Let There Be Heat
Grant Tobin

Alright, let's talk about heat. This is intended to be a somewhat cohesive guide to answer various questions about these systems and where the technology currently stands. I would like to think of it as a Wiki but doubt I'll end up maintaining it that often. The opinions present below are written with an overhead environment in mind but apply to most use cases. I will inevitably miss a few of the Euro and Asia manufacturers. If this is received in a useful manner, I'll write one on lights. Thankfully, there's some overlap.

Cold sucks. At the same time, a heating system should not be the core of your exposure protection. When used properly, it improves comfort, dexterity, and safety. We will start by categorizing "heat" into two systems. The first are component based and are not self-contained. The second are fully integrated heat inside the suit (Thermalution, Venture, etc), or wholly self-contained.

Let us start with the component system. For long range diving, this is your only option. It consists of the following:

1) Battery
2) Voltage modulation
3) Battery to bulkhead connection
4) Drysuit bulkhead
5) Bulkhead to wearables connection
6) Wearables

<u>Battery</u>

Nearly everything purchased new these days will be using lithium-ion technology. Prior batteries used in packs have included sealed lead acid (SLA), nickel-metal hydride (NiMH), lithium iron phosphate (LiFe), lithium polymer (LiPo), and lithium ion (LiOn). To spare the progression and pros and cons of each, nearly everything in rechargeable batteries in the dive industry is Li-ion. A few things about Li-ion to note:

-Do not store them full
-Do not store them at hot temps.
-Depth of discharge impacts life. It is far better to use half a battery 100 times than to use a whole battery 50 times.
-Depending on temp, storage voltage, DoD, etc, batteries generally last ~300-500 cycles.
-Charge them the night before use.
-Do not use crappy chargers.

A Li-ion pack stored in your freezer (0 C) at 40% of its rated voltage decreases in capacity by ~2% a year. A Li-ion pack stored just over room temp (25 C) at 100% of its rated voltage loses capacity by north of 15% per year. A properly constructed pack has a Battery Management System (BMS) to prevent things like overcharging, too fast of charging, and severe DoD. Batteries aren't a "throwaway" item, so to speak, but they are a consumable. For life support equipment (scooter, lights, heat packs), I strongly recommend a burn test once-a-year. A well-designed pack will kick down voltage to prevent excessive discharge. Given this test, you can judge your thirds/halves/hours of use needed to maintain an appropriate safety margin. Li-ion cells exist largely between 3 and 4.2 V.

One carry-over from SLA and NiMH days is the standardization of 11.1V battery packs. Nearly every company other than UWLD uses three 3.7V nominal cells wired in series to achieve 11.1 (or 12) volts. Manufacturers then cluster these 3s packs in parallel to increase capacity. Bobby at UWLD uses 5s configurations, creating 18.5V packs. What difference does this make? A light or heat system plugged into a 11.1V battery pack that's drawing that voltage will decrease in output over the course of the discharge. Bobby steps down the 18.5V to 12V such that there is no change in light (or heat) output between start of discharge and end of discharge. Is this noticeable? Yeah, at least when you're diving with someone with a light that doesn't do this or if you don't have a thermocline. Bobby makes some great products. Does it matter? Maybe. Low draw on Bobby's batteries means increased life expectancy. This is another potential justification to use a larger than necessary pack if you are not using his stuff. Each cell within these packs has a capacity. What we

need to do is to turn this capacity into a functional number. That functional number is Watt Hours. Thankfully, it is not terribly difficult.

Watt Hours = Voltage * Ampere Hours

For a UWLD Tall Can, we take 18.5V * 8.7Ah and get a capacity of 160Wh.
For a Light Monkey 20Ah pack, we can take 11.1V * 20Ah. Technically there are two 2 10.4Ah batteries inside the can, so the calc is closer to 11.1*2*10.4 ~230Wh. It feels necessary to point out that LM uses aH rather than Ah and this bothers me greatly (sorry Corey/Joel/Mandy).

Keep this capacity number in mind and at the end of this, we will circle back and reference how many Wh we need. Where do you mount these (sometimes small, sometimes large) batteries? In backmount, I wear them on my right waist belt. One for light, one for heat. Some people mount them to their rebreathers, some to their backplate, others in weird spots (Hey Revo divers, a great way to fix your trim is to mount one in place of the weight holder on the top of the unit 😉). In sidemount, I stroke mount mine below my right bottle like a stage. Others will butt mount, waist mount, or even spine mount. Size of battery, % of dive wearing the battery, and accessibility to the switch/piezo button determines this location.

