The Fresno City Fire & Rescue Thermal Rehabilitation Study

The following document has the results of a test that was conducted and authorized by Daniel Perkins, Operations Battalion Chief for Fresno Fire & Rescue, Fresno, California from Monday, June 12th through Friday, June 16, 2017.

It was designed to determine the efficacy of the Polar Breeze® machine, manufactured by Statim Technologies, LLC in Clearwater, Florida against two well established first responder thermal rehab modalities: a misting fan and a cooling chair.

The **Polar Breeze®** machine utilized its two different functions: cooling with a hose directed to various parts of the body; and cooling with the Polar Breeze® hood (which is attached to a hose and cools the entire head, neck, 100% of the lung surface area and approximately 45% of the skin surface area of the body).

The **Misting Fan**, sprays its watered mist on the individual in direct proportion to its proximity of the individual and is effective to the degree that it touches the skin surface of the individual.

The **Cooling Chair** used, was the type that cooled 4% of the skin surface of each arm with cold water from the finger tips to the elbow.

Table of Contents

Fresno Study Summarization

Subject: The Fresno City Fire Rescue Thermal Rehabilitation Study

Now that I have had a chance to examine the data and speak with Dr. Reich, I can better summarize results from the data of 6/12-16/2017 at the Fresno testing center.

The two most useful data segments from the Fresno Study were the ALL DATA sheet and the HIGH TEMP DATA sheet. The remainder are just basic ranging data that show no other non-random data. As such (though they occupy an additional 63 pages of data).

Dr. Reich's graphs of the data are quite interesting. He separately graphed the total data and the 'High Heat' data where the reported Heat Index was 90°F. or above.

This data separation was done because the higher the Heat Index, the more difficult it is (and the longer it takes) to thermally rehabilitate a person undergoing severe physical exercise in critically hot conditions, such as a firefighter exiting fire suppression duty.

Some of the temperature data seemed unbelievable, such as subnormal temperatures in firefighters exiting their exercise in full bunker gear and SCBA apparatus. Certain temperatures were not consistent with consciousness, such as a temperature of 89.0°F. Some were not consistent with life, such as a temperature of 78.6°F.

But these were the outliers, and such inconsistent data-points show up and are expected in any well-conducted study such as this. Such are the limitations of human beings and our test equipment. But because so many were reported as having normal or subnormal temperatures (98.6°F. or below) when they should have been quite hot, Dr. Reich reported an ALL DATA set (with the outliers reported), and a HIGH HEAT DATA set without the outlier data points.

The results ranged from quite interesting to exciting.

As working firefighters exit a hot scenario, you expect them to have blood pressures and heart rates well above normal. Increased pulse and blood pressure pushes increased blood flow through to the skin for sweating to cool

the body. Diastolic blood pressures are usually initially elevated as this further increases skin blood flow and promotes sweating, thereby cooling the skin surface more effectively. Sweating, in turn, cools the skin blood flow and then returns that cooled blood flow, via the blood vessels, to the core, thereby cooling the body core as well. This is how sweating cools the body in hyperthermia.

Temperatures, whether Tympanic Membrane (TM), rectal, esophageal, skin, or invasive sinus, should be elevated after exercise. Bunker gear and SCBA masks, due to their inhibition of effective sweating and cooling, render the skin incapable of effectively dumping heat. The more effective the Thermal Rehabilitation, the more rapid the dumping of body heat, resulting in a return to normal body temperature under normal body thermoregulation.

Looking at ALL DATA set graphs, you note the greatest drop in body temperature comes from the Polar Breeze® *Hood* data with a 2°F. drop to normal 98°F. in 5 minutes. Cooling chairs were slightly slower in this overall data, with Polar Breeze® *Tube* data third. The cooling chairs rating so highly is strange because, even with both forearms immersed in cool to cold water, that is only 9% of body surface area (BSA) being cooled. Cooling the head, neck, chest, and back with the Polar Breeze® *Tube* accounts for 28% of BSA and 45% of all cooling through the skin, with a much colder and more effective airstream for cooling the skin.

But when you examine the HIGH HEAT DATA, the difference becomes clear. Polar Breeze® *Hood* dropped temperature 3°F. to normal 98°F. in 5 minutes. The body temperature increase at the 10-minute mark indicates return of normal body thermoregulation. This is consistent with the average of at least a 1°F. drop every 2 minutes that we had observed in previous trials and demonstrations in other venues in Florida and the Southeast. Polar Breeze® *Tube* data also exhibits this return to autoregulation by 10 minutes, but inexplicably these firefighters were reported as having initial temperatures at 98.6°F. (normal) upon entering Rehab. I suspect this was initial TM temperatures being improperly taken, such as recording the ear canal instead of the TM.

