The Charcoal Vest: A Hypothermia Treatment Device for Search and Rescue Teams

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Find the Heat

For years, I have been searching for an effective hypothermia rewarming device for use in mountain and cave rescue – and I think I've finally found one that works well enough to satisfy me. It is the only field-portable device I've seen that actually delivers enough heat to rewarm someone in the field. This baby delivers 100 watts of power for 8 hours, has an overhead-cam V-8… oops, sorry, got carried away there. But it really **does** put out more heat than anything else I've carried in the field.

It's officially called a HeatPac™ (Heatpac Personal Heater HPU 33400 to be precise), but a more generic term that's commonly used is "charcoal vest." The device has tubes that wrap around the chest, and it burns a charcoal briquet to make heat. The current design doesn't look much like a vest, but the earlier ones had wide flat "straps" that wrapped around the chest, so it used to look a bit more vest-like (a good imagination also helps). Actually, if you take a look at Figure 1, you may agree with me that it looks more like a cross between a cyber-punk military elephant and an olive-drab Portuguese man-of-war.

The device was developed by ITT for the Norwegian army, is marketed in Scandinavia by Alcatel STK, and is imported into the U.S. as well (see end of article for availability). Unfortunately, the civilian version of the device is distributed with a single-page instruction sheet that is quite skimpy, which is the main reason I'm writing this article. A good understanding of the device, its characteristics and its limitations will, I hope, make it more widely used in search and rescue operations.

My first exposure to the device was many years ago in the White Mountains of New Hampshire. An ice climber had fallen in Huntington Ravine, and was being carried out in a Stokes litter. The temperature was around zero Fahrenheit, and he had been thoroughly chilled if not actually hypothermic. But by the time he reached the road at Pinkham Notch, he'd demanded that the sleeping bag be opened because he was too hot from the charcoal vest!

The major theoretical problem with field-portable rewarming devices is the heat-to-weight ratio. Most devices – heat packs, inhalation rewarming devices, and the like – only produce a small amount of heat for their weight. Energy can be carried in the form of electricity in batteries – but even lightweight, high-energy lithium cells don't provide much heat per ounce. Energy can be carried in the form of chemicals that dissolve in water and release heat (one type of heat pack), or in the form of a saturated salt solution that crystallizes and releases heat (another type of heat pack). Both of these types of heat packs deliver a lot of heat, but only for a short time, and they're pretty heavy. A third type of heat pack has powdered iron that oxidizes (burns) slowly, and are a lot lighter than the first two types of heat pack, but still don't produce a lot of heat for their weight.

Barring a portable cold-fusion device, the most effective device is going to be something that burns; oxidation provides a lot of heat from relatively light fuel. The iron-oxidation heat packs are good. But, when the iron powder "burns" the product is rust — and iron and rust are relatively heavy "fuel" and "ash." It would be nice to have something lighter to burn.

The problem, of course, is that when most other materials burn, they produce not only heat but carbon dioxide and sometimes carbon monoxide. One way to get around the carbon monoxide problem is to use a catalyst to convert all the carbon monoxide to carbon dioxide, and there are several types of charcoal-burning and gas-burning heaters on the market that use such catalysts – but none of them except the charcoal vest are suitable for rewarming a patient in a litter.

A Hot Design

The design of the charcoal vest is simple but elegant. The device contains, within its sturdy outer plastic shell, a roughly 2"x4"x6" block of charcoal, encased in a metal shell, which burns at a rate controlled by the amount of air supplied to it. A fan blows air past the metal shell and out several tubes, which can be wrapped around the patient (these are the olive-drab "tentacles" in Figure 1). The fan also blows air into the burning charcoal inside the shell, and then out the exhaust tube (the black elephant-snout in Figure 1).

Over the Top

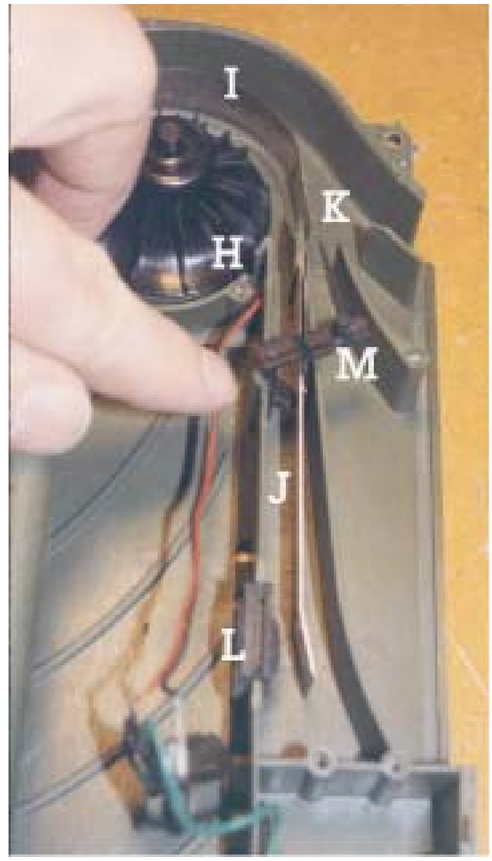
The top opens to allow access to the battery and charcoal-box compartments (Figure 2). The hinge is sturdy, and the clasp that holds it closed is likewise of heavy-duty construction. From my cave rescue experience, I hesitate to say that any piece of engineering is cave-***proof*** but this design certainly looks highly cave-resistant. If you take out the charcoal box, and look deep within the compartment in which it sits, you'll see the catalyst grid there (Figure 3). The one-page instruction sheet notes that you can snag it out with a piece of wire with a hook on the end, and replace it as needed. However, it doesn't really tell you how to tell when it needs replacement.

