Cold Stress

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INTRODUCTION

Low temperature environments present numerous challenges related to operation of equipment, systems, structure, vessel maintenance and safety equipment for the vessel's personnel as well as personnel performance. Personnel performance will typically be reduced by the effects of low temperatures. Extremely cold weather is a dangerous situation that can bring on health emergencies. What constitutes cold stress and its effects can vary across different regions of the world. Whenever temperatures drop decidedly below normal and as wind speed increases, heat can more rapidly leave crewmembers' bodies. These weather-related conditions may lead to serious health problems. Because of the significant environmental conditions that a vessel and its crew are operating in, particular attention must be paid to the personnel so that they remain effective in performing their duties.

> Cold stress: Frost nip, frost bite, trench foot, chilblains, and hypothermia are medical conditions associated with cold stress. Hypothermia is a potentially fatal condition that occurs when core body temperature falls below 95°F (35°C).

A cold environment challenges crewmembers in three ways: air temperature, air movement (wind speed), and humidity (wetness). In order to work safely, these challenges have to be counterbalanced by proper insulation (layered protective clothing), by physical activity, and by controlled exposure to cold (work/rest schedule).

TERMS/DEFINITIONS

Air Temperature: Air temperature is measured by an ordinary thermometer in degrees Celsius (°C) or degrees Fahrenheit (°F).

Chilblains: are caused by the repeated exposure of skin to temperatures just above freezing to as high as 60 degrees F. The cold exposure causes damage to the capillary beds (groups of small blood vessels) in the skin. This damage is permanent and the redness and itching will return with additional exposure. The redness and itching typically occurs on cheeks, ears, fingers, and toes.

Clo-units: The rate of a person's heat loss as measured in watts per square meter of skin area per Kelvin of temperature difference across the clothing; the value of insulation is measured by the reciprocal of this rate, in square meter Kelvins per watt (m2-K/W)

Ergonomics: The applied science of equipment design, as for the workplace, intended to maximize productivity by reducing operator fatigue and discomfort

Frost bite: is damage to tissues from freezing due to formation of ice crystals within cells, rupturing the cells, and leading to cell death. Frost bite occurs when temperatures are below freezing.

Frost nip: is the first stage of frost bite when only the surface skin is frozen. Frost nip begins with itching pain. The skin then blanches and eventually the area becomes numb.

Humidity (wetness): Water conducts heat away from the body 25 x faster than dry air.

Hypothermia: is a reduction in core body temperature that occurs when exposure to cold causes a person's body to lose heat faster than it can be replaced.

Low temperature environment: Areas of vessel operations with ambient temperatures less than or equal to -10°C (14°F).

Physical Activity: The production of body heat by physical activity (metabolic rate) can be difficult to measure. Metabolic heat production is measured in kilo calories (kcal) per hour. One kilocalorie is the amount of heat needed to raise the temperature of one kilogram of water by 1°C.

Protective clothing: Clothing that provides adequate protection from the temperature, weather conditions (e.g., wind speed, rain), the level and duration of activity, and job design.

Trench foot (also known as immersion foot): is an injury of the feet resulting from prolonged exposure to wet and cold conditions.

Wind-chill Temperature: At any temperature, it feels colder as the wind speed increases. The combined effect of cold air and wind speed is expressed as "equivalent chill temperature" (ECT), "wind chill factor", or simply "wind chill" temperature in °C or °F. It is essentially the air temperature that would feel the same on exposed human flesh as the given combination of air temperature and wind speed. Refer to Table 1, "Wind Chill Chart." It can be used as a general guideline for deciding clothing requirements and the possible health effects of cold. The "wind chill factor" is a measurement of a heat loss rate caused by exposure to wind and it is expressed as the rate of energy loss per unit area of exposed skin per second (e.g., joules/ [second-meter2] or watts/meter2).

Wind Speed: Different types of commercially-available anemometers are used to measure wind speed or air movement. These are calibrated in meters per second (m/s), kilometers per hour (km/h) or miles per hour (mph). Air movement is usually measured in m/s while wind speed is usually measured in km/h or mph. The following is a suggested guide for estimating wind speed if accurate information is not available:

- 8 km/h (5 mph): light flag moves,
- 16 km/h (10 mph): light flag fully extended,
- 24 km/h (15 mph): raises newspaper sheet,
- 32 km/h (20 mph): causes blowing and drifting snow.

