HEALTH AND SAFETY
FACT SHEET

Cold Weather Hazard

Cold is rightly regarded by many workers as a hazard. Lowering of temperatures either outdoors or indoors causes not only general physical discomfort, but a loss of dexterity, energy and alertness. It can also lead to severe physical damage and death.

The body comfort and safety of cold weather workers is dependent upon three major factors:

- climatic conditions
- body heat and water vapour production
- the entire assembly of clothing

Each of these factors is interrelated with the other.

Cold temperatures and the human body's response

A cold climate has been defined in a number of ways, ranging from the temperature below 10 °C[1] to temperatures below room temperature (approximately 22 °C[2]). For worker, safety it's sensible to say that the sensation of cold is an accurate indication of coldness and the danger from cold.

Thermoregulation is the human body's ability to regulate heat production by releasing body heat at the same rate it is produced. Blood circulation and conduction pass heat from within the body to the surface.

Blood vessels can dilate or constrict to vary the flow of blood to surface tissues. Heat is passed through the body and conducted out through clothing, can be affected by air currents. The evaporation of water vapour from the skin and respiratory tract also affects the regulation of heat production and loss. Temperature changes, physical activity and clothing all affect and alter this regulatory process in different ways.

Cold weather forces the loss of heat from the body. In order to increase the insulation and thus maintain the temperature of the inner body, the flow of blood to the skin is reduced. This causes loss of feeling and numbness in the extremities (fingers, toes, nose, and ears).

A small temperature drop in the body core produces shivering. Shivering is the body's protective mechanism of rapid muscle movement, which generates heat to help maintain inner body temperature. Shivering, numbness and discomfort are warnings that the body must be warmed by a warmer environment, by more

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vigorous physical activity or by increased insulation from the cold. As will be seen, these protective measures can themselves present their own hazards in cold weather.

Cold temperatures and wind chill

One of the most important, but often overlooked, considerations in cold weather work is the effect of wind combined with air temperature. The "wind-chill factor" can account for about 80 per cent of the total heat loss from the body.

Different combinations of air temperature and wind speed can present the same hazards. For example, when the air is calm and the temperature is –1 °C, the body will feel cool. The same temperature with 40 km/h winds can produce bitter coldness.

The wind blows away the thin layer of air that acts as an insulator between the skin and the outside air.

The importance of wind speed on cold weather work can be seen in the chart below.[3] The "wind-chill factor" is derived from a mathematical equation and measures the rate of cooling of warm objects exposed to given wind and air temperature conditions. A temperature of –11 °C and a wind speed of 16 km/h can produce a wind-chill factor of 1200 – the wind-chill factor where exposed flesh freezes. Yet the higher temperature of -2.8 °C with a wind-speed of 48 km/h can produce the same.

TABLE 1

TEMPERATURES OF		+	**WINDSPEEDS OF**		=	**WIND CHILL FACTORS**	
C	**F**		**KMH**	**MPH**			
3	(38)		48	(30)	=	1000	Very
-4	(25)		16	(10)	=		cold
-3	(27)		48	(30)	=	1200	Bitterly
					=		cold
-11	(12)		16	(10)			exposed flesh freezes
-9	(16)		48	(30)	=	1400	Exposed
					=		flesh
-19	(-2)		16	(10)			freezes in 20 minutes

1400 is the wind-chill level for the coldest month of the year in places such as Winnipeg. At a wind-chill level of 2400, exposed flesh freezes in one minute.

The following chart plots actual thermometer readings against varying wind speeds to give the equivalent temperature.[4] An actual temperature reading of –7 °C with a 24 km/h wind will give a drastically reduced equivalent temperature of –21 °C.