Air Flow

The fan is driven by a single D-size alkaline cell. I suppose you could use a "regular" carbon-zinc cell, as it will be kept warm by the device, but the alkaline will last longer than a carbon-zinc even when kept warm. The battery ***has*** to be put in the correct way, or the air will blow through the unit backwards — and the exhaust won't go through the catalyst, thus risking possible carbon monoxide production. A simple crossover diode circuit would prevent this problem and allow the battery to be inserted either way without risk of carbon monoxide production — which would be a simple but important improvement to the device. Indeed, this was the one major reason why the Heatpac was given an unfavorable rating in one article in the medical literature.[1] However, the voltage drop across the diodes would mean that there isn't enough voltage to run the fan, unless you add another battery… sigh. Maybe this "solution" introduces more problems than it solves. There is a diagram on the outside of the compartment (Figure 4) that indicates which way to insert the battery, but I think training users about the importance of battery polarity will be critical.

The airflow within the device is fascinating. I took it down to my workbench and took it apart (a simple matter of removing a few screws) to see how it works. If you look at Figure 1, you can see the slits next to the charcoal box where air enters the device. Now look at Figure 5, where the device is opened up like a clamshell. The air is warmed as it passes along the sides of the charcoal box (A), and then is drawn through a small slit into the fan itself. The next is a bit harder to imagine, but look at carefully at the grey line I've drawn at the top left of Figure 5 (marked B). The warm air that is sucked past the charcoal box and into the fan comes out and is directed in two directions. This top-left grey line indicates where the air exits to go into the "tentacles" and to warm your patient. The second grey line (C) shows where some of the air is directed into the charcoal box, then through it, then through a spiral metal around the fan, and finally out the "snout" (the black exhaust tube). You'll may have to use a little imagination for this to make sense — when the clamshell is folded back together, a little hole in the charcoal box fits (D) snugly up against a black rubber grommet (E) on the fan outflow box. If you also look at (F) you'll see a little piece of black plastic, which has a tiny black nubbin that sticks out through a curved hole in the case (G), and allows you to adjust the heat (see Figure 7 for an outside view of it).

As you can see, some of the fan's air is directed out the tentacles, and some through the charcoal box to make heat. How does it know how much air to blow which way? I took the cover off the fan outflow box to see. Look at Figure 6, where I've exposed the "artificial intelligence" unit of this device. It consists of what seem to be a bimetallic strip and some cleverly-designed air channels. (A bimetallic strip is made of two different types of metal - when warmed, one expands more than the other, causing the strip to bend.) First, note the small slit where the air is drawn into the fan (H). Next, note the bimetallic strip (I); when cold, it's tightly curled up against the fan, directing all the air



into the channel (J) leading to the charcoal box. When it starts up, all the air goes through the charcoal box to get it burning — which means rescuers should expect *no* heat out the "tentacles" for the first few minutes. Rescuers should also expect a fair bit of warmth and a smoke coming out of the elephant-proboscis-exhaust for those first few minutes, though once it's running, little if any smoke and only a little warmth come out through its nose. After it warms up, this strip uncurls and starts directing some warm air into the channels (K) leading to the "tentacles."

Pretty slick design, huh?

But now look carefully at where my finger is pointing. There's a little metal strip here, too, that partially blocks the air going through the rubber grommet (L) into the charcoal box. I'm not entirely sure, but I suspect this is also a bimetallic strip — it may serve as a "thermostat," cutting down the amount of air entering the charcoal box when it gets very hot.

To make things even more complicated, there's this little black plastic piece right at my fingertip (M). This connects to the outside of the box (Figure 7) where it serves as a high-low lever — by adjusting this up or down, you can increase or decrease the air going into the charcoal box, and increase or decrease the heat. Of course if you turn it up full blast, it won't run as long on a charcoal charge, but then even at full blast 200 Watts it lasts for 6 hours (20 hours at 50 Watts on low), and the charcoal charges are light, so you can easily carry a few extras.

