Cold Weather Clothing

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LEARNING OBJECTIVES:

1) Describe important characteristics of various clothing materials (i.e., moisture retention, insulation, moisture repulsion, drape etc.).
2) Explain function and importance of each layer in a clothing ensemble.
3) Demonstrate the adjustment in clothing layers to minimize heat or cold stress.
4) Recognize the importance of moisture management in clothing ensembles.
5) Recognize practical implications of clothing design with respect to comfort, protection, moisture management, and physical manipulation (i.e., donning and doffing in challenging circumstances).

THERE IS NO SUCH THING AS BAD WEATHER… ONLY BAD CLOTHING.

Norwegian Proverb

INTRODUCTION

Since humans are tropical animals and poorly designed to withstand a cold environment, they are reliant on external protection from the cold in order to survive. This is primarily accomplished through clothing. There are three main principles involved in choosing cold weather clothing.

1) Clothing should be assembled as a complete ensemble. **The clothing ensemble should be designed for the specific conditions to be encountered.** This can be done by keeping in mind the following:

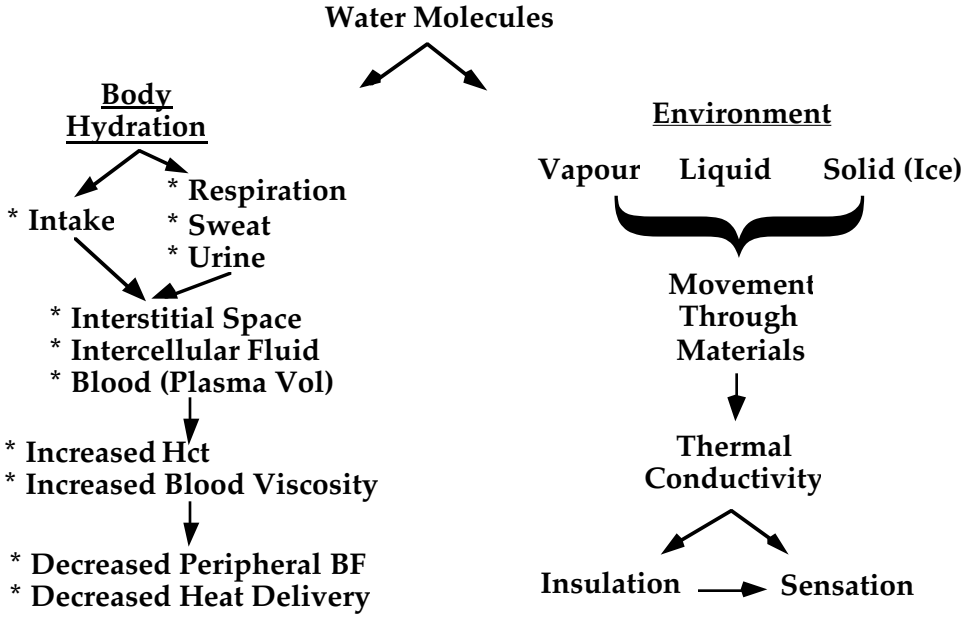
a) The physical work regime that will be done (i.e., continuous or intermittent, long or short periods, low or high work rate etc.), and

b) The environmental conditions that will be encountered (i.e., temperature, humidity, rain or snow fall expected, prevailing wind conditions etc.)

2) The principles of how clothing works should be understood completely and every effort should be made to maintain the clothing and to use it properly. If this is done, **<u>one can widen the window of conditions in which a specific clothing ensemble can be used, even though they are outside the parameters that the ensemble was originally designed for</u>**.

3) The most important factor, which can be controlled by the first two principles, is to minimize moisture accumulation in clothing. The cold weather enthusiast should religiously do everything possible to…

KEEP WATER MOLECULES OUT OF THE CLOTHING ENSEMBLE !!!!