Table 2
Actual Thermometer Reading (Celsius)

Wind speed (km/h)	10	4	-1	-7	-12	-18	-23	-29	-34	-40
calm	10	4	-1	-7	-12	-18	-23	-29	-34	-40
8	9	3	-3	-9	4	-21	-26	-32	-38	-44
16	4	-9	-16	-23	-29	-36	-43	-50	-57	
24	2	-6	-13	-21	-28	-38	-43	-50	-58	-65
32	0	-8	-16	-23	-32	-39	-47	-55	-63	-71
40	-1	-9	-18	-26	-34	-42	-51	-59	-67	-75
48	-2	-11	-19	-28	-36	-44	-53	-62	-70	-78
56	-3	-12	-20	-29	-37	-45	-55	-63	-72	-80
64	-3	-12	-21	-29	-38	-47	-56	-65	-73	-82

LITTLE DANGER if properly clothed | **INCREASING DANGER** | **GREAT DANGER** **(danger from freezing of exposed flesh)**

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If accurate information is not available, the following can be used as a guide to estimate wind velocity:[5]

8 km/h – a light flag moves;
16 km/h – a light flag fully extends;
24 km/h – raises newspaper sheet;
32 km/h – blowing and drifting snow.

It is important to remember that winds can be generated naturally or mechanically. Riding in a vehicle or standing near an air-blower can create conditions that raise the wind chill factor above the natural conditions thus causing potential hazards.

The physical hazards of cold weather

The two main hazards of cold weather work are frostbite and hypothermia. The first can cause permanent damage. The second can be fatal.

a) Frostbite

Frostbite refers to the freezing of tissues. Theoretically, the freezing point of skin is −1 °C, but frostbite may occur even if temperatures are not extremely low. It may occur at above 0 °C if the worker is wearing wet, damp clothing or if the skin comes into contact with objects below the freezing point. Decreased blood circulation can also contribute to the occurrence of frostbite. Frostbite most commonly occurs in the cheeks, nose, fingers, toes and earlobes. These areas are poorly insulated by skin and most often left exposed. Fingers, for instance, are poorly insulated because of their long, thin, cylinder-like shapes.

When frostbite occurs, crystals of ice form in the tissues, damaging them. Small blood vessels can be damaged when they become blocked with tissue debris. This causes further injury because the vessels are then unable to supply tissues with blood.

The classic signs of frostbite are loss of feeling and pallor. The first warning is a sharp, pricking sensation, but cold also produces numbness and anesthesia, which permits freezing without the warning of discomfort. Circulation and tissue can revert to their normal state if exposure is not acute.

If exposure is prolonged, tissue can actually die (tissue necrosis) in spite of the application of heat. Tissue necrosis can take place in four degrees of severity. In the first two degrees, tissue death does not extend beyond the outer layers of skin that reddens and blisters from the obstruction of blood flow. In the third and fourth degrees, there is complete necrosis of the skin and deep tissue death that can affect tendons, bones and joints. The farthest points from the affected areas become blue or blackish and gangrene can develop. The worker's general condition may deteriorate with the severity of the frostbite and there may be chills and fever.

First aid: Areas affected by frostbite should not be rubbed with ice or snow. This only causes further freezing. Superficial frostbite can be treated by gentle heating of the affected areas, which should not be massaged or exposed to open fires. With deep frostbite, it is important to keep the affected worker warm and get him/her to the hospital as quickly as possible. During work, the fingers, nose tip, toes and ears, should be periodically exercised to keep them warm and to detect numb or hard areas indicating frostbite.

b) Hypothermia

Hypothermia is an acute problem, resulting from long exposure to cold. It occurs when body heat is lost faster than it is produced, resulting in body temperatures below 35 °C. The lethal deep body temperature is 26 °C.

The body can lose great amounts of heat in numerous ways: inadequate clothing, improper insulation, or fatigue from physical activity.

As the body core temperature drops, shivering begins. If it continues to decrease, shivering actually decreases, respiration and the heart rate are slowed, and hypothermia sets in. The brain becomes less efficient, consciousness is dulled, muscular rigidity begins and breathing becomes shallow. These events could lead to eventual unconsciousness and possible death from exposure.

Some workers claim that constant exposure to cold makes them able to withstand these temperatures better. The reality is that workers learn to survive, rather than physically adapt to cold weather work. Getting used to cold weather work or habituation to cold may dull the awareness of being cold and carries with it an increased risk of hypothermia or cold injury. Hypothermia can affect a worker in temperatures well above freezing, especially when the worker is in cold water, is exposed to cool, high winds, is fatigued or has insufficient food.