Work/rest schedule: Similar to work/rest schedules recommended for hot stress, these are recommended work/rest/warm-up schedules for cold stress (ACGIH, 2009).

Table 1 – Wind Chill Chart

Wind Chill Chart											
		Ambient Temperature (°C (°F))									
		10 (50)	4 (40)	-1 (30)	-7 (20)	-12 (10)	-18 (0)	-23 (-10)	-29 (-20)	-34 (30)	-40 (-40)
Wind Km/Hr	**Velocity mph**	**Equivalent Chill Temperature (°C (°F))**									
0	0	(50)	4 (39)	-1 (30)	-7 (19)	-12 (10)	-18 (0)	-23 (-9)	-29 (-20)	-34 (29)	-40 (-40)
8	5	(48)	3 (37)	-3 (27)	-9 (16)	-14 (7)	-21 (-6)	-26 (-15)	-32 (-26)	-38 (-36)	-44 (-47)
16	10	(40)	-2 (28)	-9 (16)	-16 (3)	-23 (-9)	-30 (-22)	-35 (-31)	-43 (-45)	-50 (-58)	-57 (-71)
24	15	(36)	-6 (21)	-13 (9)	-20 (-4)	-28 (-18)	-36 (-33)	-43 (-45)	-50 (-58)	-58 (-72)	-65 (-85)
32	20	(32)	-8 (18)	-16 (3)	-23 (-9)	-32 (-26)	-39 (-38)	-47 (-53)	-55 (-67)	-63 (-81)	-71 (-96)
40	25	(30)	-9 (16)	-18 (0)	-26 (-15)	-34 (-29)	-42 (-44)	-51 (-60)	-59 (-74)	-67 (-89)	-76 (-105)
48	30	(28)	-10 (14)	-19 (-2)	-27 (-17)	-36 (-33)	-44 (-47)	-53 (-63)	-62 (-80)	-70 (-94)	-78 (-108)
56	35	(27)	-11 (12)	-20 (-4)	-29 (-20)	-37 (-35)	-46 (-51)	-55 (-67)	-63 (-81)	-72 (-98)	-81 (-114)
64	40	(26)	-12 (10)	-21 (-6)	-29 (-20)	-38 (-36)	-47 (-53)	-56 (-69)	-65 (-85)	-73 (-99)	-82 (-116)
(Wind speeds greater than 40 mph have little additional effect)		**LITTLE DANGER** - in less than one hour exposure of dry skin **Maximum danger** of false sense of security				**INCREASING DANGER** - exposed flesh freezes within one minute			**GREAT DANGER** - flesh may freeze within 30 seconds		
		Trenchfoot and immersion foot may occur at any point on this chart.									

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DISCUSSION

How the Body Maintains Thermal Balance

Cold challenges the body in three major ways (temperature, wind and wetness). Depending on the severity of cold conditions, heat loss can occur. The body maintains its heat balance by increasing production of the heat and activating heat retention mechanisms.

Heat Production	+	Heat Retention	=	Cold Challenge	=	Thermal Balance
• food intake		• decreased superficial blood flow		• temperature		
• activity		• clothing		• wind		
• shivering				• wetness		

In the situation where more heat is lost than the combined heat production processes and heat retention mechanisms can generate, the core body temperature drops below +37°C. This decrease causes hypothermia which can impair normal muscular and mental functions.

Heat Production	+	Heat Retention	<	Cold Challenge	=	Hypothermia
• food intake		• decreased superficial blood flow		• temperature		
• activity		• clothing		• wind		
• shivering				• wetness		

The heat balance equation is commonly expressed as: S = M ± C ± K ± R - E

(i) Net heat storage (S) – changes in body heat content

(ii) Metabolic rate (M) – produced in the internal cell processes and by the work of muscles. It depends on human activity, body posture, age, sex, weight and height as well as on thermal conditions and climatic seasonality

(iii) Convection (C) – depends on temperature difference between the air and the skin surface

(iv) Conduction (K) – loss of heat through direct contact of skin with a cooler object

(v) Radiation (R) – the effect of heat transfer by thermal radiation which occurs between any surfaces with a temperature > 0° K

(vi) Evaporation (E) – depends on the difference in vapor pressure in the atmospheric air and at the skin surface. Humans can only lose heat by evaporation

How the Body Looses Heat to the Environment

Radiation is the loss of heat to the environment due to the temperature gradient. In this case, it is the difference between the temperature of the air and the temperature of the body (your body's core temperature is +37°C (+98.6°F)). Another factor important in radiant heat loss is the size of the surface area exposed to cold.