<u>Figure 1</u>. While water ingestion is vital for body hydration and function, water molecules greatly decrease clothing insulation and personal comfort.

<u>SPECIFIC CONSIDERATIONS OF THE CLOTHING ITSELF</u>

1) **<u>Material properties</u>**. The following properties are important when considering clothing adequacy:

   a) <u>Insulation</u> – Generally referred to in Clo units, indicates the resistance to heat transfer. One Clo unit provides the insulation of a business suit, and the usual undergarments, and can be defined as:

   $1\ \text{Clo} = 0.18\ ^{\circ}\text{C}/(\text{kcal}/\text{m}^2/\text{hr})$

   Don't worry, no more equations. Insulative value of a garment is mainly dependant on: 1) material thickness; 2) the ability of the garment to trap air, which itself acts as an insulator; and 3) how dry the material is (as you will see later).

   b) <u>Permeability and moisture transfer</u> – Moisture is produced at the skin through sweating and insensible water loss. In the heat, liquid sweat evaporates releasing heat of

evaporation, thus increasing heat loss from the skin surface. This heat loss is not always advantageous in the cold. However, it is important to transfer as much water as possible from the skin through the clothing, either in vapor or liquid form. Permeability indicates the ability to allow vaporized moisture to pass through the material. Condensed (liquid) moisture transfer is also important as liquid can pass along material fibers to the clothing surface where it can evaporate. Moisture that remains within the material can decrease thermal insulation by as much as 30-50% because conductive heat loss is increased through wet clothing.

c) Water resistance – This indicates the ability of the material surface to repel liquid moisture from entering the material (normally the outside surface). Of course, minimizing water entry into the material will help maintain the insulation value of the material and thus the comfort level of the garment.

d) Wind resistance – The resistance to airflow (wind) through the material. This is very important as air flow carries heat away from the skin surface via convection.

2) **Comfort**. This will affect one's perception of clothing effectiveness. The fit of the clothing is important. If several layers are going to be included in an ensemble, each layer must be large enough to fit loosely over the layer beneath.

3) **Design**. Many design factors will affect not only the physical comfort/fit of the garment, but will also affect the thermal protection from the cold as well as practical usability of the garments.

a) Hoods, collars, sleeve ends and cuffs. It is important to have a high collar that zips up to the end of the collar, thus providing a 'high turtleneck' effect. This provides great comfort as the neck is especially sensitive to cold air currents. The high collar can also provide frostbite protection to much of the face.

An insulated hood is essential for cold weather (insulation may also be accomplished with a toque underneath a thin hood). Although the proportion of heat lost through the head is ***greatly overemphasized***, a good hood will indeed minimize head heat loss, stop uncomfortable cold air currents through the neck of the jacket, and protect against frostbite of the face and ears.

Although it is a matter of preference, sleeve cuffs (elastic cuffs inside the sleeve that close around the wrist) are very helpful in reducing convective air-cooling of the arms. It is very important to consider the interface between mitts and the sleeve end itself. Unless the mitt fits easily and fully inside or over the sleeve end, the bunching of the mitt against the sleeve end will create a weakness in the insulative armor; cold wrists are common with poorly integrated jacket/mitt combinations.

b) Pockets and zippers. Pockets in an outer jacket should be large enough to carry everything intended (i.e., winter mitts etc.), easy to open with mitts on, and must close easily and securely to prevent loss of pocket contents. Unfortunately, style often takes priority over function when clothing is designed. Thus, pockets are often small and openings are slanted (even vertical) to give a more 'sexy' look. Pockets should be large with the opening as close to

horizontal as possible. This will increase the amount that can be put into the pocket and minimize the possibility of contents falling out respectively.