Example retail products calced in rough watt hours.
https://uwlightdude.com/product/battery-canister/ (54, 107, 160Wh)
http://extreme-exposure.com/explorer-heater-pack/ (100, 150Wh)
https://shop.lightmonkey.us/Heater-System-Batteries-and-Controllers-_c_49.html (115, 167, 230, 345Wh)
https://smart-tex.pl/en/product/battery-for-heating-diving-111v/ (150, 267Wh)
https://santidiving.com/battery-24ah,552,en (67, 267Wh)
https://trojandiving.pl/gb/strona-glowna/ (170, 300, 340, 450Wh)
https://san-diego-divers.com/products/dui-blue-heat-jumpsuit (160Wh)

The “Out” side of the battery is most often an E/O cord. It is named for the company that used to hold the patent. They kind of suck. The cable is trash, they corrode, and the cables not even technically designed to be plugged and unplugged underwater. Do not plug and unplug them if there’s current running through them. The pins and pin females corrode quite easily. Some DeOxIt and a hammer often helps. OCDA has standardized on a different connector (some Marshall variant), DUI uses a different connector, and I believe there’s one or two other weird ones in existence. If you are reading this, you are most likely to end up with an E/O.

https://shop.lightmonkey.us/4-EO-Cord-9mm-Underwater-Unplugable_p_99.html

The last point to discuss is that of UN 38.3. IATA prohibits batteries in excess of 160wH from commercial flight. This is why you cannot fly with massive Li-ion scooters. It is also why UWLD batteries are capped out at 160wH. 38.3 certification is a pricy process. Light Monkey has a 38.3 cert because their packs technically have separate batteries inside them. It is sort of a loophole.

https://www.batteryspace.com/prod-specs/UN_Test_Manual_Lithium_Battery_Requirements%206.pdf

Voltage Modulation
There are a few things to keep in mind when using heat. If you are diving in an overhead environment or riding the edge of NDLs, you really really do not want to let your body cool down as the end of dive or deco approaches. Put simply, cold reduces inert gas uptake and offgassing. Warm increases inert gas ongassing and offgassing. Cold beginnings to dives and warm ends to dives helps to minimize ongassing and maximize offgassing.

https://pubmed.ncbi.nlm.nih.gov/7222286/
https://pubmed.ncbi.nlm.nih.gov/26415074/
https://pubmed.ncbi.nlm.nih.gov/2800052/

Additionally, you do not want to rapidly increase thermal stress on the body. Going from approaching hypothermic to 100W of heat instantaneously is also bad idea. So now, depending on duration of your dives and the total W pumped into the suit, we need to find a way to regulate watts. I am broadly of the opinion that current regulation is necessary if you pump more than 20 or so watts into your suit. So how do we do it?

Most systems that allow this use pulse wave modulation (also known as pulse-duration-modulation). You can either integrate this into the head of the can (Light Monkey Pitkin head, UWLD heat controller, SmartTex thing, Trojan controller, DUI BlueHeat) or in line between the battery and the bulkhead (LM Pitkin Controller, Fathom Pitkin 2.5).

If you are only ever going to use your batter for heat, get it built in. If you have intentions of using the battery as an alternate light battery, you'll need to use it externally. You must not plug in your light E/O slug to your Pitkin/PDM'd E.O cable. Some manufacturers make dual outlet heads (e.g LM). You can have one side hardwired to a slug and a Pitkin built into the other, or normal E/O on both, or E/O light on one and E/O pitkin head on other. Bobby uses this ingenious stack cap system that means you don't have to pick and be "stuck."

Most work and regulate % output by interfacing with a mechanical switch or a Piezo switch. In LM case, the first switch to on is 100%, a double switch (off on off on) brings to 80%, a triple to 60%, and a quad to 30%. A reset to full is started with 10 seconds in the switch in the off position. The external LM controller has LED flash patterns. The internal LM controller does not. (https://shop.lightmonkey.us/Pitkin-Heater-Controller_p_200.html vs https://shop.lightmonkey.us/275-Lid-with-Pitkin-Heater-Controller_p_213.html). The UWLD version has a Piezo on the controller with LED indicating ring and button presses to change heat mode (https://uwlightdude.com/product/heat-controller/). I am not an expert in the offerings from most other manufacturers. The Fathom 2nd Gen Pitkin Controller is a compelling alternative to the LM version because of its size (https://www.facebook.com/FathomCCR/). You could also put one of these inside your drysuit but that will require some fun self-wiring and result in loss of LED visibility).

Drysuit Bulkhead

So now, we have a battery, perhaps a Pitkin, and an E/O cable ready and charged to warm one up. But how do we get from outside the suit E/O to inside the suit garments?