Conduction is the loss of heat through direct contact with a cooler object. Heat loss is greatest if the body is in direct contact with cold water. The body can lose 25 to 30 times more heat when in contact with cold wet objects than in dry conditions or with dry clothing. Generally, conductive heat loss accounts for only about 2% of overall loss. However, with wet clothes the loss is increased 5 times.

Convection is the loss of heat from the body to the surrounding air as the air moves across the surface of the body. The rate of heat loss from the skin by contact with cold air depends on the air speed and the temperature difference between the skin and the surrounding air. At a given air temperature, heat loss increases with wind speed. However, the effect of wind speed does not increase at speeds above 64 km/h or 50 mph since the air is not in contact with the body long enough for more body heat to be transferred to the air.

Evaporation is the loss of heat due to the conversion of water from a liquid to a gas. In terms of human physiology, it is:

- Perspiration/Sweating - evaporation of water to remove excess heat
- "Insensible" Perspiration - body sweats to maintain humidity level of 70% next to skin. Particularly in a cold, dry environment, you can lose a great deal of moisture this way and not notice that you have been sweating.
- Respiration - air is heated as it enters the lungs and is exhaled with extremely high moisture content

It is important to recognize the strong connection between fluid levels, fluid loss, and heat loss. As body moisture is lost through the various processes, the overall circulating volume is reduced which can lead to dehydration. This decrease in fluid level makes the body more susceptible to hypothermia and other cold injuries.

How the Body Produces and Retains Heat within the Body

In order to survive and stay active in the cold, the constant heat loss has to be counterbalanced by the production of an equal amount of heat. Heat is both required and produced at the cellular level as a result of complex metabolic processes that convert food - a primary source of energy - into glycogen. Glycogen is a substance (biochemical compound) that is the "fuel" for biochemical processes underlying all life functions, heat production included.

- Factors important for heat production include:
- Food intake
- "Fuel" (glycogen) store
- Fluid balance
- Physical activity
- Shivering - a reflex reaction, which increases the body's heat production (up to 500%) when necessary. This reaction is limited to a few hours because of depletion of muscle glycogen and the onset of fatigue

Heat retention and tolerance to cold also depends on the body's structure, certain reflex and behavioral mechanisms that retain heat within the body as well as what you are wearing. They are:

- Size and shape of the body (surface to volume ratio)
- Layer of fat under the skin (Subcutaneous adipose tissue)
- Decreased the blood flow through the skin and outer parts of the body
- Insulation (layering and type of clothing)

SAFETY CONSIDERATIONS

Uncomfortably cold working conditions can lead to lower work efficiency and higher accident rates. Cold impairs the performance of complex mental tasks. Manual tasks are also impaired because the sensitivity and dexterity of fingers are reduced in the cold. At even lower temperatures, the cold affects the deeper muscles resulting in reduced muscular strength and stiffened joints. Mental alertness is reduced due to cold-related discomfort. For all these reasons accidents are more likely to occur in very cold working conditions.

Differences in Individual Response

Response in Men and Women

Studies have shown that response to cold in women can differ from that of men. While the core body temperature cools more slowly in women, women are not usually able to create as much metabolic heat through exercise or shivering. In addition, the rate of cooling of the extremities (feet, hands) is faster among women. As a result, women are generally at a greater risk of cold injury.

Predisposing Conditions

Susceptibility to cold injury varies from person to person. In general, people in good physical health are less susceptible to cold injury. While anyone working in a cold environment may be at risk, the following conditions may make the risk of cold injury greater:

- Age (infants less than one year, and older adults are more susceptible)
- Diseases of the blood circulation system
- Injuries resulting in blood loss or altered blood flow
- Previous cold injury
- Raynaud's Phenomenon
- Fatigue
- Diabetes

- Consumption of alcohol or nicotine (smoking)
- Use of certain drugs or medication

Monitoring Environmental Conditions

Working in cold environments requires an understanding of the interaction between ambient temperature, wind speed, relative humidity, personnel protective equipment and task being performed. In order to limit the risk during operational activities due to cold stress and further prevent local cold injuries and general freezing, specific preventative measures should be evaluated and introduced during the planning and execution of the daily work activities.