Cabanac & Caputa (1979) first noted evidence of *selective brain cooling* in humans undergoing hyperthermia. This is the body's effort to keep the brain and its anterior hypothalamus cool enough to continue to effectively regulate body temperature. This mechanism completely

fails with the onset of *heatstroke*. Pulse, per Cabanac & Caputa, monitors brain temperature. The higher the pulse, the hotter the brain and the greater the heat stress.

Note: *Heatstroke* itself appears to be caused by a combination of dehydration (loss of body water available for sweating) and loss of anterior hypothalamus control of thermoregulation.

Therefore, *pulse* is a critical assessment of heat stress in the human body. Resolution of pulse towards normal monitors the resolution of body heat stress in humans.

In the HIGH HEAT DATA, the greatest decline in pulse rate was again the Polar Breeze® *Hood* data line. Second was a tie between the Polar Breeze® *Tube* data and the CERT data, a tie statistically because the *Tube* data started with higher pulse rates.

Thus, so far, the best Thermal Rehabilitation method appears to be the Polar Breeze® *Hood* with the Polar Breeze® *Tube* coming in second. This is consistent with the known thermal physiology data amassed over the last 40 years. This data notes the greatest heat loss from the body is through the scalp, face, and neck followed by the upper chest and back (28% of BSA, 45% of all heat loss). This is easy to confirm clinically as hyperthermic exercising men and women tend to sweat most in these areas.

Also noted was that the greater the temperature gradient between hyperthermic body temperature and the Rehab environment, the faster and greater will be the heat loss from the body. Thus, the Polar Breeze® *Hood* should be the most effective Thermal Rehabilitation method as it cools the scalp, face, neck, upper chest and back, especially when the Heat Index approaches or exceeds 90°F.

The effectiveness of Polar Breeze® is further borne out by other measurements, such as the Mean Arterial Pressure (MAP), a synthesis of systolic and diastolic pressure that is proportional to the Cardiac Output or forward blood flow from the heart.

The higher the heat stress, the more the heart pumps out blood to the skin to cool it, and thereby decreases total body heat and especially brain temperature. As total body heat and brain temperature decrease, so should the MAP. Thus, tracking MAP is also an indirect measure of body thermal stress. As MAP takes systolic and diastolic

pressures into consideration, it is an easier measure to track thermal stress over systolic/diastolic pressures.

Examination of the HIGH HEAT DATA shows the greatest drop in MAP with the Polar Breeze® *Hood* and comes at the 5-minute mark, as a result of the initial rapid drop of body and brain temperature. There is an excessive adjustment climb (as 'thermal reset' phenomenon occurs) at the 10-minute mark before dropping down to normal rates at the 20-minute mark and full thermal rehabilitation. The MAP curve is delayed 5-minutes for the Polar Breeze® *Tube* data before similar thermal reset and accommodation to normal occurs. The other cooling methods could not return normal MAP data within the 20-minute recorded data period.

Unexpectedly, the **Pulse Oximetry** (SpO_2) slope data gives some supporting evidence of *Thermal Hyperpnea* (see the attached monograph for explanation of this) in humans, seen better in the HIGH HEAT DATA. We expect firefighters, entering Thermal Rehabilitation, to have physical exhaustion and their metabolic demand to have exceeded their oxygen delivery through the lungs, This results in lower SpO2 values which resolve over the period of Thermal Rehabilitation.

However, the slope of the SpO2 resolution curves appears to indicate the Polar Breeze hood may be increasing the rate of this SpO2 resolution, which could be construed as evidence of *Thermal Hyperpnea*.

Thermal Hyperpnea means using the lungs to cool the bloodstream and thereby cool the core body directly. This is the primary means of body cooling in mammals without sweat glands such as dogs and cats. Here ambient air, below body temperature, is breathed into the lungs where that cooler air is separated from the capillaries of the bloodstream only by the one-cell thickness of the alveolar air-sacs. As oxygen is taken into the bloodstream and carbon dioxide exhaled, bloodstream heat is also exhaled with the carbon dioxide in normal respiration. This is known as mechanism in mammals, but one segment of the Thermal Physiology community asserts this does not occur in humans.

However, the Resuscitation Physiology community recently has found conflicting data that supports Thermal Hyperpnea in humans. The outcome of

this debate remains unsettled at the time of this writing.