There are three options:
1) Combination Inflator
2) Stacking cap
3) Independent drysuit adaptor

A combination inflator replaces entirely your drysuit inflator. Consider four things:
A) Correct size. Your suit is either cut for Apeks diameter inflator hole (36mm, same as DUI valve) or a Si-Tech diameter inflator hole (33mm).
B) Cost
3) Depth. Integrated inflators are thinner than stack caps. You know if this extra 0.5" matters
4) Rotation of outlet. Some heat inflation bulkheads allow for one, both, or neither of the following to rotate independently: Inflator and E/O outlet. I don't think it matters much and prefer the fewer moving parts of something like the LM bulkhead. Your options include:
https://shop.lightmonkey.us/Dual-Outlet-Heater-Valve_p_141.html (Apeks only)
https://www.golemgear.com/p-552-combo-bulkhead-connector-for-q-vest-eo-version.aspx (Apeks or Si-Tech)
http://www.sitech.se/products/inflation-valves/vega.aspx (Si-Tech)
https://www.sftech.ch/en/valve/ (Apeks)
https://santidiving.com/thermovalve,549,en (Apeks or Si-Tech)

A stacking cap heat bulkhead fits sandwiched between your current inflator valve and the backing to the inflator valve. These again have two sizes. They tend to be cheaper at the cost of being bulkier. Your options include:
https://shop.lightmonkey.us/Drysuit-Inflation-Valve-Heater-Bulkhead_p_140.html (Apeks or Si-Tech)
https://www.golemgear.com/p-769-eo-bulkhead-connector-for-q-vest.aspx (Apeks or Si-Tech)
https://santidiving.com/drysuit-connector,547,en (Apeks or Si-Tech)

https://smart-tex.pl/en/product/adapter-to-valve-add-sitech-or-apeks/ (Apeks or Si-Tech)

Your last option is to add an additional hole to your suit. You can hide it in a pocket, on your side, inside the drysuit zipper cover, inside the telescoping portion of your drysuit, or simply elsewhere on your chest. Upside, small and hidable. Downside, it requires cutting an additional hole in your suit. The only one I am familiar with is this: https://shop.lightmonkey.us/Drysuit-Heater-Adapter-with-Cable_p_204.html

I use a dual outlet LM one. I do not have strong opinions and I have found it to be solidly built and it did not require punching another hole in my suit (which gets beat up enough as is).

Bulkhead to Wearables Connection

One last step before we get to your vest/gloves/socks/undies. How do we connect the bulkhead wire to the wearable wire? Fortunately, standardization is starting to happen. Unfortunately, there's still at least two connector types and (seemingly) half of companies leave the male on the bulkhead and half leave the female on the bulkhead. Gag.

You have T-Dean: https://www.amazon.com/Plug-Connectors-Deans-Style-Female/dp/B0070RS7V0
You have "Push-Lock": https://shop.lightmonkey.us/Push-Lock-Connector_p_286.html

T-Dean connectors have been a while and they are available for cheap. I have not found a cheap domestic source for the push-locks. If you can solder, you can use whichever you wish. Most people that will sell you a bulkhead are happy to attach whichever connector you want. I prefer the push-locks because they do not pull apart when pulled. They're also (slightly) waterproof. At the same time, they are bulkier and more expensive. If you elect to mix and match brands, ensure which side each part uses. By default, LM bulkheads use a FEMALE pushlock and a MALE garment. Santi bulkheads use a MALE pushlock and a FEMALE garment. Smart-Tex (Jerzy) does whatever you would like. If you're doing the wiring yourself, there are a few other connectors you could pick.

I will add here that if you want to have multiple garments connected together (e.g gloves + vest, gloves + suit, socks + vest + gloves, etc), you'll need to fashion some sort of a splitter. Santi sells one and Jerzy sells one. You cannot control the output % of each of these independently unless you have two inlets to your suit. I don't think it's super necessary.

Wearables

Alright we have finally made it. The actual thing that keeps you warm. Motorcycle batteries are the same voltage as most dive light batteries and the original in-drysuit heated vests are mostly heated motorcycle vests. Same story for gloves and socks. The technology has changed but not by that much. These garments worth either with wires running through the garment OR with a carbon fiber wrap. Unfortunately, there are not that many that use the carbon fiber. To my knowledge, there is the old UTD, Typhoon Rebranded Exo2 Vest (https://www.exo2theheatinside.com/products/heated-clothing/utd-solar.html) which uses a carbon impregnated panel, the Light Monkey shirt (https://shop.lightmonkey.us/Heater-Base--Top_p_301.html) which uses a carbon fiber heating element, and the Scuba Force X-Heat. Traditional, wire-based element can short if wires are broken.

Let's assume you purchase a Light Monkey heated shirt. The shirt has two 20W heat elements, one in the front, and one in the back. How long does this last? Above, I referenced that a LM 10Ah battery is 10Ah*11.1V = 111Wh. To calculate duration, with some variability, we first multiply plugged in items times 1.1. Let's assume a 40W vest pulls something closer to 44.

111Wh/44W = 2.52h ~ 151min. On full power, a 40W vest with a 10Ah battery should last about two and one half hours.

Topics to be continued:
Other garments
Socks
Gloves

Splitters

UN38.3
http://uwlightdude.com/battery-power-for-nerds/
https://www.batteryspace.com/prod-specs/UN_Test_Manual_Lithium_Battery_Requirements%206.pdf