Cold Weather Flying and Survival Information Packet

Naval Safety Center

Updated 7/17/13

Ms. Kelsey Leo

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A Deeper Threat

BY CAPT JOHN BOUCEK, USMC

While preparing for a reconnaissance mission over San Clemente Island, I reviewed the mission's sequence of events. As is my habit before every hop, I mentally rehearsed the admin, tac-admin, mission objectives and emergency procedures. However, nothing could have prepared me for the type of exposure my body was about to experience.

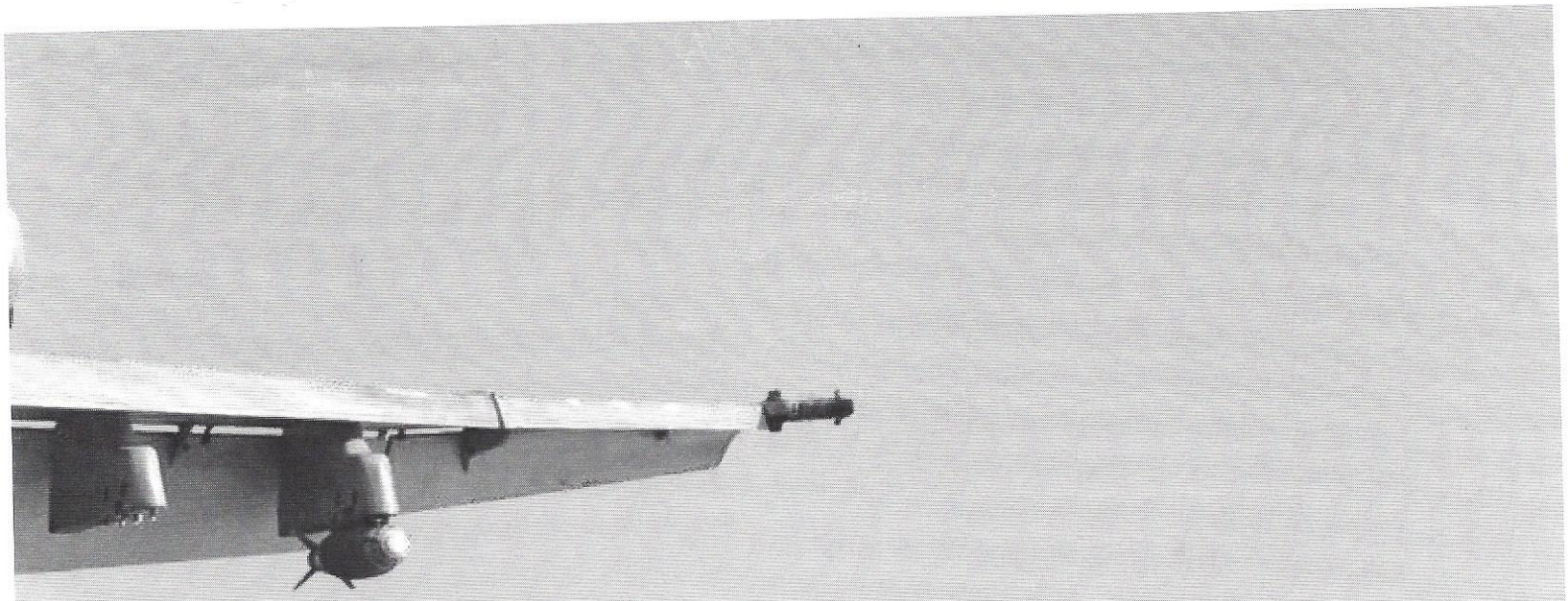
The sortie was scheduled to be a standard day, Case 1 launch, tank, check in for tasking, execute reconnaissance, and come back for the good-deal trap at sunset. I had 170 hours in the Hornet, very few of which had been flown from the carrier. Much of my attention was still focused on the basic admin and tac-admin procedures around the ship. My experience level played a key role in my ability to focus on the most rudimentary skill sets required in the carrier environment.

I saluted, grabbed the canopy handle, leaned forward in the seat, and took cat 1 for a ride. While outbound from the ship, I immediately noticed an abnormal flow of air from the environmental control system (ECS). Once established in a climb, I switched the ECS to manual, with no change in the system. I turned the temperature-control knob, but it had no influence on the flow of cockpit air. The air flow remained comfortable; however, it was colder than usual.

After the rendezvous on the tanker, I had difficulty hearing other aircraft transmissions as the ECS airflow intensified and got progressively louder. Twenty minutes into the flight, I set all the radios to max volume. This selection made it hard to distinguish which radio had received a transmission without looking at the up-front control (UFC).

I told lead of my difficulties with the ECS and the effect it had on the radios. We kept troubleshooting and decided to press on with the mission. When we reached our area of operation, the airflow volume continued to increase while the temperature plummeted. The cold became an annoyance, but not severe enough to jeopardize the mission. Lead and I maintained an ongoing dialogue. Throughout the flight, I manipulated the ECS controls to every possible configuration—to no avail.

My next indication of the rapidly deteriorating conditions was the seemingly locked defog handle. The increased cold airflow froze the handle so that I needed two hands to operate it. I slammed the defog handle



Who among us would choose to call base and tell them we are not going to complete the mission because we are cold?

forward to keep the airflow off my hands as much as possible. The redirected airflow allowed my hands to maintain sufficient tactile function and dexterity to operate switches.

About one hour after launch, as we neared the end of the mission, I tried to write some notes on my kneeboard. I couldn't get my pen to write, so I pulled out the pen I keep in my sleeve—it didn't work either. I opened my bag to find my water bottle had crystallized with ice on top. The conditions in my cockpit had deteriorated at such a rate that I needed to speak up before being boxed into a corner.

WHEN WE FINISHED OUR MISSION, we checked out with the E-2 overhead San Clemente, and I joined up with my flight lead. Fifteen minutes later, I began to lose feeling in my hands and fingers. The information passed to my brain grew increasingly vague. I had to consciously watch my hand push each button or switch to confirm that I had actually pushed it. I trimmed the jet with my palm because of the lack of finger dexterity. My jaw stiffened, as well—speaking required more effort. The flight rapidly evolved into intense discomfort.

I checked in with marshal, and told my lead that I needed straight-and-level time. I removed my gloves and mask, and breathed into my hands.

We called the squadron rep on the auxiliary radio to include him in our decision matrix. The rep quickly determined that NATOPS did not have a course-of-action for ECS stuck in full cold. In lieu of an appropriate procedure, he referenced "Cockpit Temperature High." We decided to descend and move the cabin-press switch to the RAM/DUMP position to dump the cabin pressurization and raise the temperature. The decision to dump the cabin pressure successfully halted the decrease in temperature, and while it remained cold, it prevented further degradation.

Lead wrote down my marshaling instructions and read them back to me. I carved my push time, holding radial and DME into my kneeboard. I noticed my mind internalizing and losing focus while I worked my timing problem in marshal. The sun quickly escaped the horizon, barely leaving behind a sliver of ambient light. My teeth chattered as I assessed whether I could fly the approach without an unnecessary elevation of risk. I could have easily diverted to North Island if I had not been comfortable with my physical state. Having

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breathed into my palms to warm them and at a lower altitude, I began to regain sensation in my hands. I now felt comfortable making the approach.

We told the squadron rep that we could recover on a standard CV 1 approach. We coordinated with marshal to have lead fly a loose formation off me to monitor my progress. He supervised my holding, made sure I leveled off at the proper altitudes, and turned to the correct headings. If any problems arose, I could have easily found him off my left wing and diverted to North Island. I pushed out of the marshal stack first and returned for an uneventful trap.

I parked the jet and opened the canopy to a welcome rush of warm ocean air. Every display in the jet immediately fogged up. I climbed out and noticed that I couldn't feel the ladder under my feet. I had not realized that my feet had become completely numb. During the next two hours, the sensation in my hands and feet gradually returned. I successfully walked away from my first winter in the Hornet.

The maintenance analysis showed that the cabin-air-flow-temperature sensor had failed. Also, the seal within the cabin-add-heat valve had a leak which resulted in a "full cold" condition. The system-flow-modulating-pressure-regulating valve (SMRF) received inaccurate information from the failed sensor, which resulted in strong airflow regardless of the settings on the ECS panel. Maintenance removed and replaced the faulty sensor and the cabin-add-heat valve. The aircraft returned to service.

There were several important takeaways from this flight. First, there was a lack of established NATOPS procedures to help guide me through this situation. My slow recognition of the deteriorating conditions could have resulted in a divert to North Island or more drastic measures. Currently, there is not a checklist in the Hornet NATOPS that addresses ECS full cold. However, steps can be taken to help you in the same situation. Descending and switching the cabin-pressurization switch to RAM/DUMP earlier might have alleviated the drastic decrease in temperature. I thought about requesting a Mode 1 approach, but the ship's system was not working that day. As a last resort, you could shut off your engine bleeds, but you must keep in mind the critical systems you will lose (such as OBOGS, cabin pressurization, anti-G and external fuel transfer). Cockpit temp high is a good reference point for the other systems you can manipulate.

Second, our continuous crew coordination was vital to making the proper decisions and keeping the right people informed throughout this emergency. CRM and ORM allowed the team to make an educated decision to bring me aboard, and was vital in risk mitigation.