The increased rate of SpO2 rise with the Polar Breeze hood could indicate more effective cooling through the lung may be occurring, and this would support the evidence for *Thermal Hyperpnea* in humans.

The limited numbers of participants in the HIGH HEAT data set prevents power necessary for a statistically significant result. However, the slope of the Polar Breeze data line over other Rehab modalities could represent actual evidence of *Thermal Hyperpnea* in hyperthermic human field studies for the first time

A 6-foot male at 170 pounds has a body surface area (BSA) of ~2.0m^2. Yet this same individual has a lung surface area (LSA) of 118m^2 (+/- 11m^2). That means this 6-foot individual has ~59x the lung surface area (LSA) as body surface area (BSA). Blood vessels in the skin must contend with fat in the skin to dump their body heat as cooling sweat on the skin, and work that cooled blood back into the core to cool the body and the brain. Cooling through the lung hits the capillary blood vessels through only one layer of cells in the alveolus without any insulating fat to hold heat within the blood vessels. Therefore, cooling through the lung should be efficient in hyperthermic individuals needing to rid themselves of excess body heat. Further studies will look more closely at this possibility of Thermal Hyperpnea in hyperthermic humans as a mechanism of body heat reduction in extreme hyperthermia. A study is slated for trial shortly that will address this mechanism directly and hopefully will be able to deliver statistically significant results and a possible answer to the question.

Basic Burn Medicine mandates burn damage is a function of temperature *and time*. A burning acetylene torch (>6000°F.) does little damage to the human hand *IF* that hand is flashed through the aurora of that flame in a fraction of a second (I have inadvertently done that, but I do not recommend it). Yet low-grade heat of 130°F. can do great contact damage to the human skin (second-, even third-degree burns) if left in contact with that skin for a long enough period of time. Thus, thermal damage is a consequence of *temperature* and *time*. Essential to treatment is the removal of the thermally stressing cause with return to normal temperature of that body part, *including the entire body*.

By extension, it makes sense when the body is stressed by hyperthermic conditions, the more rapid and effective the elimination of that body/brain hyperthermia, the less will be the damage done by that hyperthermia.

Firefighters suffer increased rates of cardiovascular disease compared to the average population. Part of the cause of this increase has been deemed the severe hyperthermia firefighters suffer in fire suppression work. Anything that can rapidly and more effectively return that firefighter to normal body temperature should decrease his overall thermal stress and thereby the cardiovascular stress that leads to cardiovascular disease.

In this respect, the results of this study indicate the Polar Breeze® device (*Hood* more so than *Tubes*) is able to accomplish this return of body temperature to normal far more efficiently and effectively than the other Thermal Rehabilitation methods against which it was pitted in these trials. The claim of reducing TM temperature 1°F. every 2 minutes appears substantiated.

In Summary:

1. Temperature data supports Polar Breeze® *Hood* as the most rapid and efficient of any of the Thermal Rehabilitation methods of this study. Both the ALL DATA and the HIGH HEAT DATA sets support the decrease of TM temperature1°F. every 2 minutes or faster.

2. The second most efficient Thermal Rehabilitation method was Polar Breeze® *Tubes*.

3. Blood pressure Mean Arterial Pressure and pulse rate data also supports Polar Breeze® *Hood* (rather than *Tubes)* as being the most effective of Thermal Rehabilitation methods studied.

4. Pulse Oximetry (SpO_2) data shows unexpected organization consistent with Thermal Hyperpnea in humans.
I must thank Daniel Perkins, Operations Battalion Chief for Fresno Fire and Rescue, and the Fresno F/R for this opportunity to inspect and analyze its data. The SpO_2 data was quite a surprise. The insights I have gathered in this analysis I will use in designing our next study of Thermal Rehabilitation in firefighters, and I believe that study will be improved because of your input.

Thank you again.

Ralf W. Blackstone, MD

The Science of Polar Breeze®

A Simplified Explanation of the Science Behind Polar Breeze®

(For more in-depth data, please refer to *Science Behind Polar Breeze®*)

Ralf W. Blackstone, MD, DABA, FACPM, FACEP *ret.*

Polar Breeze® is a micro environmental air-chiller, a new type of device derived from the technology of air-conditioners, but able to cool its limited airstream more than twice as cold as any air-conditioner, and it works outdoors!

Polar Breeze®'s airstream is too limited to cool even a very small room effectively, but is able to cool its specially designed hoods 30°F. or more from the ambient air surrounding it. In 90°F. heat, it produces a cool airstream of 60°F. or even lower (dependent upon humidity). This means someone sweating in 90°F. heat can suddenly be made comfortable in this 60°F. hood.