Zippers must be able to be OPERATED WITH MITTS ON. This can be greatly assisted by attachment of 5-8 cm (2-3") tabs to EACH zipper on a garment. Again, fashion concerns dictate that zippers be small and inconspicuous. Unfortunately, all things being equal, small zippers 'catch' or 'snag' more often and are more prone to breaking. They are also considerably more difficult to operate, even with the tabs.

c) Length and overall coverage. One major weakness in a clothing ensemble is often the decreased thermal insulation at the waist. It is important that upper and lower body garments either are continuous (one piece or attached) or overlapping. It is important to forgo the fashionable short jacket for a longer model that will overlap your pants and protect your seat while you are sitting. Extra protection can also be gained by switching from a normal pant to a bib design for the outer layer.

d) Ventilation. It is EXTREMELY important to be able to ventilate a clothing ensemble while it is being used. Two main functions of clothing ventilation are: 1) removal of water vapor from inside the ensemble; and 2) to allow convective, conductive, evaporative and even radiative heat loss from the skin surface. Ventilation may be facilitated by opening sleeve ends, 'pit zips' and the front zipper (which is a reason not to use a solid front pullover design). The 'pit zips' should be long enough to actually allow the arms to be placed through them, if the need to increase radiative and convective heat loss from the arms occurs.

STRATEGIES FOR USING CLOTHING

1) **Layering design**. The clothing ensemble should have several layers instead of one large thick layer. This provides the obvious advantage of fine-tuning or adjusting the thermal insulation value in order to adjust to warmer or colder conditions. In addition, each layer should also be chosen to perform specific tasks.

   a) Inner layer. It is common knowledge that the inner layer (usually polyester) should be highly vapor permeable so that moisture is transferred or 'wicked' away from the skin through to the next layers of clothing. Having dry skin greatly increases one's comfort level.

   b) Middle layer(s). The middle layer(s) are mainly for insulation and can be fleece, pile, wool or even thicker polyester. It should be reemphasized that this middle zone should comprise multiple insulative layers rather than one thicker layer.

   c) Outer layer. The main function of this layer is to provide wind and/or moisture protection, depending on the prevailing conditions. Various materials can be used including Gortex, 60/40 cloth, cordura, windstopper (PTFE laminate), nylon, and others.

2) **Layering Strategy**. As stated above, it is important that a clothing ensemble

have several layers, AND that the appropriate layers be designed for plenty of ventilation. Therefore, heat loss can be finely tuned and moisture removal should be optimized. These characteristics are useless unless the layers and ventilation openings are used properly.

The VISCOUS CYCLE. One common problem is that one gets cold while preparing or waiting to start working in the cold, therefore several layers are worn. Travel then begins and eventually (sometimes very quickly) the person gets very warm and moisture begins to accumulate in the clothing. The traveler is hesitant to stop to adjust the clothing and 'puts up' with the discomfort. Finally a rest stop is made and layers are taken off to allow some cooling. However, no work is being done and heat production is lower. The remaining layers are now wet and uncomfortable and rapid cooling occurs causing significant discomfort. By the time the traveler is ready to start again, he/she has put on the outer layers to get warm again. Thus, travel starts with all of the clothing on and more heating and moisture accumulation will occur during travel. The traveler will be colder during the next break when outer layers are taken off again. This cycle continues and gradually gets worse.

The best strategy is to BE PROACTIVE IN LAYER ADJUSTMENT. Just before starting out, realize that you will soon get warm. Therefore, take a layer or two off just before starting. Even though it will feel cold initially, you will warm up once you are moving. Now when you stop for a break, you can put extra layers on for added insulation when your heat production is lower. Your inside layers will not be as moisture laden and you will be more comfortable. Again, just before starting out again, shed the extra layers in anticipation of increased heat AND moisture production.

One main principle to remember in the cold is that…

IT IS PREFERABLE TO OPERATE WITH A COOL SKIN SURFACE,

especially while working.

Under normal conditions, sweating is mainly determined by skin temperature, thus cooler skin will result in less sweat production and consequent moisture accumulation in clothing layers.