Last, and most significantly, I learned an important lesson about hubris. In hindsight, my focus on the mission, rush of adrenaline, and increased blood flow all contributed to heating my body. I did not know that the cockpit would cool at such an exponential rate. My focus on the mission allowed me to ignore external environmental factors while I was "in the zone." Only after everything settled down, and I had a minute to relax, did I recognize the severity of the situation. Like most Hornet emergencies, the proficiency and experience of the pilot dictates how the emergency concludes. However, this emergency affected the pilot on a more personal level, because it challenged both the pilot and his ego. Type A personalities don't exude submission. Who among us would choose to call base and tell them we are not going to complete the mission because we are cold?

This question points to a potentially deeper threat to our community: pride. If we find ourselves considering what our peers may think, we are wrong. We usually have black and white answers in NATOPS that tell us what to do and when to do it. In this case, there is nothing in NATOPS that addresses ECS full cold. Understanding your systems and a deeper knowledge of NATOPS will greatly increase your success rate in handling situations. We often take a jet flying with degraded systems. However, we remain confident it will get us to and from our area of operation without significant complications. We rarely consider the degraded pilot.

The above scenario demonstrated that an aircraft can fly flawlessly, however the pilot can potentially become the weakest link.

CAPT BOUCEK FLIES VMFA-323.

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Below Freezing in the Day—Colder at Night

An MH-60s crew goes down in a wooded area in West Virginia on a training flight with 17 people onboard. Rescue is hours away. It's cold and getting colder.

BY LTJG. TIM LABRESH

The weather is something that aviators continually review. We use temperature, pressure altitude, and density altitude to calculate what power we expect to get from our engines and performance from our aircraft. That result matches up to what power is needed for the different phases of flight such as takeoff and landing. We use projected weather for the areas in which we intend to operate to make decisions on where we are going to fly, what we expect to encounter, and if we can get the operational or training mission completed.

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As much as we consider the weather for the mission, we do not always prepare for the conditions we might encounter if we were forced to unexpectedly land, ditch or eject. In recent years, the military has been operating in primarily hot climates such as Iraq and Afghanistan. Most of the emphasis for the last decade, understandably, has been on training and equipping our forces for the hot weather they will encounter. Although not as often, we train in cold weather back in the states.

I rarely feel cold in the cockpit, regardless of the outside temperature; the environmental control system (ECS) works as advertised. Even in the Virginia winters, I am comfortable flying with only the required gear: flight suit, helmet, gloves, boots and survival vest. This is the basic gear we wear on every flight, regardless of the time of year. On flights like this, the only part of a pilot that typically gets cold is their feet, and those freeze regardless. We didn't wear cold-weather boots.

In a recent mishap involving a helicopter operating in mountainous terrain in the middle of winter, there was a lack of ade-

quate cold-weather gear. The crew went down in a very remote, wooded area in the mountains of West Virginia. The aircrew found themselves in snow-covered terrain, cold-weather survival came to the forefront—this was no longer a training scenario. Some crew members were stranded in this environment for more than 14 hours. Were they prepared?

The aircrew and passengers were from three different Navy, Marine and Army commands. Realizing the crew did not have adequate gear, they had to improvise or go without. Some had thermal underwear and others had wool socks, but nobody was fully prepared. The doors had stayed closed in flight, so they didn't feel the wind or the chill. On the ground, the temperatures were below freezing during the day and even colder at night.

MONTHS BEFORE THIS MISHAP, a training evolution known as Southbound Trooper was completed in Blackstone, VA., at the Fort Pickett National Guard Training Facility. Ten of our pilots and 10 aircrewmen supported this exercise. The temperatures were in the 50s and 40s during the day and dipped at night. We wore our flight suits and our light summer-weight jackets—the only jackets we were issued and are approved for aircraft use. Several crew members had lightweight fleece vests. This equipment was fine for the short time we spent coming and going from our operations building and inspecting the aircraft, but not adequate for extended periods in freezing temperatures. We were issued winter gloves but no pilot wore them, as they are too bulky to maneuver the controls and still do all the button-pushing required to operate our aircraft. We also had long underwear and winter socks, but it was more of a personal preference than required equipment. Most of the flying we did was within the confines of the base, and you didn't have to worry about being outside for a long period of time, so naturally we wore what was comfortable. Months later, the mishap crew flew farther west into the mountains, and did not adjust their cold-weather clothing and survival gear.

Obviously, that was the wrong approach. We were well prepared for the worst flying conditions, however, we weren't adequately prepared for what we would encounter if we were outside of the aircraft.

The value of land-survival training for the crew and most of the passengers prevented frostbite or cold-weather injuries. They made use of their personal and aircraft survival gear and items, such as the two wool blankets kept in the SAR curtain. Some of the passengers brought day packs which provided e-tools and MREs.

There were three different types among the crew, so selecting which radios would be most effective became a concern. Being in a canyon in a quiet area with no nearby cell phone towers didn't help the situation. Interference among the radios and with the downed aviator locator system (DALS) also was a problem. The Army radios seemed to have the best reception, and by turning the other radios off, as well as the emergency locator, we eventually contacted a civil aircraft, who relayed our situation.

Small amounts of engine oil and pyrotechnics helped make a controlled fire that kept the crew and passengers warm and occupied. The injured were kept inside the helicopter to keep them warm, and out of the wind and driving snow. Improvisation and survival training helped prevent hypothermia and other cold-related injuries.

Pencil flares were instrumental in the rescue process. They could be seen through the driving snow. Several people climbed a tree and hung a reflective orange sheet. When the weather cleared the rescue crews spotted the crash site only because of the orange sheet.

We hadn't adequately managed all the potential risks, and were not prepared with the optimum survival gear. Fortunately, everyone made it home and without any major cold-weather injuries. As in all our flights, and certainly in any mishaps, we try to learn from the mistakes that cost us as well as the ones that didn't.

LTJG. LABRESH FLIES WITH HSC-26.

Cold-weather gear is costly, and here we see the necessity for the gear to be on the person, if not in the aircraft. Don't dress for the flight, dress for the crash.—Editor.

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Hypothermia

Hypothermia is a core body temperature < 35° C. Symptoms progress from shivering and lethargy to confusion, coma, and death. Mild hypothermia requires a warm environment and insulating blankets (passive rewarming). Severe hypothermia requires active rewarming of the body surface (eg, with forced-air warming systems, radiant sources) or core (eg, inhalation, heated infusion and lavage, extracorporeal blood rewarming).

Primary hypothermia causes about 600 deaths each year in the US. Hypothermia also has a significant and underrecognized effect on mortality risk in cardiovascular and neurologic disorders.

Etiology

Hypothermia results when body heat loss exceeds body heat production. Hypothermia is most common during cold weather or immersion in cold water, but it may occur in warm climates when people lie immobile on a cool surface (eg, when they are intoxicated) or after very prolonged immersion in swimming-temperature water (eg, 20 to 24° C). Wet clothing and wind chill increase risk of hypothermia.

Conditions that cause loss of consciousness, immobility, or both (eg, trauma, hypoglycemia, seizure disorders, stroke, drug or alcohol intoxication) are common predisposing factors. The elderly and the very young also are at high risk. The elderly often have diminished temperature sensation and impaired mobility and communication, resulting in a tendency to remain in an overly cool environment. These impairments, combined with diminished subcutaneous fat, contribute to hypothermia in the elderly—sometimes even indoors in cool rooms. The very young have similarly diminished mobility and communication and have an increased surface area/mass ratio, which enhances heat loss. Intoxicated people who lose consciousness in a cold environment are likely to become hypothermic.

Pathophysiology

Hypothermia slows all physiologic functions, including cardiovascular and respiratory systems, nerve conduction, mental acuity, neuromuscular reaction time, and metabolic rate. Thermoregulation ceases below about 30° C; the body must then depend on an external heat source for rewarming. Renal cell dysfunction and decreased levels of ADH lead to production of a large volume of dilute urine (cold diuresis). Diuresis plus fluid leakage into the interstitial tissues causes hypovolemia. Vasoconstriction, which occurs with hypothermia, may mask hypovolemia, which then manifests as sudden shock or cardiac arrest during rewarming (rewarming collapse) when peripheral vasculature dilates.

Immersion in cold water can trigger the diving reflex, which involves reflex vasoconstriction in visceral muscles; blood is shunted to essential organs (eg, heart, brain). The reflex is most pronounced in small children and may help protect them. Also, hypothermia due to total immersion in near-freezing water may protect the brain from hypoxia by decreasing metabolic demands. The decreased demand probably accounts for the occasional survival after prolonged cardiac arrest due to extreme hypothermia.

Symptoms and Signs

Intense shivering occurs initially, but it ceases below about 31° C, allowing body temperature to drop more precipitously. CNS dysfunction progresses as body temperature decreases; people do not sense the cold. Lethargy and clumsiness are followed by confusion, irritability, sometimes hallucinations, and eventually coma. Pupils may become unreactive. Respirations and heartbeat slow and ultimately cease. Initially, sinus bradycardia is followed by

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slow atrial fibrillation; the terminal rhythm is ventricular fibrillation or asystole. However, these rhythms are potentially less ominous than in normothermia.

Diagnosis

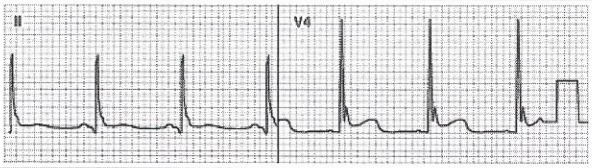
- Core temperature measurement
- Consideration of intoxication, myxedema, sepsis, hypoglycemia, and trauma

Diagnosis is by core temperature, not oral temperature. Electronic thermometers are preferred; many standard mercury thermometers have a lower limit of 34° C. Rectal, bladder, and esophageal probes are most accurate.

