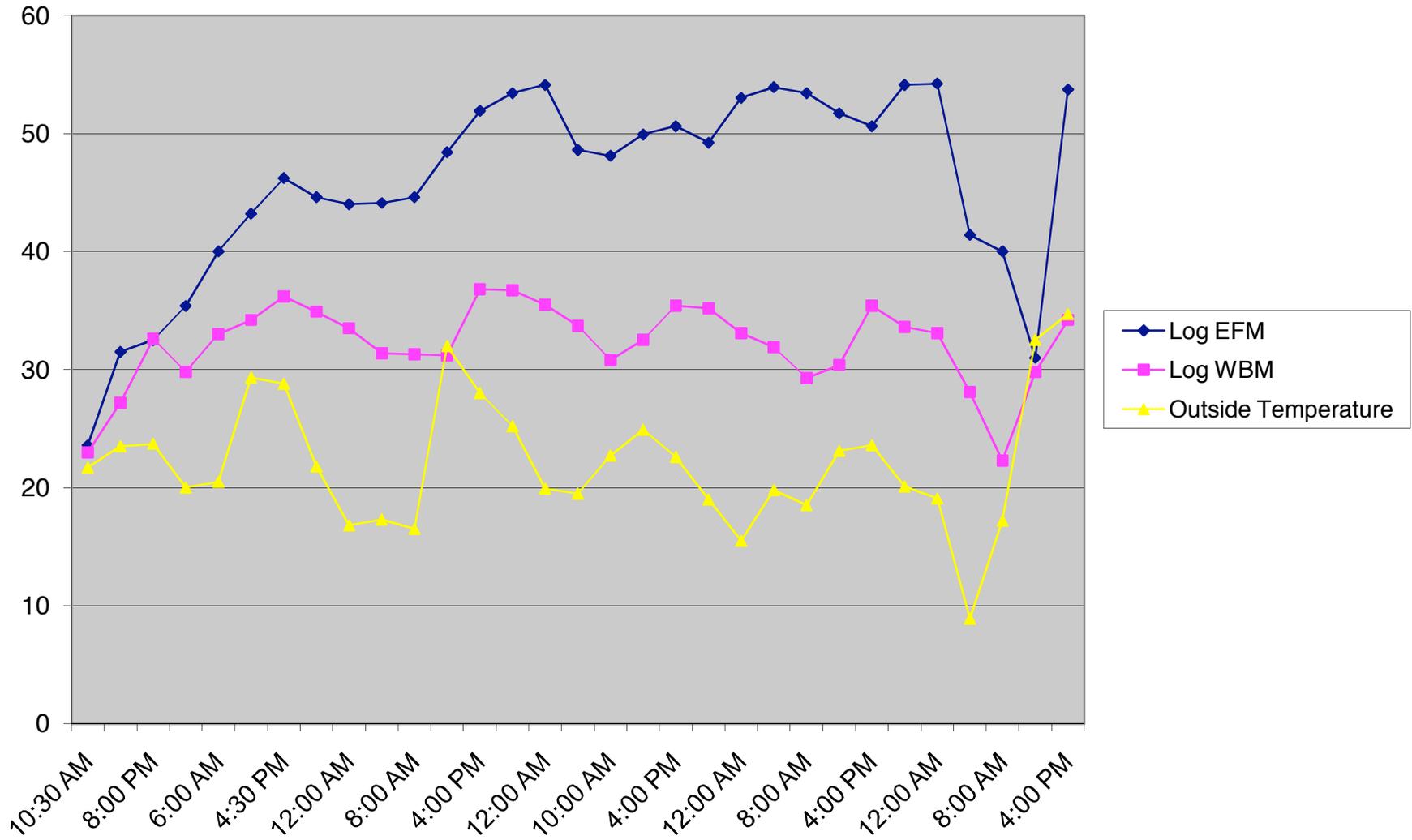
RH Inside versus Outside



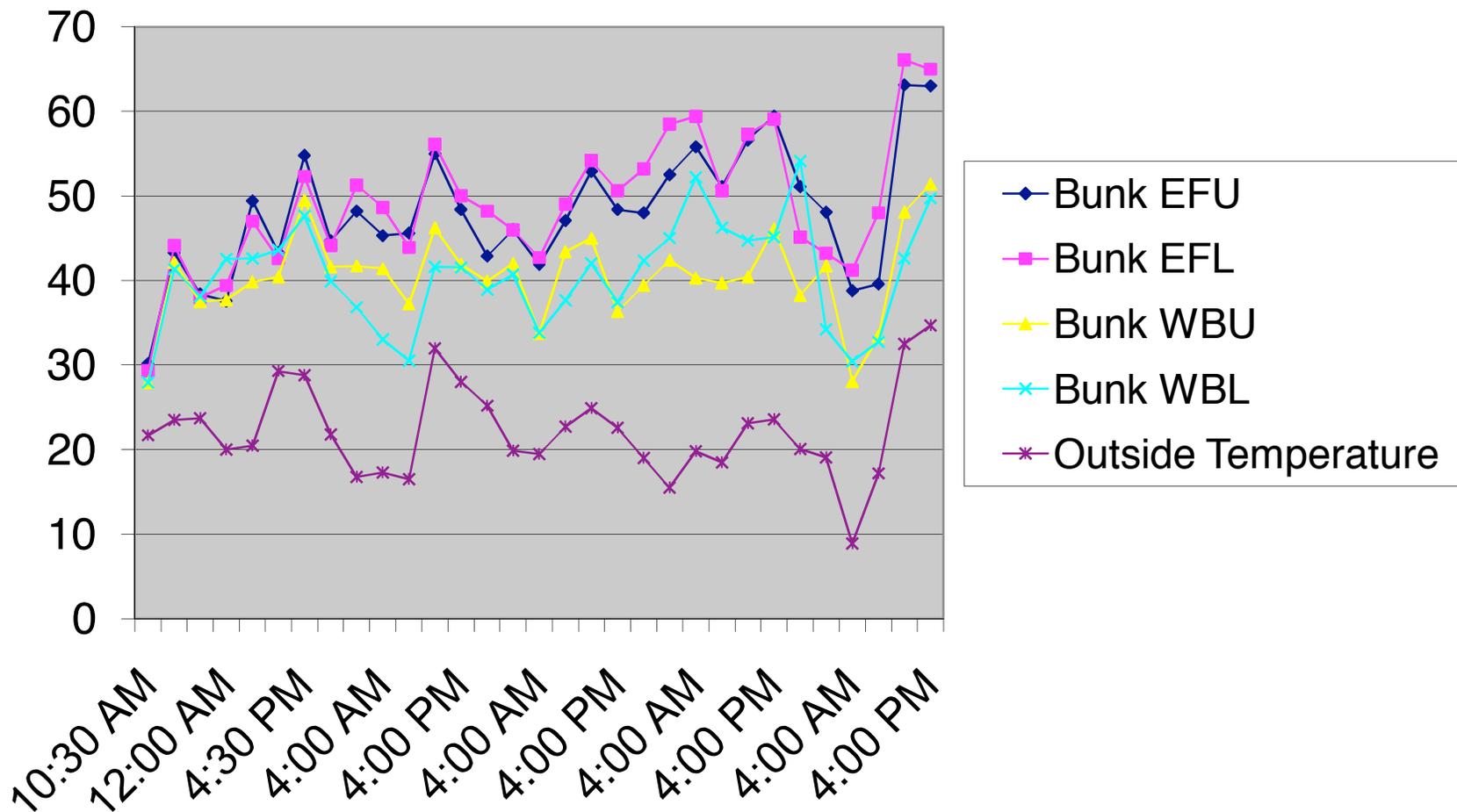
Temperature of the Soil Inside Versus Outside



Temperature Log Versus Outside



Temperature Bunks Versus Outside



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