3) **Moisture removal at the end of the day**. It is best to avoid the "weekend adventurer syndrome" where many mistakes are made, not corrected, and merely tolerated because one can put up with almost anything for a few days. One should always act as if clothing and equipment will be used on a continual daily basis. Thus, at the end of the day it is important to extract as much moisture out of the clothing ensemble as possible in order to restore maximum insulation and comfort for the next day's activities.

   Considerable time and effort may be necessary to dry clothing over a stove or fire, but it will be worth it! Studies have shown that over the period of a week or two, insulative ability of clothing can decrease considerably even when efforts are made to remove moisture each day. You will get very cold if your clothing looses 30-50% of its insulation value.

4 **Maintenance**. It is also important to take care of any physical problems or damage to any element of the clothing ensemble. Clothing cannot be expected to perform properly if its physical integrity is compromised. Therefore, have adequate sewing equipment and repair kits and know how to use them.

It is also important to care for clothing according to manufacturer's instructions. For instance, Gortex garments should be washed (remember to follow instructions) periodically in order to remove dirt particles from the pores in the material. Otherwise the moisture transfer characteristics may be greatly compromised.

A PRIMER ON MOISTURE CONDENSATION WITHIN CLOTHING

As stated above, it is VITALLY IMORPORTANT that water vapor pass through the clothing layers before condensing into liquid form. If condensation does occur, liquid moisture must reach, AND PASS THROUGH the outside layer of the clothing before it freezes. In a cold environment, the moisture may freeze and be trapped within the clothing.

It is time for a little science here. The **Dew Point** is the important factor determining if, and where, moisture vapor condenses. As air temperature decreases, it can hold less water in vapor form. Consider a temperature at which air is completely (100%) saturated with moisture vapor. If air temperature then decreases, the resultant maximum vapor capacity of the air will be lower than what was in vapor form just before the temperature decreased. Thus, some of the moisture will condense or form liquid water. This threshold temperature is the Dew Point.

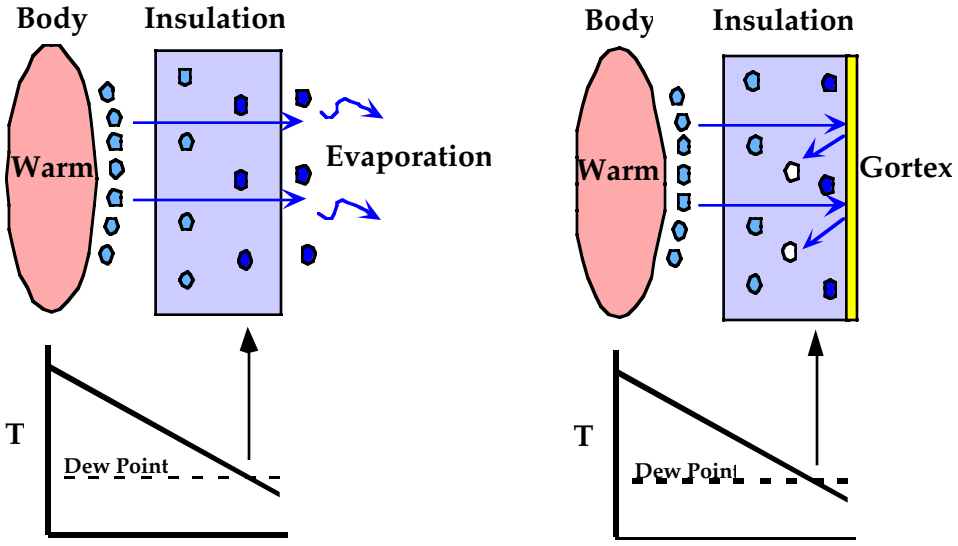


Figure 2 indicates that temperature (T) decreases as water vapor (light circles) moves from the warm body, through the clothing to the exterior environment. When the air temperature decreases below the Dew Point (dashed line), condensation will occur. **Left Panel**. If the liquid moisture (dark circles) can still pass through the material it will evaporate with minimal moisture accumulation within the material itself (Left).