Laboratory tests include CBC, glucose (including bedside measurement), electrolytes, BUN, creatinine, and ABGs. ABGs are not corrected for low temperature. ECG typically shows J (Osborn) waves (see Fig. 1: Cold Injury: Abnormal ECG showing J (Osborn) waves (V4).) and interval prolongation (PR, QRS, QT), although these findings are not always present. Causes are sought. If the cause is unclear, alcohol level is measured, and drug screening and thyroid function tests are done. Sepsis and occult head or skeletal trauma must be considered.

Fig. 1

Abnormal ECG showing J (Osborn) waves (V4).



Clinical Calculator
Corrected QT Interval (QTc)
Provided by MD+CALC

Prognosis

Patients who have been immersed in icy water for 1 h or (rarely) longer have sometimes been successfully rewarmed without permanent brain damage (see Drowning: Prognosis), even when core temperatures were very low or when pupils were unreactive. Outcome is difficult to predict and cannot be based on the Glasgow Coma Scale. Grave prognostic markers include evidence of cell lysis (hyperkalemia > 10 mEq/L), intravascular thrombosis (fibrinogen < 50 mg/dL), and presence of a nonperfusing cardiac rhythm (ventricular fibrillation or asystole). For a given degree and duration of hypothermia, children are more likely to recover than adults.

Treatment

- Drying and insulation
- Fluid resuscitation
- Active rewarming unless hypothermia is mild, accidental, and uncomplicated

The first priority is to prevent further heat loss by removing wet clothing and insulating the patient. Subsequent measures depend on how severe hypothermia is and whether cardiovascular instability or cardiac arrest is present. Returning patients to a normal temperature is less urgent in hypothermia than in severe hyperthermia. For stable patients, elevation of core temperature by 1° C/h is acceptable.

If hypothermia is mild and thermoregulation is present (indicated by shivering and temperature typically 31 to 35° C), insulation with heated blankets and warm fluids to drink are adequate.

Fluid resuscitation is essential for hypovolemia. Patients are given 1 to 2 L of 0.9% saline solution (20 mL/kg for

children) IV; if possible, the solution is heated to 40 to 42° C. More fluid is given as needed to maintain perfusion.

Active rewarming: Active rewarming is required if patients have cardiovascular instability, temperature < 32.2° C, hormone insufficiency (such as hypoadrenalism or hypothyroidism), or hypothermia secondary to trauma, toxins, or predisposing disorders. If body temperature is at the warmer end of the range, external rewarming with forced hot air enclosures may be used. External heat is best applied to the thorax because warming the extremities may increase metabolic demands on a depressed cardiovascular system. Patients with lower temperatures, particularly those with low BP or cardiac arrest, require core rewarming.

Core rewarming options include

- Inhalation
- IV infusion
- Lavage
- Extracorporeal core rewarming (ECR)

Inhalation of heated (40 to 45° C), humidified O_2 via mask or endotracheal tube eliminates respiratory heat loss and can add 1 to 2° C/h to the rewarming rate.

IV crystalloids or blood should be heated to 40 to 42° C, especially with massive volume resuscitations.

Heated lavage of the bladder or GI tract transfers minimal heat, although closed thoracic lavage through 2 thoracostomy tubes is very efficient in severe cases. Peritoneal lavage with dialysate heated to 40 to 45° C requires 2 catheters with outflow suction and is expecially useful for severely hypothermic patients who have rhabdomyolysis, toxin ingestions, or electrolyte abnormalities.

There are 4 types of ECR: hemodialysis, venovenous, arteriovenous, and cardiopulmonary bypass. ECR measures require a prearranged protocol with appropriate specialists. Although they are intuitively attractive and heroic, these measures are not routinely available, and they are not commonly used in most hospitals.

CPR: CPR is not done if patients have a perfusing rhythm, even if pulses are not palpable. Fluids are given, and active rewarming is done. Hypotension and bradycardia are expected when core temperature is low and, if due solely to hypothermia, need not be aggressively treated. Patients with a nonperfusing rhythm require CPR. Chest compressions and endotracheal intubation are done. Defibrillation is difficult if body temperature is low; one attempt with a 2 watt sec/Kg charge may be made, but if ineffective, further attempts are generally deferred until temperature reaches > 30° C. Advanced life support should be continued until temperature reaches 32° C unless obviously lethal injuries or disorders are present. However, advanced cardiac life-support drugs (eg, antiarrhythmics, vasopressors, inotropes) are usually not given. Low-dose dopamine (1 to 5 µg/kg/min) or other catecholamine infusions are typically reserved for patients who have disproportionately severe hypotension and who do not respond to fluid resuscitation and rewarming. Severe hyperkalemia (> 10 mEq/L) during resuscitation typically indicates a fatal outcome and can guide resuscitation efforts.

Key Points

- Measure core temperature using an electronic thermometer or probe.
- Above about 32° C, heated blankets and warm drinks are adequate treatment.
- Below about 32° C, active rewarming should be done, typically using hot air enclosures, heated, humidified O_2, warm IV fluid, and sometimes heated lavage or extracorporeal methods (eg, cardiopulmonary bypass, hemodialysis).
- At lower temperatures, patients are hypovolemic and require fluid resuscitation.
- CPR is not done if there is a perfusing rhythm; when it is done, defibrillation is deferred (after one initial attempt) until temperature reaches about 30° C.
- Advanced cardiac life-support drugs are usually not given.

Last full review/revision May 2012 by Daniel F. Danzl, MD

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Content last modified May 2012

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Overview of Cold Injury

Exposure to cold may cause decreased body temperature (hypothermia) and focal soft-tissue injury. Tissue injury with freezing is frostbite. Tissue injury without freezing includes frostnip, immersion foot, and chilblains. Treatment is rewarming and selective, usually delayed, surgical treatment for injured tissues.

Susceptibility to all cold injury is increased by exhaustion, undernutrition, dehydration, hypoxia, impaired cardiovascular function, and contact with moisture or metal.

Prevention

Prevention is crucial. Several layers of warm clothing and protection against moisture and wind are important even when the weather does not seem to threaten cold injury. Clothing that remains insulating when wet (eg, made of wool or polypropylene) should be worn. Gloves and socks should be kept as dry as possible; insulated boots that do not impede circulation should be worn in very cold weather. A warm head covering is also important. Consuming ample fluids and food helps sustain metabolic heat production. Paying attention to when body parts become cold or numb and immediately warming them may prevent cold injury.

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Overview of Cold Injuries

The skin and the tissues under it are kept at a constant temperature (about 98.6° F, or 37°C) by the circulating blood and other mechanisms. The blood gets its heat mainly from the energy given off by cells when they burn (metabolize) food—a process that requires a steady supply of food and oxygen. A normal body temperature is necessary for proper functioning of all the cells and tissues in the body. In a person with low body temperature, most organs, especially the heart and brain, become sluggish and eventually stop working.

Body temperature falls when the skin is exposed to colder surroundings. In response to this fall in temperature, the body uses several protective mechanisms to generate additional heat. For example, the muscles produce additional heat through shivering. Also, the small blood vessels in the skin narrow (constrict), so that more blood is diverted to vital organs, such as the heart and brain. However, as less warm blood reaches the skin, body parts such as the fingers, toes, ears, and nose cool more rapidly. If body temperature falls much below about 88° F (about 31° C), these protective mechanisms stop working, and the body cannot warm itself. If body temperature falls below 83° F (about 28° C), death is likely.

Cold injuries are less likely to occur, even in extremely cold weather, if the skin, fingers, toes, ears, and nose are well protected or are exposed only briefly. The risk of cold injuries increases in the following circumstances:

- When the flow of blood is too slow
- When food intake is inadequate
- When dehydration or exhaustion occur
- When the environment is wet or when a body part contacts something wet
- When the person comes into contact with a metal surface
- When insufficient oxygen is available, as occurs at high altitude

Keeping warm in a cold environment requires several layers of clothing—preferably wool or synthetics such as polypropylene, because these materials insulate even when wet. Because the body loses a large amount of heat from the head, a warm hat is essential. Eating enough food and drinking enough fluids (particularly warm fluids) also help. Food provides fuel to be burned, and warm fluids directly provide heat and prevent dehydration. Alcoholic beverages should be avoided, because alcohol widens (dilates) blood vessels in the skin, which makes the body temporarily feel warm but actually causes greater heat loss.

Cold injuries include hypothermia, frostnip, chilblains, immersion foot, and frostbite. Other problems related to the cold include Raynaud syndrome (see Peripheral Arterial Disease: Raynaud's Syndrome) and allergic reactions to the cold (see Allergic Reactions and Other Hypersensitivity Disorders: Physical Allergy).

Did You Know...

- Drinking alcoholic beverages actually makes the body colder because the widening of blood vessels that makes a person feel warm allows more heat to escape from the body.

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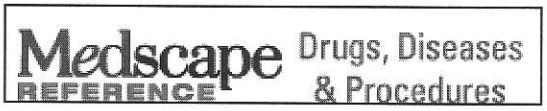

Causes

Hypothermia or systemic cold injury is a clinical condition in which the core body temperature has decreased to 35°C (95°F) or less. The causes of hypothermia are either primary or secondary. Primary, or accidental, hypothermia occurs in healthy individuals inadequately clothed and exposed to severe cooling.[4] Accidental hypothermia can be divided into immersion and nonimmersion cold exposure. The high thermal conductivity of water leads to the rapid development of immersion hypothermia. Although the rate of heat loss is determined by water temperature, immersion in any water less than 16°C (60.8°F) may lead to hypothermia within minutes.