A plan for monitoring exposure to cold should be devised and should take account of variations in thermal conditions. Any time the temperature may fall below 16°C the crew should be equipped with a suitable thermometer to monitor any further temperature changes. For colder workplaces with temperatures below the freezing point, the temperature should be monitored at least every 4 hours. For indoor workplaces, whenever the rate of air movement exceeds 2 meters per second (5 miles per hour) it should be recorded every 4 hours. In outdoor workplaces with air temperature below the freezing point, both air temperature and wind speed should be recorded.

Ship managers should, if practicable, eliminate the need for extended work in cold conditions (for example, by rescheduling work to be performed in a warmer season, or by moving the work from outdoors to indoors, or separating the cold parts of a process from the workers, as far as practicable). If elimination of such work is impracticable, other measures to reduce risk from cold conditions should be devised.

Employers should ensure that workers are not positioned near very cold surfaces or, if this cannot be avoided, that the workers are protected by radiation shields. For standing tasks, the floor should, where practicable, have an insulating surface.

Climatic metrics such as temperature, wind speed and humidity should be regularly monitored in the locations where outside work is to be performed. Of primary importance is a regular reporting of the wind chill or equivalent temperature.

Regular communications should be maintained regarding allowable time to work outside. Indoor personnel should regularly monitor outside workers so that best work-to-rest/warming schedules are maintained. Table 2, "Suggested Maximum Allowable Work Times", provides guidance.

Table 2 – Suggested Maximum Allowable Work Times

Equivalent Temperature	Consequence - Action
Below -30°C (-22°F)	No outdoor work performed unless deemed critical from a safety or operational perspective
Below -21°C (-6°F)	Available outdoor working time is below 50% of working hour.
Below -12°C (10°F)	Available outdoor working time is below 75% of working hour.
Below -6°C (21°F)	Available outdoor working time is below 90% of working hour.
Above -6° C (21°F)	Normally 100% Available working time

COLD STRESS MANAGEMENT

The risk of cold injury can be minimized by proper equipment design, safe work practices and appropriate clothing. The following is a summary of actions.

Preparing for the Cold

Acclimatization is the term given to the development of resistance to, or tolerance for, an environmental change. Although people easily adapt to hot environments, they do not acclimatize well to cold. However, frequently-exposed body parts can develop some degree of tolerance to cold. This adaptability is noticeable among fishermen who are able to work with bare hands in extremely cold weather. The blood flow in their hands is maintained in conditions which would cause extreme discomfort and loss of dexterity in un-acclimatized persons. However, acclimatization should not be relied upon as method to reduce cold stress.

Design and Operational Considerations

The analysis of outdoor work situations should be performed early in design/layout development and should be updated when design changes are made that will influence personnel’s exposure to cold stress. Outdoor operations analyses (an examination of the tasks to be carried out in cold conditions) should be carried out for open work areas and semi-open work areas. The objective of these analyses is to identify and remedy task performance issues due to overall exposure to temperature, wind, icing and precipitation, including investigation of the weather protection necessary to comply with exposure limits. Environmental measurements and assessments (air temperature, humidity and wind speed and direction) should be performed on a routine basis and at regular intervals throughout the day during cold periods with temperatures below zero degrees. All personnel working in exposed locations should be monitored at regular intervals. A person is usually unable to recognize their own signs and symptoms of hypothermia. As a precaution, use of the “buddy system” to detect signs of cold injury in coworkers is recommended.

Crew should be allowed sufficient time to acclimatize to an extremely hot or cold environment, including major changes in climatic conditions.

Monitoring of thermal conditions should be performed and should take account of:

- All stages of work cycles and the range of temperature and humidity under which tasks are performed
- The range of clothing worn during the tasks
- Major changes in physical activity level (metabolic heat production)
- Occasional tasks such as cleaning and maintenance of hot equipment and cold areas, and renewal of hot or cold insulation

A log that is to be maintained by the onboard Safety Officer during operations in cold periods to keep records of the specific areas and work activities where administrative measures are introduced is recommended. Work areas where administrative measures are introduced on a regular basis should be identified by periodical review of such records.

Workers in the cold will often need to urinate more frequently, and employers should ensure that suitable arrangements are available, where feasible, and that the design of protective clothing allows easy urination.