A final interesting piece in this box — you can't see it very well in Figure 6, but it's at (F) — is something that turns off the fan when it gets too hot, a reasonable safety feature.

Practical Things

I said above that this device is reasonably cave-resistant (which means it's fine for almost any above-ground rescue), and it really doesn't need much if any protection — it can just be stuffed into a cave pack. However, I've found that this isn't true of the charcoal elements — though they are sealed in waterproof foil, this foil can easily be punctured, letting the charcoal get wet. And, the metal case around the charcoal can get so dented that you can't fit it into the charcoal vest.

There are two types of charcoal refills. The more expensive refills are prepackaged in an outer aluminum case, and have a fuse at one end, so that lighting them is easy. The cheaper kind is basically a brick of charcoal that you have to set on fire and, then insert in a metal case, and only then insert in the charcoal vest proper. The cheaper version may be applicable for ice fishing or other leisurely pursuits, but for search and rescue teams the fused refills are worth the cost.

Each of the fused charcoal refills that comes prepackaged with two matches and a small piece of match-striking paper at one end. Figure 8 shows condition of one of these after being carried through a cave for a few hours. So, it's best to put spare charcoal elements in a Pelican case or ammo box if you're taking them into a cave.

The prices in April 1997 when I ordered one were:

- Heatpac itself: $299.95
- Charcoal heater elements (about 12 hours each):
- With fuse for lighting: 7/case, $69/case
- Charcoal Element Metal Cover: $20
- Without fuse (requires above cover): 10/case, $63.33/case.

Charcoal vests are available in the U.S. from:
Attn: Bill Tashjian
Hawill's, Ltd.
P.O. Box 685
Westborough, MA 01581
(508) 366-7496
(508) 366-0211 (FAX)

And from:

Attn: George Zilahi
Emergco Technical Solutions
(604) 980-8411
1-800-980-8416
http://www.emergco.com

Using the charcoal vest in a tent or cave presents certain risks — if the battery is in wrong way around, you could get dangerous carbon monoxide levels. And, even if you have the battery in the right way around, it still uses oxygen and produces carbon dioxide. So, I think I'd only use it in a cave or tent that has good air circulation.

I can remember two problems that cropped up when using this device on a mock cave rescue — problems that prevented its use, but that can be easily overcome. First, rescuers started it up properly, but when after a minute there was a bit of smoke coming out the "nose" and no heat coming from the tentacles, decided that it didn't work and quit using it. Secondly, when they lit it up and put it on the patient with the smoke still coming out the "nose" the patient started panicking and thrust it away. Starting the unit in a large passage with good airflow, and letting it warm up for about five minutes before introducing it to the patient, should prevent both these problems. Once it warms up, there's a slight burning smell, but virtually no visible smoke, and the warmth of the device should make anyone who's cold snuggle right up to it. As with any warming device, though, you should not put the unit itself up against bare skin — it might get a bit too warm and cause burns. Having the device itself strapped to the outside of the packaging over the patient' s chest, with the exhaust "nose" directed away from the patient's face, but the "tentacles" inside the packaging, seems to work quite well.

Training Points

If your SAR team is thinking about using one of these devices, please take the time to train your members in its use. Note the copyright: it's OK to print off a copy of this document and give to each member. But also fire it up in a meeting and let everyone play with it during the meeting so they are comfortable with it and will be happy to fire it up and use it when needed — and can avoid the two problems noted above. During the training, emphasize the following critical points:

- Battery in the right way! Or you may get carbon monoxide. Just like we recommend that riggers have a second member check critical rigging, always have a second team member check to see that the D cell "button" is sticking up as shown in Figure 2 before operating the device.
- Expect a small amount of smoke and hot exhaust from the "nose" and no heat out the "tentacles" for the first 5-10 minutes.
- Adjust the lever to produce the desired amount of heat.

Conclusion

I think that, even given its expense, dangers and limitations, that, in both warmth per unit weight and ease of use, this is the best hypothermia rewarming device that a search and rescue team can get. I'd love to see a version with circuitry to allow battery insertion both ways, but I'm reasonably pleased with it the way it is. Until we have a cold-fusion-powered field-portable hot tub, or have a field-portable wrap-around radio wave rewarmer vest and can simply push the button for three minutes on high, this is the best we've got.

I welcome comments on the device, and will update and repost this article as I get new information. Updates will be announced on the wilderness-emergency-medicine Internet discussion list. (Check http://www.wemsi.org for more about this discussion list.) A copy of this article is posted at my personal website: http://www.pitt.edu/~kconover/

Reference

1. Sterba JA. Efficacy and safety of prehospital techniques to treat accidental hypothermia. J Emerg Med 1991; 20:896-901.