When individuals are buried in the snow of an avalanche, they must be extricated from the scene of the avalanche accident as soon as possible.[5] In fact, rapid extrication is the most important determinant of positive outcome in snow avalanche victims. To facilitate the rapid localization of avalanche victims, avalanche transceivers are widely used during off-piste and back country activities.

Hohlrieder et al conducted a retrospective study to analyze the influence of transceivers on the mortality of avalanche victims.[5] In the 194 accidents in Austria between 1994-2003, 278 victims were totally buried. Avalanche transceivers were used by 156 victims (56%), and transceiver use was associated with a significant reduction in the median burial time, which decreased from 102 minutes to 20 minutes ($P < .001$). Transceiver use was also associated with a significant reduction in mortality, which decreased from 68.0% to 53.8%. This reduction reflects a decrease in mortality during back country activities that involved ski tourists in free alpine areas. Transceivers did not significantly reduce mortality when they were used in off-piste activities beside or near organized ski slopes.

Even if a person is using a transceiver, mortality is significantly higher if burial depth exceeds 1.5 m. Despite a significant reduction in mortality, mortality still exceeds 50% even with transceivers. Consequently, even with the use of emergency equipment and life transceivers, avoiding avalanches is critically important. The authors conclude that the fairly modest influence of the use of transceivers on survival probability may also be due to the high efficiency of the mountain rescue service in the Austrian Alps.

In secondary hypothermia, another illness predisposes the individual to accidental hypothermia. The mechanism of secondary hypothermia appears to be an acute failure of thermoregulation; shivering does not usually occur in these patients. In many reports, alcohol seems to be a predominant cause of cutaneous vasodilation, loss of shivering, hypothalamic dysfunction, and lack of concern regarding the environment.[6] Other factors that predispose an individual to acute hypothermia include the following:

- Endocrine diseases (eg, hypothyroidism, pituitary insufficiency, Addison disease, diabetes mellitus[7])
- Cardiovascular diseases (eg, myocardial infarction,[8] congestive heart failure, vascular insufficiency)
- Neurologic diseases (eg, cerebrovascular accident, head injury, tumor, spinal cord injury, Alzheimer disease[9])
- Drugs (eg, phenothiazines, barbiturates, antidepressants)
- Pancreatitis
- Cirrhosis
- Hypoglycemia

Clinical presentation

Hypothermia affects multiple organs.[10] Initially, the metabolic rate increases, with tachycardia, tachypnea, increased muscle tone, and peripheral vascular resistance to generate maximal shivering. With continued hypothermia, the metabolism progressively declines, with bradycardia and hypoventilation and subsequent carbon dioxide retention. The heart rate drops to half its normal rate at 28°C (82.4°F), and ventricular contractility decreases. The risk of ventricular fibrillation increases at temperatures below 28°C (82.4°F). Cerebral metabolism is decreased 6-7% per 1° C drop in temperature, which results in a declining level of consciousness. Autoregulation of cerebral blood flow is impaired at temperatures below 25°C (77°F). The shivering mechanism of thermoregulation stops at 31°C (87.8°F).

The symptoms of hypothermia vary depending on the severity of the cold injury. In mild hypothermia, clinical symptoms are often vague and include dizziness, fatigue, joint stiffness, nausea, and pruritus. The skin is pale and cool as a result of peripheral vasoconstriction. The patient may exhibit lethargy, flat affect, impaired judgment, and mild confusion progressing to motor incoordination, ataxia, and slurred speech.

In severe hypothermia, mental status is further impaired, leading to hallucinations, stupor, and even coma. Atrial and ventricular arrhythmias are common with moderate hypothermia. The Osborn (J) point, an upward deflection at the junction of the QRS complex and the ST segment, can usually be seen on the ECG. The patient may appear clinically dead, with nonpalpable peripheral pulses, fixed and dilated pupils, loss of ocular reflexes, and stiff extensor

posturing. Cardiac standstill usually occurs at 20°C (68°F), but one report described a survivor whose temperature was 15°C (60.8°F).

Diagnosis

The diagnosis of hypothermia is easy if the patient is a mountaineer who is stranded in cold weather.[11, 12] However, it may be more difficult in an elderly patient who has been exposed to a cold external environment. In either case, the rectal temperature should be checked with a low-reading thermometer. The diagnosis of accidental hypothermia has proved elusive, largely because clinical thermometers do not record temperatures below 35°C (95°F). The only inexpensive low-reading thermometer is the Zeal (Zeal Group Ltd; London). Electronic thermometers with digital readouts and remote electric probes are made by several companies. Rectal temperature measurements are influenced by lower body temperature and probe placement. An inaccurate reading may result if the rectal probe was inserted in cold feces or to a depth of less than 15 cm.

Other methods of determining core body temperature include infrared tympanic thermometers, esophageal probes in intubated patients, and bladder thermistors embedded in a urinary catheter. The tympanic probe accurately measures hypothalamic temperature and most rapidly changes to reflect variations in core body temperature. On the basis of temperature measurements, the arbitrary classification of the level of hypothermia is mild (< 34°C [93.2°F]), moderate (28-34°C [82.4-93.2°F]), and severe, with a boundary core temperature of less than 28°C (82.4°F).

Treatment & Management

Field First Aid and Prehospital Management

The general principles of prehospital management are to (1) prevent further heat loss, (2) rewarm the body core temperature in advance of the shell, and (3) avoid precipitating ventricular fibrillation. The application of these principles depends on the patient's core temperature, the equipment available, and the presence of complicating illnesses or injuries.

Mild hypothermia

For a person with mild hypothermia (≥ 33°C [91°F]), found in a cold environment, the first priority is to search for other injuries in that person and/or other affected individuals. The second priority is to increase the patient's core temperature to normal, before and during transport to the hospital. The patient should be moved into a tent or other dry shelter for protection from the wind. Wet clothing should be removed by cutting along the seams. Insulation, such as a sleeping bag, should be placed under and over the patient, who should not be allowed to stand or sit and whose head should be covered. A fire should be built or a stove lit. No fluids should be given by mouth. The patient should be transported to the hospital in an ambulance heated to 30°C (86°F).

Severe hypothermia

Severe hypothermia (< 28°C [82.4°F]) should be treated as a life-threatening emergency. Attention should be directed first to the cardiopulmonary system. If the patient is breathing, humidified vented oxygen (10 L/min) should be administered using a nonrebreathing reservoir mask. If the patient is not breathing, ventilation should be initiated with a bag-valve-mask ventilator or a pocket mask connected to a humidified, heated oxygen delivery system.

The patient should not be hyperventilated because this may induce ventricular fibrillation. If bradycardia and hypotension are evident, do not perform cardiac compressions because this, too, may precipitate ventricular fibrillation. To avoid inappropriate chest compressions, prehospital personnel must examine the patient for a full minute before diagnosing pulselessness. If the patient is pulseless, external cardiac compressions with ventilations should be initiated unless the exterior wall is frozen and not compressible. Cardiopulmonary resuscitation should continue until the patient is evaluated and treated in the hospital.

Always follow the dictum that patients with severe hypothermia are never dead until they are warm and dead. Even with prolonged cardiac arrest, resuscitation is possible. Many physicians who are specialists in hypothermia believe that patients with severe hypothermia should not be rewarmed in the field, but, rather, kept in a "metabolic icebox" until in a hospital setting in which physiologic monitoring and advanced life-support equipment are available.

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Hospital Treatment

Upon the patient's arrival in the emergency department, the physician must focus on cardiopulmonary function. If the patient is still not breathing, endotracheal intubation should be undertaken to maintain the airway. Frozen skin may require cricothyroidotomy. External cardiac compressions must be continued in pulseless patients with compressible chest walls. A central venous access line should be established to obtain blood for laboratory studies and to administer fluids for volume expansion. A venous cutdown may be necessary because vasoconstriction and hypovolemia may make percutaneous catheterization impossible. Central venous pressure monitoring is useful to determine the results of volume expansion in patients with severe hypothermia and hypovolemic shock.

Baseline laboratory determinations should include a complete blood cell count; levels of blood glucose, electrolyte, phosphorus, creatinine, amylase, lactic dehydrogenase isoenzyme, and creatine kinase isoenzyme; prothrombin time; activated partial thromboplastin time (aPTT); and arterial blood gas values. These laboratory studies should be repeated as indicated. A toxicologic evaluation is recommended for any patient whose history is unknown or who may have ingested a drug or poison. An initial 12-lead ECG should be obtained, after which the patient should have continuous cardiac monitoring. Intensely cold skin may preclude adequate transmission of electrical impulses to the electrocardiographic electrodes. A Foley catheter is introduced into the bladder to monitor urine output and to provide specimens for urinalysis and toxicology screening, including urine myoglobin levels.

(For detailed descriptions of catheterization, see Clinical Procedures articles Urethral Catheterization, Women, and Urethral Catheterization, Men.) Expired carbon dioxide analysis may help determine the level of asphyxiation.

Treatment of hypothermic patients should include volume expansion, cardiopulmonary support, and rewarming. Blood volume should be expanded using heated crystalloid solutions, such as dextrose in saline, to maintain blood pressure and coronary perfusion. In adults, 300-500 mL should be administered rapidly, with the subsequent rate of infusion adjusted according to the blood pressure. The solution should be warmed to 45°C (111°F) by heat exchangers or blood warmers. Fluid replacement may lead to increases in ventricular filling pressures, increased cardiac work, and pulmonary edema.