Suitable protection should be given to the hands and fingers, particularly where dexterity is needed, as well as other exposed parts of the body. Employers should provide:

- Facilities for warming the hands, for example, by warm air, where appropriate
- Tools with insulated handles, especially in temperatures below the freezing point
- Measures to ensure that the bare hand does not touch surfaces below -7°C (workplace design or protective clothing)
- Measures to ensure that bare skin does not touch liquids below 4°C
- Appropriate measures to be taken in the event of insulating clothing getting wet
- Face and eye protection, as appropriate, for outdoor work and working in snow (e.g., safety goggles against glare)
- Adequate facilities for changing
- Arrangements for cleaning such clothing and drying clothing and footwear between shifts. Slips and falls are also much more common in winter seasons.
- Walk slowly on slippery, icy surfaces to prevent danger of slipping. Stop occasionally to break the momentum.
- Avoid carrying heavy loads or loads that obstruct vision during transportation.
- Use approved snow removal compounds.
- Use mats at entrances to prevent slippery conditions indoors caused by melting snow or ice.
- Stairs, ladders and walking surfaces should be provided with non-skid surfaces
- Hand railings should be provided with non-slip surfaces or should be heated to prevent formation of ice
- Exterior stairs should be made of grated material to aid in snow and ice removal

Put up visible signs emphasizing the risk for cold-related injuries at all outdoor workstation locations. Knowledge of the work area at risk for slippery conditions, augmented with proper hazard signage, is important. If individuals are aware of the cold weather conditions, they will rely on additional muscle-based reflexes (i.e., reaction time), postural control, and muscular strength to adjust to the environment and prevent slipping and falling.

Other cold related design considerations include:

- Consider providing enclosed bridge wings.
- Consider providing a temperature transition area (such as a heat vestibule) at exit/entry points to soften the often harsh transition from bitter cold to warmth, and vice versa)
- Assess possibility for temporary local shielding around working area(s) if permanent shielding is not possible.
- Clearly post locations for nearest re-warming or break areas.
- Power tools and other equipment generally require specific maintenance schedules for usage in cold weather.
- Cold tool handles reduce grip force. Therefore, tools with larger handles may be required for cold weather usage to accommodate the protective hand wear and reduced grip capacity.
- Cold exposure aggravates the effects of mechanical vibration, making manual work more difficult and painful.
- Effort should be made to minimize exposure to vibration at its source.
- Hospital/medical kits should be stocked with materials appropriate to treat cold weather illnesses and maladies.
- Cold weather illnesses training and procedures should be provided with emphasis on both symptom identification and treatment of the cold-related illness.

Clothing

Protective clothing is needed for work at or below 4°C. Clothing should be selected to suit the temperature, weather conditions (e.g., wind speed, rain), the level and duration of activity, and job design. These factors are important to consider so that you can regulate the amount of heat and perspiration you generate while working. If the work pace is too fast or if the type and amount of clothing are not properly selected, excessive sweating may occur. The clothing next to body will become wet and the insulation value of the clothing will decrease dramatically. This increases the risk for cold injuries.

- Clothing should be worn in multiple layers which provide better protection than a single thick garment. The air between layers of clothing provides better insulation than the clothing itself. Having several layers also gives you the option to open or remove a layer before you get too warm and start sweating or to add a layer when you take a break. It also allows you to accommodate changing temperatures and weather conditions. Successive outer layers should be larger than the inner layer; otherwise the outermost layer will compress the inner layers and will decrease the insulation properties of the clothing.
- The inner layer should provide insulation and be able to "wick" moisture away from the skin to help keep it dry. Thermal underwear made from polyesters or polypropylene is suitable for this purpose. "Fishnet" underwear made from polypropylene wicks perspiration away from the skin and is significantly thicker than regular underwear. It also keeps the second layer away from the skin. The open mesh pattern enables the moisture to evaporate and be captured on the next layer away from the skin. The second layer covers the "holes" in the fishnet underwear which contributes to the insulation properties of the clothing.
- The additional layers of clothing should provide adequate insulation for the weather conditions under which the work being done. They should also be easy to open or remove before you get too warm to prevent excessive sweating during strenuous activity. Outer jackets should have the means for closing off and opening the waist, neck and wrists to help control how much heat is retained or given off. Some jackets have netted pockets and vents around the trunk and under the arm pits (with zippers or Velcro fasteners) for added ventilation possibilities.
- For work in wet conditions, the outer layer of clothing should be waterproof. If the work area cannot be shielded against wind, an easily removable windbreak garment should be used. Under extremely cold conditions, heated protective clothing should be made available if the work cannot be done on a warmer day.
- Almost 50 percent of body heat is lost through the head. A wool knit cap or a liner under a hard hat can reduce excessive heat loss.
- Clothing should be kept clean since dirt fills air cells in fibers of clothing and destroys its insulating ability.
- Clothing must be dry. Moisture should be kept off clothes by removing snow prior to entering heated shelters. While the worker is resting in a heated area, perspiration should be allowed to escape by opening the neck, waist, sleeves and ankle fasteners or by removing outerwear. If the rest area is warm enough it is preferable to take off the outer layer(s) so that the perspiration can evaporate from the clothing.
- If fine manual dexterity is not required, gloves should be used below 4°C for light work and below -7°C for moderate work. For work below -17°C, mittens should be used.
- Cotton is not recommended. It tends to get damp or wet quickly, and loses its insulating properties. Wool and synthetic fibers, on the other hand, do retain heat when wet.
- Immersion suit protection should be provided.