Why is that important?

Two leading physiologists in the 1970's (Cabanac & Caputa[1]), building upon the work of earlier researchers, were the first to show the body tries to cool the brain separately from the rest of the body in hot conditions. It does this by flushing hot blood from the brain to the skin of the head. The skin blood vessels of the scalp, face, neck, and upper chest have only dilating capacity with almost no constrictive capacity. This means the scalp, face, neck, and upper chest can dump massive amounts of body heat, thereby cooling the brain.

Thus, hot blood from the brain is flushed to the skin of the scalp, face, neck, and upper chest where, like a radiator, it is cooled by sweat and evaporation. This cooled venous blood then returns to the brain, cooling it directly and lowering brain temperature. Though the head and neck comprise less than 10% of the body surface area, this mechanism can account for 50% of body heat lost during exercise.

It is cooling the brain that is important to prevent thermal stress illness, not the body. The hypothalamus (a structure behind the

[1] Cabanac M, Caputa M, "Open Loop Increase in Trunk Temperature Produced by Face Cooling in Working Humans", 1979, Journal of Physiology **289**:163-174.

eyes at the base of the brain) is the center of body heat regulation. When it gets too hot and the person gets dehydrated, the hypothalamus may cease to function properly, body heat regulation is lost, and heat stroke can follow. This is why cooling the brain and hydrating regularly with electrolyte-containing fluids (like Gatorade) is so important.

Thus, cooling the head, face, neck, and upper chest with Polar Breeze allows the body to dump much more body heat during exercise in hot conditions. In turn, this helps keep the brain and its hypothalamus cooler and in control of body heat while also giving greater relief from thermal stress. People who have used Polar Breeze® report much greater relief from overheated stress. Vital signs taken during this time reveal a much greater drop in pulse rate and blood pressure over other types of Thermal Rehab methods. **Tympanic membrane (TM)** temperatures with Polar Breeze® have shown an average drop of 1°F. every 2 minutes.

Cabanac & Caputa[1] were also the first to point out TM-temperature is very different from core body temperatures, such as rectal temperature. But TM-temperature *directly* reflects *brain*, not *core body* temperature, thus TM is the more important temperature to know when assessing heat stress and possible heat injury. Heart, lungs, liver, kidneys, and gut can withstand much higher temperatures, but the brain is by far the most sensitive of these to excess heat. It has even been shown[2] excess heat, well below the level of heat stress injury, impairs the ability to think and reason. As such, the TM temperature is of prime importance in assessing the fitness of someone returning to work in heat stress conditions.

Note that currently the TM is used to assess brain and hypothalamic temperatures. But the TM temperature is fraught with problems. Ear wax can prevent accurate temperatures unless manually removed. Malposition of the TM thermometer can read the ear canal instead of the TM, causing inaccuracies. In short, the TM is not the ideal method of determining brain and hypothalamic temperature.

Shortly, the **Brain Tunnel Temperature (BTT)** should become available. Being developed by Abreu and

[2] Gaoua N, Racinais S, Grantham J, Massioui F, "Alteration in Cognitive Performance during Passive Hyperthermia are Task Dependent", 2011, International Journal of Hyperthermia 27(1):1-9.

Silverman at Yale University Medical School, this BTT device directly reads hypothalamic temperature with an infra-red sensor through the eyelid, through the back of the orbit, right to the hypothalamus itself! This should give the most accurate noninvasive hypothalamic temperatures available and hopefully will be on the market in the near future. As such, it should provide the most accurate hypothalamic temperatures to Health and Safety Officers, coaches, and others monitoring the need for safety of their exercising hyperthermic charges.

Even beyond cooling of the head, neck, and upper chest to lower brain temperature, Polar Breeze® also provides that cooled airstream to the lung where it cools the lung and its blood supply directly. As the lung has ~59x the surface area of the body and without insulating fat as in the skin, the lung would seem to be the ideal means of cooling the core body temperature and, subsequently, the brain. Yet many researchers[3,4] had concluded this does not occur in humans.

But, more recently, other researchers[5,6,7] have disagreed with those older conclusions with convincing new evidence that cooling through the lung *does* cool the bloodstream directly and efficiently. While this is an ongoing debate in the physiology world, Polar Breeze® is providing this lung (and thereby core body) cooling now with its Polar Breeze® hood. This hood contains the cool air around the head and neck before it is breathed into the lungs to cool the bloodstream directly. We believe this increase in cooling efficiency through the lung is at the heart of Polar Breeze®'s remarkable performance bringing down firefighter temperatures 1°F. every 2 minutes.