Supplemental oxygen is necessary to prevent hypoxia, reduce the risk of ventricular fibrillation, and treat pulmonary edema. Oxygen delivery to hypothermic patients should be maximized by the use of 100% oxygen during rewarming. Hyperventilation should be avoided because it may trigger ventricular fibrillation.

Although severe cardiac arrhythmias in hypothermic patients may represent an immediate threat to life, most rhythm disturbances (eg, sinus bradycardia, atrial fibrillation or flutter) require no therapy and revert spontaneously with rewarming. Ventricular fibrillation may be refractory to therapy until the patient is rewarmed to at least 34°C (93.2°F). At core body temperatures below 30°C (86°F), the heart is usually unresponsive to defibrillation, pacemaker stimulation, and cardioactive drugs.

Patients with ventricular fibrillation should receive 1-2 attempts at electrical defibrillation once the temperature is above 28°C (82.4°F). One dose of 10 mg/kg of bretylium (Bretylol) may be given; it is the only antiarrhythmic drug effective at low temperatures. If this is unsuccessful, cardiopulmonary resuscitation should be started or continued with active rewarming until the patient's core body temperature is above 32°C (89.6°F). As the myocardium warms, the rhythm may revert spontaneously or in response to electrical defibrillation.

The hypothermic heart is poorly responsive to the pharmacologic effects of medications. Excessive medication levels can accumulate as a result of decreased hepatic metabolism and increased protein binding, resulting in toxicity when rewarming occurs. Therefore, nonessential medications should not be given until after rewarming. For information on various medication toxicities, see the eMedicine Emergency Medicine Toxicology section.

Coagulopathy is an underappreciated cause of morbidity in patients with moderate and profound hypothermia. Platelets are sequestered in frostbitten areas and in the lungs, causing thrombocytopenia and failure of platelets to clot. The aPTT becomes prolonged as core temperatures decrease. The combination of a prolonged aPTT and thrombocytopenia produces clinical disseminated intravascular coagulation. The passage of a nasogastric tube through friable nasal passages may produce torrential bleeding.

Rewarming Techniques

The 2 general techniques of rewarming are passive rewarming and active rewarming.[13] The capacity of humans with mild-to-moderate hypothermia to rewarm spontaneously after removal from the hypothermic condition accounts for the beneficial effects of passive rewarming. Because patients often become hypothermic over a period of days or hours, passive rewarming is physiologically sound, avoiding rapid changes in the cardiovascular status and the complications associated with active rewarming methods. Passive rewarming is a safe and simple method of treating

mild hypothermia, and it is frequently the only method available for field management. Passive rewarming and noninvasive methods can also be used for patients with severe hypothermia (< 28°C [91.4°F]) with a stable cardiac rhythm (including sinus bradycardia and atrial fibrillation) and stable vital signs. However, it is not recommended for patients with cardiovascular compromise.

Passive rewarming involves effective insulation of the patient, allowing the patient's spontaneous metabolic heat to rewarm the body. With this technique, the patient is covered with 1-2 blankets and rewarmed at a room temperature of 25-33°C (77-91.4°F). The increase in core temperature varies from 0.5-2°C/h; 24 hours may be required to achieve a normal temperature. If the increase in temperature is less than 0.5°C/h, the presence of a complicating disease, such as hypothyroidism, should be considered.

Active rewarming involves the internal or external addition of heat to the body. Active external rewarming works best for patients with mild or moderate hypothermia because it applies exogenous heat to the surface of the body in the form of warm packs, heating blankets, radiant heat, and warm water immersion. Concern has been raised about the efficacy of actively rewarming from the surface because of inherent physiologic changes that may aggravate the effects of hypothermia on dermal tissues that are poorly perfused because of vasoconstriction.

Active external rewarming may precipitate hypovolemic rewarming shock by decreasing the circulating blood volume secondary to peripheral vasodilation in an already hypovolemic patient. This peripheral vasodilation paradoxically causes central cooling by shunting stagnant, cold blood to the core, thus further chilling the myocardium, depressing contractility, and increasing its vulnerability to ventricular fibrillation.

The safest method of active rewarming of patients with severe hypothermia is internal rewarming that increases the core temperature. Active core rewarming should be used in patients with core temperatures lower than 32°C (90°F), who are hemodynamically unstable, or in whom more conservative rewarming methods have failed. Internal or core rewarming has the advantage of minimizing rewarming shock by warming the central core circulation first. Heat may be added internally by heated humidified inhalation, peritoneal dialysis, mediastinal irrigation, gastrointestinal tract irrigation, arterial venous shunting including hemodialysis, or extracorporeal bypass.

Airway rewarming at 40-45°C (104-113°F) prevents respiratory heat loss and raises body temperature 1-2°C/h. It also provides warm blood to the coronary arteries. In patients with severe hypothermia, air rewarming should be used as an adjunct to more rapid rewarming methods.

Peritoneal lavage with warmed potassium-free dialysate 40-45°C (104-113°F) is more effective, raising the body temperature 2-4°C/h. Irrigation of the stomach or colon with warm fluids produces minimal rewarming because the surface area available for heat exchange is small; also, this may cause mucosal sloughing in the very cold tissues. Arterial venous shunts and hemodialysis warm the blood directly but require cannulas to be inserted into arteriotomies.

Extracorporeal rewarming is the most rapid and efficient method of rewarming and is indicated in patients with cardiac arrest or impending cardiac arrest. Cutdowns may be necessary to place cannulas in the heart, aorta, or femoral vessels. A cardiopulmonary bypass circuit can achieve rewarming of 1-2°C every 3-5 minutes, but it mandates anticoagulation. Cardiopulmonary bypass resuscitation has been successful even after prolonged cardiac arrest unresponsive to other resuscitative and rewarming methods. Contraindications to the use of cardiopulmonary bypass for rewarming are severe brain injury, hyperkalemia (potassium level >7 mEq/L), and clotted or gelled blood in the arteries.

Gilbert et al reported the results of resuscitation of a 29-year-old skier who sustained accidental hypothermia after skiing down a waterfall gully.[14] She responded to a treatment using extracorporeal membrane oxygenator (ECMO) for 5 days. During that time, several organ dysfunctions developed that required hemodiafiltration and respiratory support, in addition to ECMO. Hemodiafiltration is an extracorporeal renal-replacement technique using a highly permeable membrane in which diffusion and convection are conveniently combined to enhance solute removal in a wide spectrum of molecular weights. Transitory hemorrhagic diathesis, atrophic gastritis, ischemic colitis, and polyneuropathy also occurred. At follow-up, 5 months after the accident, the patient had residual but improving partial pareses of the upper and lower extremities. Her mental function was excellent, and she was gradually returning to work. She also resumed hiking and skiing.[14]

ECMO has even been reported to be successful in near drowning associated with deep hypothermia. Thalmann et al described a case of near drowning of a 3-year-old girl who was admitted to the emergency department with a core temperature of 18.4° C.[15] After rewarming on cardiopulmonary bypass and restitution of her circulation, respiratory failure resistant to conventional respiratory therapy prohibited weaning from cardiopulmonary bypass. Consequently, the medical team instituted ECMO. Fifteen hours later, the patient could be weaned from ECMO but required assisted ventilation for 12 days. Twenty months later, no neurological deficits were in evidence.[15]

Cardiopulmonary bypass and ECMO are not available in hospitals without cardiopulmonary bypass capabilities.

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Winegard reported an instance in which closed thoracic cavity lavage was used successfully in the treatment of severe hypothermia.[16] In Winegard's patient, closed thoracic cavity lavage was initiated through a 28-mL straight chest tube inserted into the left pleural cavity. Closed thoracic cavity lavage was performed with a saline solution at a temperature of 40°C. This lavage was continued after the patient began to make spontaneous respirations and was successfully defibrillated. The patient was discharged 10 days after admission. Follow-up neurological examination revealed relatively minor neurological sequelae. Two months after the accident, the victim had minor numbness, mostly in his feet. This was considered a cold neuropathy rather than a pressure palsy neuropathy.[16]

Because a large proportion of hypothermic patients are thiamine-depleted and alcoholic, they should be given thiamine at 100 mg intramuscularly, followed by 50-100 mL of 50% dextrose. Administration of antibiotics, steroids, and thyroid hormones must be considered. Very cold patients are immunosuppressed, and antibiotics are usually withheld until a definite infection is evident. Hydrocortisone should be administered to patients with a history of adrenal suppression or insufficiency and to hypothermic patients with cachexia and/or generalized weight loss. Levothyroxine (Synthroid) is necessary for patients in a myxedema coma and may be helpful in elderly persons.

Peripheral Cold Injuries

The mechanisms of peripheral cold injuries can be divided into phenomena that affect cells and extracellular fluids (direct effects) and those that disrupt the function of the organized tissue and the integrity of the circulation (indirect effects).[17] Generally, no serious damage is seen until tissue freezing occurs. During frostbite, ice crystals many times the size of individual cells form from the available extracellular compartment, producing intracellular dehydration. The cell content becomes hyperosmolar, and toxic concentrations of electrolytes may cause cell death.[18] Usually, no gross rupture of the cell membrane is evident. A reversal of this process probably occurs during thawing of frozen tissues. After tissue thawing, vasodilation and leakage from capillaries occur, causing tissue edema. Alternating freeze-thaw cycles potentiate the vascular injury and lead to ischemic infarction.