Footwear

The surface contact area of the sole is important for frictional force on ice. It is suggested that shoes/boots with rounded heels increase the contact with the surface and reduce the risk of slipping. When there is a layer of water along icy surfaces, the contact with the sole of the shoe is reduced. Therefore, the addition of sharp cleats to shoes is suggested. However, wearing shoes/boots with steel cleats on steel decks can be quite dangerous because of the loss of frictional force.

Boot selection should involve procuring a boot with proper insulation for the duration of the activity, required protection and the intensity of the work.

Socks

Woolen, polypropylene, or other thermal socks should be worn to protect ankles and feet. Keep snow and water out of footwear and replace damp socks with a dry pair.

Head, Face, and Eye Protection

In extremely cold conditions, where face protection is used, eye protection must be separated from the nose and mouth to prevent exhaled moisture from fogging and frosting eye shields or glasses. Select protective eye wear that is appropriate for the work you are doing, and for protection against ultraviolet light from the sun, glare from the snow, blowing snow/ice crystals, and high winds at cold temperatures. Use an appropriate hard hat liner to reduce heat loss when wearing protective headwear. Wear a warm hat with ear protection to prevent heat loss from the head.

Hand Protection

Do not wear gloves or scarves that can get caught in moving parts of machinery.

While glove use is always recommended for outside work, the use of cold-protective gloves likely impairs the ability to carry out fine motor skills, while gross motor skills are less affected.

Mittens or gloves provide sufficient insulation to prevent frostbite. Mittens will retain heat for a longer period of time compared to wearing gloves. However, mittens can interfere with a person's ability to grasp and manipulate objects.

EFFECTS OF COLD STRESS

The core (trunk) of the human body should remain within a small temperature range for healthy function. Excessive cooling or excessive heating will result in abnormal cardiovascular and neurological function. The skin is the organ through which a person regulates body temperature. With an average skin temperature of 33°C (91.4°F), conductive heat loss occurs at temperatures below this value. Therefore, it is easy to see how cold weather performance can significantly influence normal body function. As a person cools:

- Metabolism is increased to generate more body heat – as cooling continues a person will begin to "shiver" – a visible sign that body cooling has progressed beyond a comfortable level. Increased metabolism will reduce the amount of time a person can sustain work.
- Safe manual materials handling tasks require the use of tactile senses, hand dexterity, strength, and coordination. Decreases in the ability to produce force, exhibit fine control over objects, and sustain muscular workloads occur in cold working environment.
- Work in cold environments is related to an increased risk for musculoskeletal injury.
- Motor function impairments of the arms and hands will occur long before cognitive or hypothermic-related disabilities occur. Impaired cognitive performance will lead to poor decision-making and increased risk for accident.
- Persons suffering from arthritis or rheumatism will generally experience increased levels of pain during cold weather operations.

Extremely cold conditions [below 10°C (50°F)] adversely influence mental skills and coordination.

As operational temperatures decrease, the frequency of cognitive error will increase. Tasks requiring vigilance may be hampered after prolonged exposure to cold. Decision verification procedures should be implemented. Cold weather operations, coupled with other physical distracters, such as noise or motion environments, will influence the quality of perception, memory and reasoning and compound the risk of decision making error.