First aid: When a worker suffers from hypothermia, immediate medical attention is necessary. The worker should be slowly warmed and hospitalization may be necessary for evaluating and treatment.

c) Immersion foot

The immersion of feet in cold water over an extended period or the wearing of damp footwear in cold weather can cause what is known as immersion foot or trench foot. Blood vessels spasm and extensive damage cause to foot muscles. The accumulation of fluid in tissues causes swelling, tingling, itching and severe pain followed by blistering, superficial skin necrosis and ulceration (skin lesions). Gangrene could also develop. When the foot heals, it is more sensitive to cold and the pain may last for years.

d) Other problems

Some research indicates that exposure to temperatures below freezing leads to chronic lung disease and sinus irritation. Other possible effects may be chronic headaches, arthritis and an increase in virus infections.[6] There is also an association between acute pneumonia and unusual cooling. Blood system abnormalities may be caused or worsened.[7]

Falling temperatures can cause hands and fingers to become insensitive, so the probability of malfunction and accidents increases. Shivering can make it still more difficult to properly manipulate equipment.

Hypothermia can cause confusion, leading to clumsiness that endangers the worker and those around him/her.

Under conditions of wind noise, severe cooling and the perceived threat of injury, workers may show lack of attention, hostility and a desire to withdraw from the workplace. This leads to work inefficiency, which could present a danger to the worker and others.

Preventative measures

In order to protect the body from the dangers of cold weather work, measures must include periodic warming of the body and the use of protective clothing. The provision of heated rest facilities for workers is essential and rest allowances should be increased.

a) Rest allowances

The following work/warm-up schedule can be used as a guide to the maximum work periods and number of rest periods that should be allowed at varying temperatures and wind speeds during moderate to heavy work activity. For example, at a temperature of –26 °C with a 16 km/h wind, a worker should have a maximum work period of 75 minutes with two ten-minute breaks in a four-hour period. If wind speed increases to 32 km/h at the same temperature, the maximum work period should be only 40 minutes with four ten-minute breaks in a four-hour period.

Table 3
Work and rest schedule

	Maximum Work Period (within any 4 hr period) Minutes					Number of Breaks (ten-minute breaks)				
Wind speed kph	No	8	16	24	32	No	8	16	24	32
Mph	Wind	5	10	15	20	Wind	5	10	15	20
Temperature										
-26 to -28C			75	55	40	1	1	2	3	4
-29 to -31C		75	55	40	30	1	2	3	4	5
-32 to -34C	75	55	40	30	**	2	3	4	5	**
-35 to -37C	55	40	30	**	**	3	4	5	**	**
-38 to -39C	40	30	**	**	**	4	5	**	**	**
-40 to -42C	30	**	**	**	**	5	**	**	**	**
-43 and below	**	**	**	**	**	**	**	**	**	**
-45 and below										

** Non-emergency work should cease.

Note: This schedule applies to moderate to heavy work activity. During light to moderate work the schedule is applied one step lower (i.e. at –26 °C with a 16 km/h wind the maximum work period would be 55 minutes with two rest periods in a four-hour work period.

During rest periods, certain precautions should be taken. Warmer clothes for resting in the cold weather should be provided since heat production from physical activity is decreased. Workers should also beware that carbon monoxide hazards can result from charcoal burning fires indoors, where there is inadequate ventilation.

In some cases, more physical activity could prove beneficial so that surveillance tasks without activity should be avoided in the cold. Increasing physical effort required for light tasks could increase needed body heat production.

Wind shields should be used when possible.

b) Clothing

Clothing is the main barrier against cold weather and prevents body heat loss. An adequate "clothing system" which keeps workers comfortably warm is necessary. Clothing should provide high insulation, allow the escape of moisture from within, resist wetting from outside, shed snow, have a means of varying insulation and air flow, not restrict movement, have minimum weight and bulk, be easy to put on and take off and be durable.

Clothing must allow the escape of moisture from inside, yet not allow wetness in from outside. That is, workers should look for fabrics that breathe, allowing water from perspiration and sweat out, yet are waterproof. If the perspiration, resulting from increased

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physical activity, can't escape, the body's ability to regulate heat production and loss will be impaired.

Heat losses resulting from the accumulation of water in clothing can be large, particularly in windy conditions. The thermal conductivity of water is approximately 20 times that of dry fabric. So clothing meant to insulate the body from outside cold and maintain heat can be reduced to a fraction of its original value. Body heat is lost faster than it is produced. Depending on the degree of contact between clothing with the body, wearing wet clothing could be like immersing oneself in cold water.