The indirect effects of frostbite, a fulminating vascular reaction and stasis, are associated with the release of prostaglandins that have been implicated in progressive dermal ischemia. Both prostaglandin F2 and thromboxane A2 cause platelet aggregation and vasoconstriction. Therapy with antiprostaglandin agents and thromboxane inhibitors has been shown in experimental and clinical studies to increase tissue survival.

Frostnip

The mildest form of peripheral cold injury is frostnip, which tends to occur in apical structures (nose, ears, hands, feet), where blood flow is most variable because of the richly innervated arteriovenous anastomoses. Frostnip most often occurs in skiers exposed to fast-moving, very cold air. Simple warming either by pressure of a warm hand or by placing the hand in the axilla is sufficient treatment. More consequential local cold injuries may be divided into freezing (frostbite) and nonfreezing (chilblains and immersion foot) injuries. The diagnosis of freezing and nonfreezing injuries can generally be made on the basis of history and clinical manifestations.

Chilblain (Perniones)

Chilblain represents a more severe form of cold injury than frostnip and occurs after exposure to nonfreezing temperatures and damp conditions. This condition is characterized by a chronic, recurrent vasculitis manifested by red-to-violaceous raised lesions in unprotected extremities, such as the hands, feet, and face. Blisters, erosions, or ulcers are sometimes seen. It commonly affects young and middle-aged women and is associated with a variety of chronic disorders, especially Raynaud phenomenon.

The lesions usually resolve spontaneously in 1-3 weeks, but they may recur in some individuals. Management involves local heat, gentle massage, and lubricants to keep the skin supple. Nifedipine (Procardia) at 20-60 mg/d may be used to reduce the pain and speed the resolution of the lesions.

Immersion (trench) foot

Immersion foot, or trench foot, a disease of the sympathetic nerves and blood vessels in the feet, is observed in shipwreck survivors or in soldiers whose feet have been wet, but not freezing, for prolonged periods.[19] It may occur at ambient temperatures near or slightly above freezing and is usually associated with dependency and immobilization of the lower extremities with constriction of the limb by shoes and clothing. Immediate symptoms include numbness and tingling pain with itching, progressing to leg cramps and complete numbness. Initially, the skin

is red; later, it becomes progressively pale and mottled and then gray and blue. The soles of the feet are wrinkled and very tender to palpation.

The progression of this cold injury has 3 stages. The first is a prehyperemic phase, lasting for a few hours to a few days, in which the limb is cold, slightly swollen, discolored, and possibly numb. Major pulses are barely palpable. The second, or hyperemic phase, lasts 2-6 weeks. It is characterized by bounding, pulsatile circulation in a red, swollen foot. The third, or posthyperemic, phase lasts for weeks or months. The limb may be warm, with increased sensitivity to cold. The injury often produces a superficial, moist, liquefaction gangrene quite dissimilar to the dry, mummification gangrene that occurs with severe frostbite.

Management of this injury entails careful washing and air-drying of the feet, gentle rewarming, bed rest, and slight elevation of the extremity. Improvement occurs within 24-48 hours, while the injury completely resolves in 1-2 weeks. Early physical therapy is essential. The patient should be warned that subsequent chilling will preferentially affect the previously injured area. Key to prevention of immersion foot injury is keeping the feet dry for at least 8 h/d.

Frostbite

Patients with frostbite frequently present with multisystem injuries (eg, systemic hypothermia, blunt trauma, substance abuse). The health professional must detect these multisystem injuries and appropriately triage care according to the most life-threatening injuries.[20]

Several days after the injury, frostbite can be classified into 4 degrees of severity. In first-degree frostbite, hyperemia and edema are evident. Second-degree frostbite is characterized by hyperemia and edema, with large, clear blisters that may extend the entire length of the limb, digit, or facial feature. Third-degree frostbite is characterized by hyperemia, edema, and vesicles filled with hemorrhagic fluid that are usually smaller than those of second-degree frostbite and do not extend to the tip of the involved digit. Fourth-degree frostbite, the most severe type, involves complete necrosis with gangrene and loss of the affected part.

The classification of frostbite into 4 degrees of severity is not favored by clinicians, who find assessing the full extent of tissue injury difficult in the acute setting. A simpler classification divides frostbite injury into 2 types: superficial or deep. Superficial frostbite (first- and second-degree frostbite) involves the skin and subcutaneous tissues. The skin is cold, waxy white, and nonblanching. The frozen part is anesthetic but becomes painful and flushed with thawing. Edema develops and clear bullae filled with serous fluid appear within the first 24 hours. Deep frostbite (third- and fourth-degree frostbite) involves the muscle, tendons, neurovascular structures, and bone, in addition to the skin and subcutaneous tissues. The frozen part is hard, woodlike, and anesthetic. It appears ashen-gray, cyanotic, or mottled and may remain unchanged even after rewarming. Edema develops, but bullae may be absent or delayed. Bullae, if present, are filled with hemorrhagic fluid.

Initially, as the tissue is freezing, the patient experiences discomfort or pain. This progresses to numbness and loss of sensation. Upon examination, the frozen tissue is white and anesthetic, owing to intense vasoconstriction. Tissues that remain frozen can appear mottled, violaceous, pale yellow, or waxy. Favorable signs include warmth, normal color, and some sensation. Several factors predispose to this cold injury. Clinical experience suggests that frostbite occurs at higher temperatures in patients with preexisting arterial disease.[21] In addition, a physiologic basis seems to exist for the reported susceptibility of black persons to frostbite. Finally, it has been demonstrated repeatedly that a person who previously suffered frostbite is more prone to develop this cold injury in the same body part than an individual with no history of such a cold injury.

Several principles of frostbite treatment are universally accepted. The patient must be removed from the cold environment. Treatment should not be attempted in the field if a hospital is available within a short distance or if a risk exists that the extremity will be refrozen. Once the rewarming process has begun, weight-bearing on the affected part is almost certain to result in additional injury. Rubbing the frostbitten part with snow or exercising it in an attempt to hasten rewarming is absolutely contraindicated. Contrary to popular belief, walking some distance on frostbitten feet can result in tissue fracture. Consequently, this ambulation should be avoided.

Upon arrival at the emergency department, normal body temperature should be restored before treating the local injury. The preferred initial treatment for frostbite is rapid rewarming in a water bath at a temperature of 39-42°C (102.2-107.6°F). Strict aseptic technique (eg, mask, powder-free gloves) should be used by all personnel during the warming procedure and during subsequent wound treatments. The rewarming bath should be large enough so that the frostbitten part does not rapidly reduce the temperature of the water. The temperature of the bath is monitored carefully as the bath cools. Additional hot water is added to the bath only after the extremity is removed from it. After hot water is added, the bath is stirred and the temperature retested before the extremity is reintroduced.

Rewarming is continued until the frostbitten tissue has a flushed appearance, demonstrating that circulation is reestablished. This rewarming procedure usually lasts 30-45 minutes. Because rewarming is painful, narcotics are

often required. After rewarming, the skin is washed gently with a fine-pore cell sponge soaked in poloxamer 188 (Shur-Clens) to remove any residual dirt. The skin is then carefully dried with fine-pore cell sponges without surfactant. Tetanus prophylaxis is indicated with a tetanus vaccine (Td) without thimerosal because frostbite injuries are considered tetanus-prone wounds.[22] A vaccine information statement, which outlines the adverse effects of the vaccine, should be given to the patient or a family member, along with the National Vaccine Information Compensation Program.[23] The benefit of prophylactic antibiotics continues to be debated, and the authors reserve them for specific infectious complications.

Heggers et al recommended a therapeutic approach devised to prevent the progressive dermal ischemia of frostbite.[24] The combination of the systemic prostaglandin inhibitor ibuprofen (Motrin) and the topical antithromboxane agent aloe vera was used to inhibit localized thromboxane production, which had been implicated as the cause of dermal ischemia.[24]

Severe frostbite can have devastating consequences, including the loss of limbs and digits. One of the mechanisms of cold injury to human tissue is vascular thrombosis. The effect of tissue plasminogen activator and heparin in limb and digit preservation has been recently demonstrated by Twomey et al.[25] Patients with severe frostbite were divided into 2 groups. A group of 6 patients was treated with intra-arterial tissue plasminogen activator (TPA) and intravenous heparin. A group of 13 patients was treated with intravenous TPA and intravenous heparin.

Patients eligible for this study included all patients with severe frostbite between January 1, 1989 and February 1, 2003 whose symptoms were not improved by rapid rewarming, who had absent Doppler pulses in distal limb or digits, who did not have perfusion by technetium-99m three-phase bone scan, and who had no contraindications to TPA use.[25] Efficacy was assessed on the basis of predicted digit amputation before therapy, given the clinical and technetium-99m scan results versus partial or complete digits removed. Fortunately, no serious complications with intravenous TPA occurred. Two patients with intra-arterial tissue plasminogen activator experienced bleeding complications. On the basis of historical technetium-99m scan data, the investigators predicted which digits were at risk for amputation. In their study, 174 digits were at risk in 18 patients, and only 33 were amputated.

In 2007, Bruen et al further confirmed the reduction of the incidence of amputation in frostbite injury with thrombolytic therapy.[26] From 2001-2006, their patients with severe frostbite within 24 hours of injury underwent digital angiography and treatment with intra-arterial tissue plasminogen activator (tPA) if abnormal perfusion was documented. These patients were compared with those treated from 1995-2006 who did not receive tPA. In their study, 32 patients with digital involvement were identified. Seven patients received tPA (6 within 24 h of injury). The incidence of digital amputation in patients who did not receive tPA was 41%. In those patients who received tPA within 24 hours of injury, the incidence of amputation was decreased to 10%. The authors concluded that the use of tPA represents the first clinically significant advancement in the treatment of frostbite in more than 25 years.