The list of potential injuries and issues for occupational work in cold environments is lengthy. Personnel should have adequate training to enhance preparation for work in cold environments. Proper planning and precaution can deter the potential risks of cold work.

Potential Medical Effects

The list of potential injuries and issues for occupational work in cold environments is lengthy. Personnel should have adequate training to enhance preparation for work in cold environments. Proper planning and precaution can deter the potential risks of cold work. The following discusses some of the potential medical effects.

Frost nip: is the first stage of frost bite when only the surface skin is frozen. Frost nip begins with itching pain. The skin then blanches and eventually the area becomes numb. Treat by moving victim to a warmer area and follow the treatment recommendations for frostbite.

Chilblains: are caused by the repeated exposure of skin to temperatures just above freezing to as high as 60 degrees F. The cold exposure causes damage to the capillary beds (groups of small blood vessels) in the skin. This damage is permanent and the redness and itching will return with additional exposure. The redness and itching typically occurs on cheeks, ears, fingers, and toes.

Frost bite*:* is damage to tissues from freezing due to formation of ice crystals within cells, rupturing the cells, and leading to cell death. Frost bite occurs when temperatures are below freezing. Symptoms include a burning sensation at first, whitened areas of skin, blistering, and the affected part may be cold, numb, and tingling. Treat by covering the frozen part, providing extra clothing and blankets, placing the affected part in warm water or covering with warm packs. Discontinue warming when part becomes flushed and swollen. Do not place pressure dressings on the affected area, or rub body part. Give sweet, warm fluids. Do not use heating device on part. Obtain medical assistance immediately.

Trench foot: (also known as immersion foot) is an injury of the feet resulting from prolonged exposure to wet and cold conditions. Trench foot can occur at temperatures as high as 60 degrees F if the feet are constantly wet. Injury occurs because wet feet lose heat 25-times faster than dry feet. Therefore, to prevent heat loss, the body constricts blood vessels to shut down circulation in the feet. Skin tissue begins to die because of lack of oxygen and nutrients and due to the buildup of toxic products.

Hypothermia: is a reduction in core body temperature that occurs when exposure to cold causes a person's body to lose heat faster than it can be replaced. Symptoms include pain in extremities, uncontrollable shivering, reduced core temperature, cool skin, rigid muscles, slower heart rate, weakened pulse, low blood pressure, slow irregular breathing, slurred speech, drowsiness, incoherence, lack of coordination, diminished dexterity, and diminished judgment. Treat by moving victim from the cold source. Remove wet clothing and get into dry clothing. Wrap victim with a blanket. Pack neck, groin and armpits with warm packs or warm towels. Give sweet, warm drinks. Keep the victim awake. And transport them to a medical facility immediately. Table 3, “Symptoms of Hyperthermia”, provides additional detail.

Table 3 – Symptoms of Hyperthermia

Mild Hypothermia	Moderate Hypothermia	Severe Hypothermia
Increased heart rate, resulting from venous return increase	Impaired respiration	Limited or no cognitive ability
Shivering	Decreased heart rate, blood pressure	Twitching of the heart muscles (atrial and ventricular fibrillation)
Excessive discharge of urine - resulting from central pooling of blood flow and resulting in rapid delivery to the kidneys	Blue-gray lips, nail beds or skin color	Possible cardiac arrest
Increased muscular tone	Muscle spasms	Unconsciousness
Decreased nerve conduction	Loss of feeling in or use of arms and legs	Death
	Loss of muscle function	
	Slurred speech	
	Blurred vision	
	Impaired cognition	
	Confusion	
	Shivering stops (resulting of used energy in prior stages)	

SUMMARY

Cold stress conditions have significant impacts on safety and productivity aboard vessels and offshore installations. Cold stress can lead to medical conditions, disabilities, and even death. Sustained cold temperatures leading to cold stress conditions can lower work performance and morale and impair mental alertness, increasing the risk of workplace accidents, and ultimately compromising the operation of the vessel/offshore installation. Moreover, cold stress may directly impact manpower requirements aboard ship when heat exposures are high enough to require work-rest rotations.

Designing for proper temperature control and utilizing better technology to avoid or reduce cold stress conditions aboard ship or offshore installation may result in crewmembers performing their duties in a comfortable and efficient manner. Designs that control or eliminate cold stress conditions will reduce the need for additional manpower (thereby reducing costs) and may improve shipboard safety, productivity, and quality of life.

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