The **Right Panel** illustrates a potential problem with a "liquid-resistant, vapor-permeable" material, such as Gortex, in extreme cold. If the Dew Point is reached within the clothing, the liquid moisture cannot escape through the liquid-resistant membrane. It then freezes (clear circles) within the clothing, thus addidng weight and decreasing insluation.

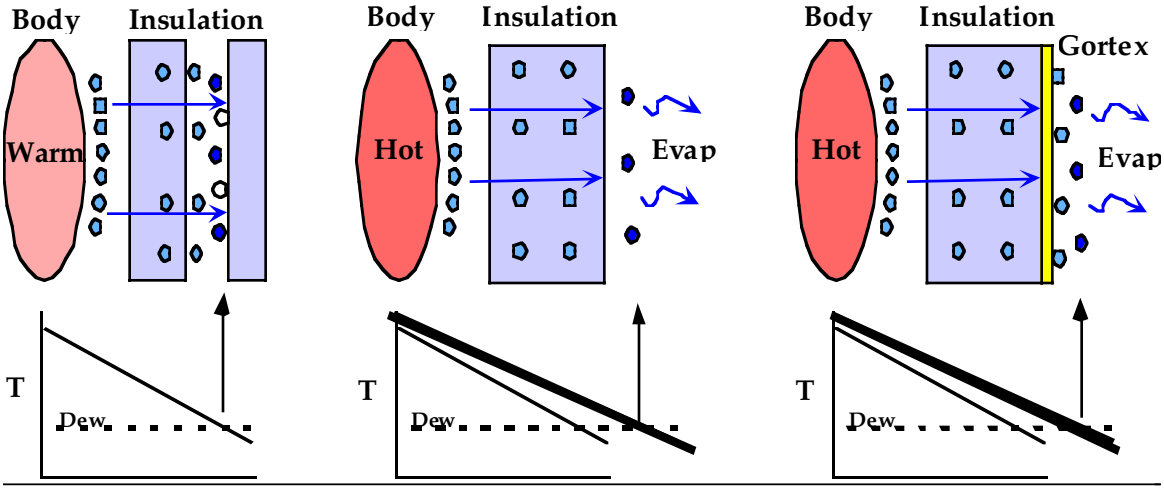


Figure 3 indicates some strategies to minimize moisture accumulation within clothing.

Left Panel – Multiple layering increases the chance that the temperature reaches the Dew Point somewhere between clothing layers. Thus if moisture condenses and freezes between the layers, ice can be brushed of from the material surfaces instead of being trapped with the material itself.

Center Panel – Heavy work will increase the skin surface temperature. The new temperature profile (dark line) shows that the Dew Point occurs past the outside layer of the clothing instead of within the material, as would have occurred with a lower initial skin temperature (light line).

Right Panel – This shows that an increased skin temperature is required to allow the forcing of moisture vapor through the "liquid-resistant, vapor-permeable" surface material before it condenses and evaoprates or freezes.

Based on these principles, it is advisable that the outer shell should not be combined with the insulation. Therefore if condensation and freezing does occur on the inside of the outer layer it can be brushed off.

CONCLUSION

Remember the following points and you will go a long way to ensuring comfortable safe clothing use in the harsh cold climate:

1) THERE IS NO SUCH THING AS BAD WEATHER… ONLY BAD CLOTHING.
2) As much as possible, the clothing ensemble should be designed for the specific conditions to be encountered.
3) You can widen the window of conditions in which a specific clothing ensemble can be used, even though they are outside the parameters that the ensemble was originally designed for.
4) KEEP WATER MOLECULES OUT OF THE CLOTHING ENSEMBLE !!!!!

   This requires commitment to:

   a) Proactive layering changes,
   b) Aggressive clothing ventilation to expel moisture during the day,
   c) Continued efforts to remove moisture at the end of the day.