The clear blisters are debrided immediately, and the aloe vera (Dermaide Aloe) is applied directly to the debrided wound. In contrast, the hemorrhagic blisters are left intact and treated with aloe vera. The aloe vera is reapplied to the frostbitten wounds every 6 hours. When the hemorrhagic blisters rupture, the blisters are debrided, facilitating application of the aloe vera to the wound. Unless contraindicated by medical history (eg, aspirin allergy, peptic ulcer disease), ibuprofen (12 mg/kg/d for 1 wk) is administered orally to counteract the deleterious effects of increased thromboxane production. These treatments should reduce the length of hospital stay and the morbidity of patients with frostbite.

The affected part should be protected from trauma and infection, and it should be elevated above the patient's heart to minimize edema. A protective cradle should cover frostbitten lower extremities to prevent trauma. An environmental temperature of 21-26°C (69.8-78.8°F) in the hospital room is usually comfortable for the patient. Tobacco should be avoided because of its vasoconstrictive effect.

Patients with first- or second-degree frostbite of the feet should continue bed rest until the edema has receded and the vesicles and bullae have dried, which usually takes 2 weeks. Patients with more severe frostbite should remain in bed until wound repair is complete. Whirlpool treatments at 37°C (98.6°F) are instituted daily and should include active movement of all joints to maintain range of motion. Avoidance of joint stiffness and wound contraction is an essential goal of the rehabilitation program. The intrinsic muscles of the hands are particularly sensitive to frostbite injury. Night splinting of the hand in the intrinsic-plus position is recommended. Suppurative or loose necrotic debris should be removed by gently wiping the wound with the fine-pore cell sponge soaked in poloxamer 188.

The difficulty in determining the depth of tissue destruction has led to a conservative approach to the care of local cold injuries. As a general rule, amputation and surgical debridement should be delayed for 60-90 days unless severe infection with sepsis develops. The natural history of most injuries is one of gradual demarcation of the injured area, followed by dry gangrene or mummification of the area, with later sloughing of necrotic tissue, resulting in a viable, but shortened, extremity beneath the eschar.

Emergency surgery is occasionally required for patients with a frostbitten extremity. Open amputations are indicated

in patients with persistent infection with sepsis that is refractory to debridement and antibiotics. Compartment syndrome may be encountered in a frostbitten extremity, which mandates fasciotomy.

The intense vasoconstrictive effects of increased sympathetic tone in cold injuries have attracted attention for many years. The theoretical benefit from sympathetic blockade is the release of vasospasm that may precipitate thrombosis in injured vessels. The vasospastic effects may, therefore, be counteracted by intra-arterial drugs, such as tolazoline, or by surgical sympathectomy. However, a controlled clinical study by Bouwman et al demonstrated no subsequent differences in the natural history of the acute frostbite injury between patients who underwent early operative sympathectomy within 20 hours of hospitalization and those who underwent intra-arterial drug infusion within the first hour of hospitalization followed by operative sympathectomy.[27] Apparently, the injury was well established by the time the patient sought help, so therapeutic manipulation of the microcirculation was too late to be of benefit.

Adjunctive Treatment

Multiple experimental therapies have been proposed for the treatment of frostbite. Antithrombotic agents such as heparin, dextran, and dipyridamole (Persantine), thrombolytic agents, calcium channel blockers, steroids, and hyperbaric oxygen have not been shown to enhance tissue salvage. Pentoxifylline (Trental), 400 mg every 8 hours, may aid small vessel perfusion. Phenoxybenzamine (Dibenzyline), 10-60 mg/d, may reduce refractory vasospasm in some patients.

Despite the lack of effectiveness in the acute phase, sympathectomy does appear to provide prophylaxis against the deleterious effects of subsequent cold exposure. This observation may have clinical implications in patients who need such prophylaxis for occupational reasons, such as professional skiers with cold sensitivity. In addition, the results of digital sympathectomy in the management of chronic vasospastic frostbite sequelae, such as vasospastic pain, are encouraging.

A body part that suffers frostbite seldom recovers completely. Some degree of cold sensitivity and hyperhidrosis are common. Neuropathies, decreased nail and hair growth, lymphedema, ulcerations, and persistent Raynaud phenomenon in the affected part are other residua of the injury. Permanent tissue damage, such as subcutaneous tissue atrophy, bony defects on x-ray examination, and abnormal epiphyseal growth, may occur. In children, the healed frostbitten hand frequently develops shortening of the digits, skin redundancy, joint laxity, and distal interphalangeal joint radial deviation. Surgical management options for the sequelae of frostbite of the juvenile hand include epiphyseal arrest, arthrodesis, and angular osteotomy.

Ophthalmic Injuries

Freezing of the corneas has been reported to occur in individuals who have kept their eyes open in high-windchill situations without protective goggles (eg, snowmobilers, cross-country skiers). Initial corneal flare and pain during rewarming are signs of this injury. Keratitis and corneal opacification may require corneal transplantation.

Snow blindness is produced by ultraviolet (UV) solar radiation reflected from snow, ice, or water. It tends to be more common at high altitudes, where the air filtration of UV radiation is diminished. Excess radiation produces corneal pitting and disruption of the epithelium. Retinal damage may also occur. Symptoms develop 4-12 hours after exposure and include a painful eye and excessive tearing. The lids and corneas of the eyes may be swollen and red. Treatment includes induced cycloplegia, mydriasis, and eyelid closure with a dressing. Artificial tears and antibiotics are indicated early in the treatment.

Scientific Basis for the Selection of Medical Gloves

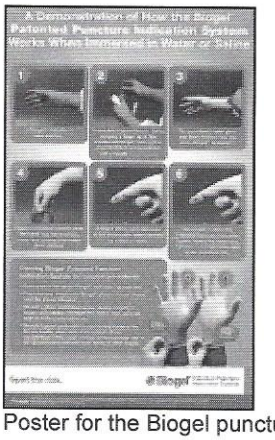
When treating patients with cold injuries, the emergency medical technician or paramedic should wear powder-free emergency medical examination gloves with a glove hole leakage rate of 1%. In a hospital setting, the Food and Drug Administration (FDA) requires that examination gloves have a 4% glove hole leakage rate.[28]

In 2008, 13 health professionals filed a citizen's petition with the FDA to ban cornstarch powder on all medical gloves.[29] Cornstarch has been documented as promoting wound infection and causing serious peritoneal adhesions and granulomatous peritonitis, and it is a well documented vector of the latex allergy epidemic.

The FDA allows 1.5% of surgical gloves to have holes. These holes allow blood with deadly borne viral infections to be transmitted between the patient and the surgeon. Consequently, the Biogel double-glove hole indication system

should be used to detect the location and presence of holes in the gloves, allowing the surgeon to change the gloves when a hole is detected.[30] After surgery has begun, one of the major causes of glove holes is surgical needle penetration, which can be detected by the double-glove hole indication system.

In collaboration with Dr. Robert Zura of Duke Medical Center, the authors have developed a poster entitled: A Demonstration of How the Biogel Patented Puncture Indication System Works When Immersed in Water or Saline.



Poster for the Biogel puncture indication system.

This poster can be framed and placed in the operating room as a guide to the appropriate use of the double-hole indication system during surgery. Copies of the poster can be obtained by contacting Mr. Milt Hinsch at Milt.Hinsch@biogelusa.com.

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In trauma surgery, we are continually inspired by our beloved patients, such as Jamie Hunter, as well as her courageous parents John and Wendy Hunter, of Seattle, Washington, who have acknowledged to us and our country the importance of having an organized approach to trauma care in our nation that will save lives of those who are critically injured. This is our quest.

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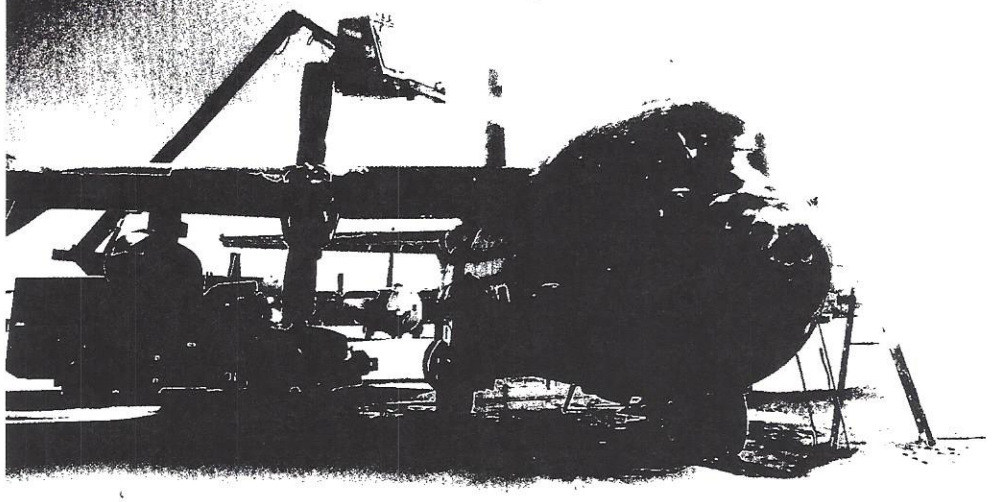
COLD WEATHER FLYING:

Refresher 101



By TSgt Julie Meintel,
445th Airlift Wing

SMSgt Ken Pulliam, 189th Aircraft Maintenance Squadron flight chief, de-ices a C-130 at Little Rock Air Force Base, AR

USAF PHOTO BY SRA JIM ARAOS

Flight Safety International's website, which offers several different types of e-learning training courses, among other products and services, has a great slogan on the banner across the top of each page: "The best safety device in any aircraft is a well-trained crew." That's certainly a statement that holds true anytime, under any circumstances and in any season.