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[3] McFadden E, Pichurko B, "Intraairway Thermal Profiles during Exercise and Hyperventilation in Normal Man", 1985, Journal of Clinical Investigations 76:1007-1010.

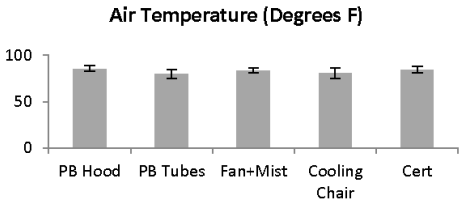
[4] McFadden E, Pichurko B, Bowman F, Ingenito E, Burns S, Dowling N, Solway J, "Thermal Mapping of the Airways in Humans", 1985, Journal of Applied Physiology **58**(2):564-570.

[5] White MD, Cabanac M, "Exercise hyperpnea and Hyperthermia in Humans", 1996, Journal of Applied Physiology **81**(3):1249-1254.

[6] Mariak Z, White MD, Lyson T, Lewko J, "Tympanic Temperature Reflects Intracranial Temperature Changes in Humans", 2003, Pflugers Archive- European Journal of Physiology **446**:279-284.

[7] Kumar MM, Goldberg AD, Kashiouris M, et. al., "Transpulmonary Hypothermia: a Novel Method of Rapid Brain Cooling through Augmented Heat Extraction from the Lungs", 2014, Resuscitation **85**(10) 1405-1410.