The insulation value varies from fabric to fabric. Denim is loosely woven, it allows water to penetrate and cool winds to blow away body heat. Duck or goose down stops wind, but easily becomes waterlogged. Clear plastic or woven nylon, is a good protection against wind and water, but provides little insulation and can prevent moisture from escaping.

As already mentioned, fabrics used in cold weather clothing should be tightly woven and highly "air-permeable". Air entrapped within clothing fabrics and between clothing layers is a more effective insulator than the cloth itself. Clothing should also be worn loosely and in layers, thus adding to this warm air circulation. Even this insulation can be reduced by compression and disturbance of air layers caused by physical activity and winds. Insulated clothing could lose much of its thermal insulation just by the simple act of walking. Thus, two layers of tightly woven "breathable" fabric with a space between them are more effective wind breaks than one outer layer of fabric with low air-permeability.

A good cold weather clothing system might consist of the following garments:
Underwear. Cotton shirt and shorts should be worn under thermal underwear. Long underwear in a two-piece style is better than one single garment. The fit should be loose so that blood vessels are not constricted.

Socks. High wool socks are best and should encourage evaporation of sweat. Stretch socks restrict circulation.

Trousers. Wool and quilted trousers or lined thermal types, are the best. They should be roomy enough to prevent compressing. Belts are constricting; suspenders should be used. Conventional pants should be tucked into boots to prevent entry of snow and cold water.

Boots. The best are felt lined, rubber bottomed, leather-topped with removable insoles. Footwear should be waterproof and reach high up the leg.

Shirt. A wool shirt (cotton or synthetic shirt worn under for those allergic to wool) should be worn over underwear tops and suspenders with shirttail worn outside pants to aid ventilation.

Head covers. At –4 °C, a worker could lose up to 50 per cent of his/her heat production when resting and 75 per cent of it at -15 °C, from an uncovered head. Long hair and beards provide little insulation. They can, in fact, serve as a basis for ice build up and can mask the appearance of frostbite. Wool knit caps or hat liners that extend down the back of the neck, should be worn. A balaclava provides further face protection.

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Face masks. These can be worn by workers who cannot afford reduced vision on the job. It is essential, when wearing facemasks, that they be removed periodically to check for frostbite.

Gloves and mittens. Mittens win for protection, but limit finger movement. It is best to carry both and they should never be worn when wet.

c) Other precautions

Food. Balanced meals and adequate liquid intake are essential for body heat production and the prevention of dehydration. Warm liquids should be provided.

Alcoholic drinks should not be given because they cause dilation of blood vessels. This allows the rapid loss of body heat and increases the risk of hypothermia.

Training. Workers should be trained in the use of proper clothing and the recognition of the early signs and symptoms of frostbite and hypothermia.

Machinery. Machinery and tools should be carefully designed to make them less hazardous and easier to use during cold weather. Metal parts should be insulated and sharp protrusions should be eliminated.

Fitness. Physical fitness can make work in cold weather easier. However, those suffering from vascular diseases should avoid working in cold weather.

Vehicles. Vehicle breakdowns in bad weather conditions can maroon workers (especially in rural areas). All vehicles should be provided with survival kits and a two-way communications system.

FOOTNOTES

1. L.H. Turl, "Clothing for Cold Conditions", Journal of Occupational Medicine, March, 1960, p. 123.

2. William Fox, "Human Performance in the Cold", Human Factors, 1967, 9 (3) p. 203.

3. J.V. Morris, "Developments in Cold Weather Clothing", American Occupational Hygiene, Vol.17, Pergamox Press, 1975, p. 281.

4. Julian B. Olishifski (ed.), Fundamentals of Industrial Hygiene, National Safety Council, Chicago, 1985, p. 372.

5. "Cold Conditions Guidelines for Outside Workers", Saskatchewan Department of Labour, Education and Research Branch, p. 2.

6. C.R. Bell, "Headache associated with cold exposure", Occupational Health, September 1977, p. 393-397.

7. Marcus Key, et al. (ed.), Occupational Diseases: A Guide to Their Recognition, U.S. Department of Health, Educational and Welfare, Washington, 1977, p. 503.

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