All Data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PB Tubes
Fan+Mist
Cooling Chair
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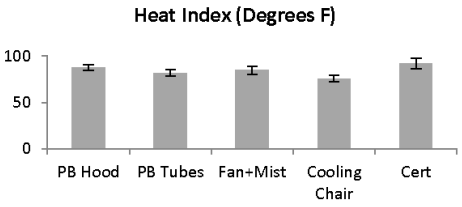
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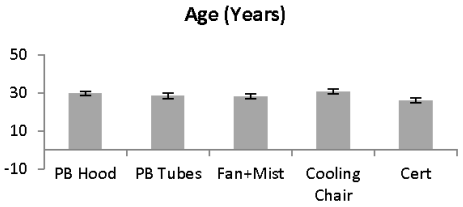
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Fan+Mist
Cooling Chair
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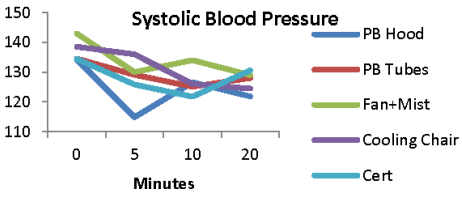
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Fan+Mist
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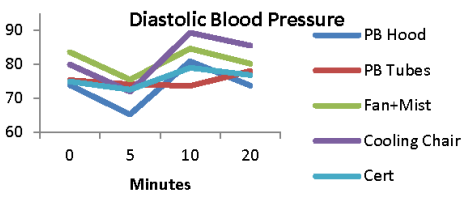
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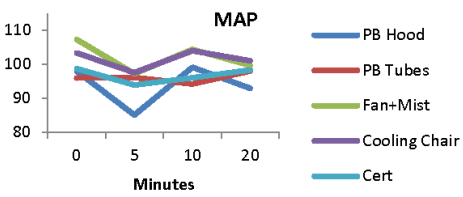
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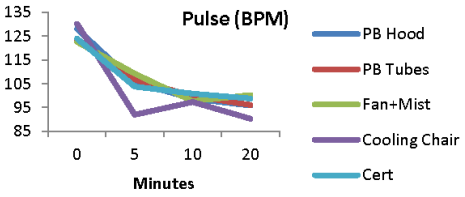
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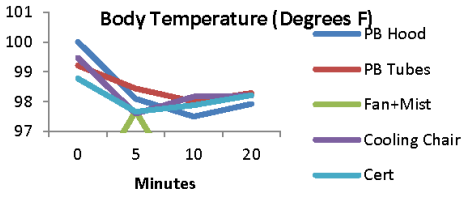
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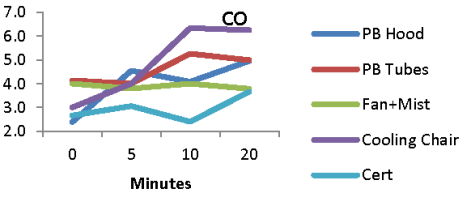
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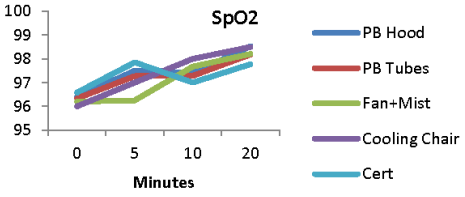
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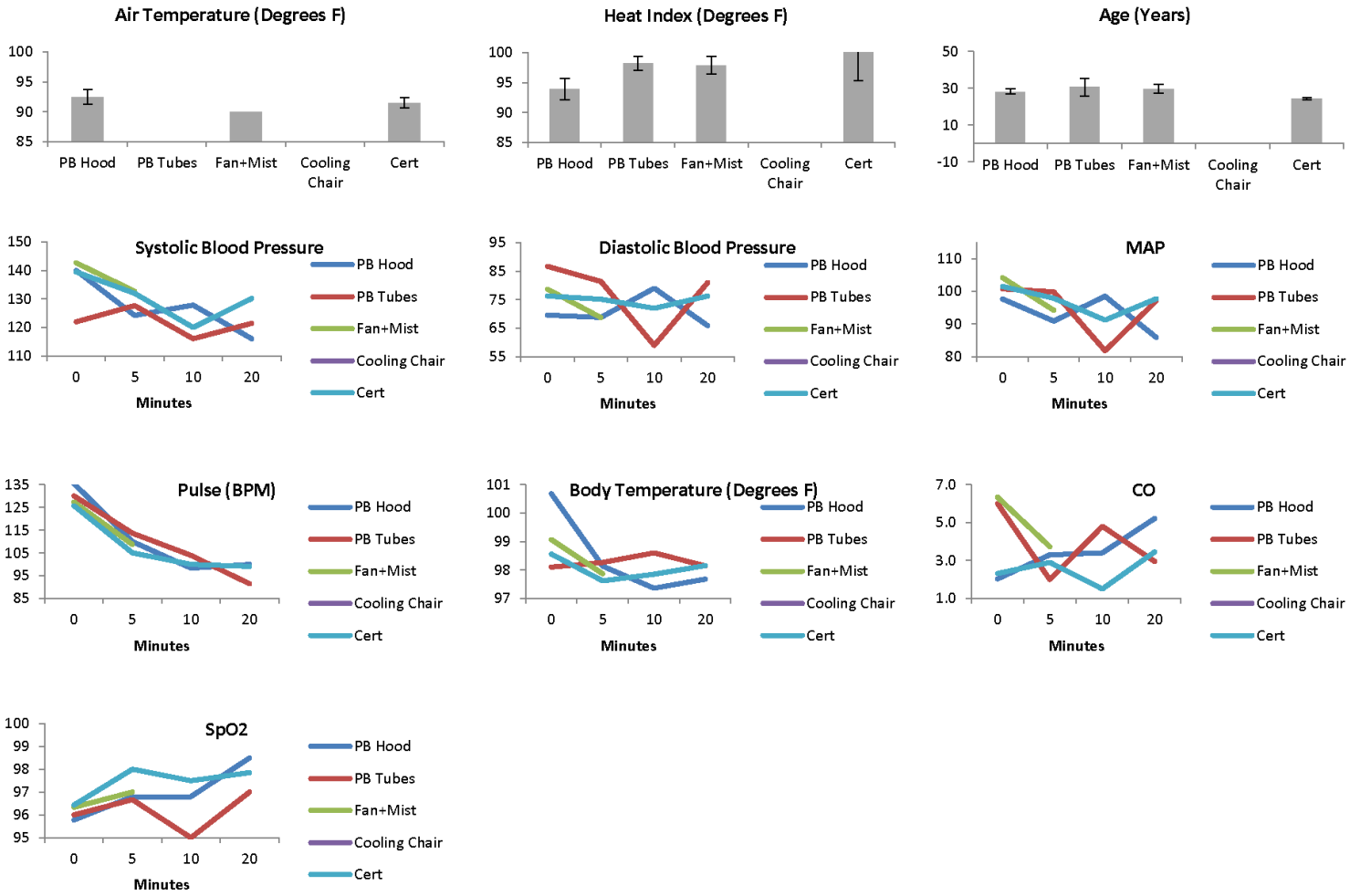
High Heat Data



There are 62 pages of additional data that are available upon request - (It's called Fresno - Variable Data Distribution).