It's critically important to keep your skills as sharp as they can possibly be, and situational awareness is a big part of your skill set. Paying attention to the weather is something we always do as flyers, as the change of season always brings about a different set of rules to play by. Winter means thinking about things like cold temperatures, snow and icing conditions; and how they will affect how our airplanes operate and how we all do our jobs.

Aircraft are designed to operate most efficiently within certain temperature ranges. While there is a wide variation of conditions in which military aircraft operate, it's important to be aware of their limitations.

The way our aircraft operates changes as the temperature drops. Oil and fluids may become thicker as they sit in the cold and move a little bit more sluggishly through lines, so preflighting and warming up the machinery and moving parts may take longer than it does in warm temperatures. Fuel can become contaminated if your aircraft is parked warm with half-full tanks because water can condense inside of them. When it's cold outside, you may be a little more likely to hurry through preflight inspections so you can get inside the aircraft that much more quickly. However this is exactly when you need to take a little extra time and care to be sure you're performing a thorough check.

Before you call "complete" on your preflight checklist, one of the most important things you can do is check for aircraft icing. If it's cold enough, you will probably have at least a thin layer of frost, which can cover your windshield or canopy and create a takeoff hazard, restricting visibility and affecting the lift to drag ratio. Frost forms on exposed surfaces of parked aircraft when temperatures are below the freezing point.

Rime icing is rough and grainy ice you might encounter; it is lightweight and freezes instantly as it hits the aircraft. It is also brittle because there is air trapped in with the moisture, making it easy to remove. Rime icing is most likely to be found when the mercury hovers between zero and -20 degrees Celsius, but don't be surprised if you

come across rime icing in storms as cold as -40 degrees Celsius.

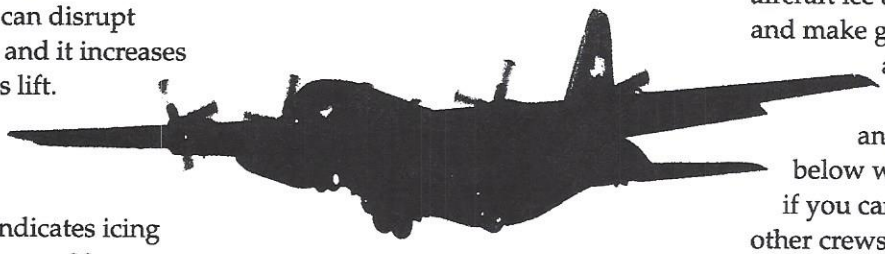
You could also possibly see a thick layer of clear ice, which can be more difficult to remove because it adheres so firmly to the aircraft. Clear ice is a result of freezing rain made of large water droplets and high water content, with very little air mixed in. You'll find clear ice at temperatures between zero and -10 degrees Celsius, but you still might see it as low as -25 degrees Celsius.

You might encounter any of these types of ice by themselves or in combination, and all of it needs to be removed before you can get going.

Ice is dangerous in any of its forms because of how it affects aircraft operation. It can disrupt airflow over airfoils, and it increases weight and decreases lift. *Air Force Handbook (AFH) 11-203, Vol I, Weather for Aircrews,* states that test data indicates icing reduces wing lift by up to 30 percent and increases drag by up to 40 percent. That can make an enormous difference in performance, or lack thereof, so stay on top of it, and make sure your aircraft's surfaces are clear of all ice before you take off.

Once you are airborne, your icing concerns are still not over, since it is even colder at altitude than it is on the ground. Your aircraft can, and does, accumulate icing in flight, on surfaces and intake ducts. The formation of aircraft icing in flight is mostly a result of temperature and cloud type and structure. As a general rule of thumb, aircraft icing happens when the temperature is between zero degrees and -20 degrees Celsius, although it can certainly occur at much colder temperatures too, all the way down to -40 degrees Celsius.

Cloud type and structure dictates the type of ice to the extent of the water content of the clouds themselves. The lower the water content of the cloud structure, the less severe any icing will be. Although icing is most common in winter in temperate zones like the United States, it is important to remember that you can come across it at any time of the year, depending on where your missions take you and the types of terrain you are flying through. Mountainous terrain is conducive to more severe icing, due to the upward motion of the air on the windward side. These vertically moving swaths of air support and lift the large water droplets that would normally be falling raindrops over level ground, bringing them into air that is cold enough to freeze them — and there it is, aircraft icing.



A C-130 Hercules takes off from the flightline at Little Rock Air Force Base, AR. Airmen enabled flying operations by clearing aircraft and the flightline of snow.

USAF PHOTO BY A1C ELLORA STEWART

The best and safest method of dealing with icing in flight is to avoid it, but that is not always going to be possible. Be certain to remove all aircraft ice and snow before takeoff, and make good use of your de-icing and anti-icing equipment. Read weather reports and PIREPS, fly above or below where icing is most likely if you can, and be sure to give other crews in your area a heads-up if weather conditions are different than forecast. Avoid clouds if possible when temperatures at altitude are between zero and -20 degrees Celsius.

The rules of cold weather flying don't really change from year to year. Keep your skills sharp and keep those rules in mind as the seasons change. Review Chapter 11 of *AFH 11-203, Vol I* as winter approaches to refresh your memory, and fly safe!

Cold Weather Flying

MAJ. PETER LAURIN
Aviation Safety Division
Air Force Safety Center
Kirtland AFB, N.M.

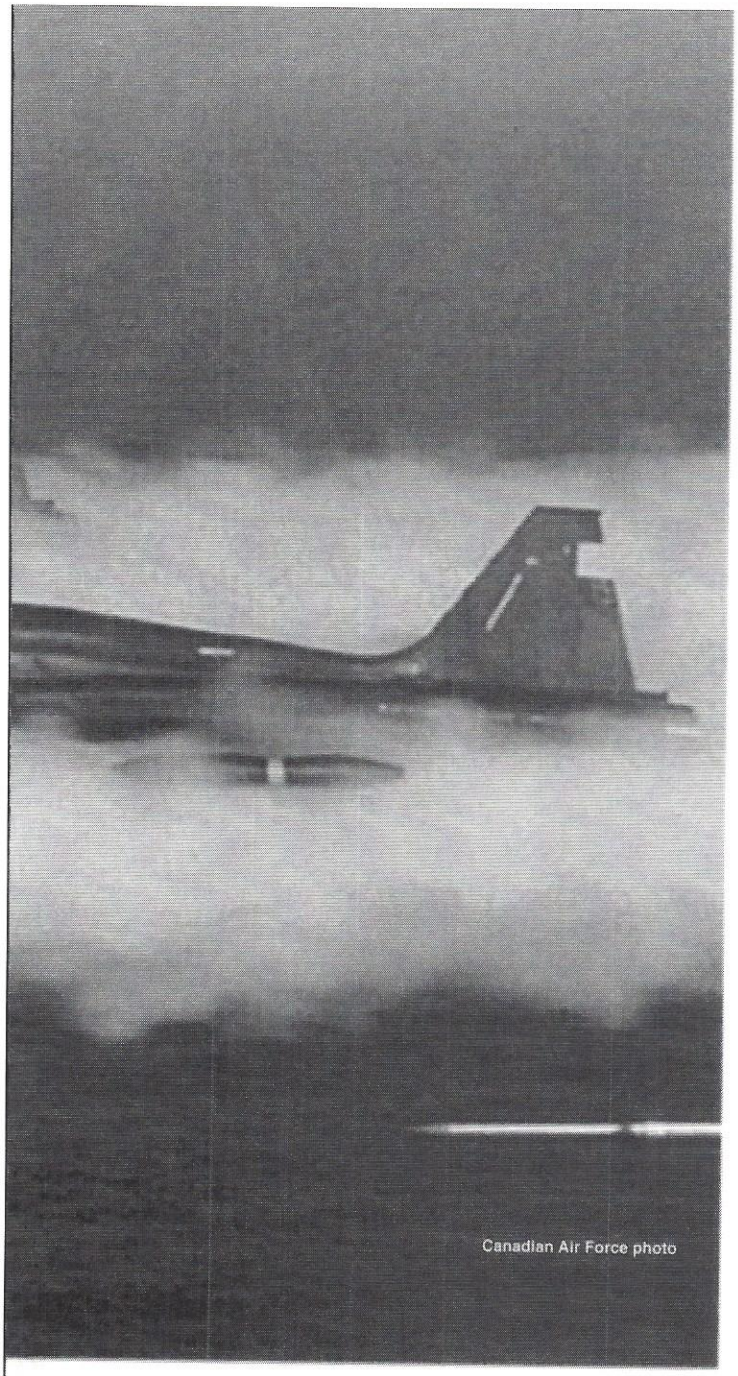
Canadian Forces Base Cold Lake, Alberta, Canada, is a winter wonderland in December. One year, the area had received a large amount of snow early in the winter season, and a few winter storms had already hit the base. The holidays were just a few days away, and I was going to celebrate them with my wife and our 9-month-old daughter.

The week before the holidays, our squadron flew regular air-ground missions. Part of the training involved heading to the Jimmy Lake Weapons Range in Alberta for practice weapons delivery. I was No. 3 in a four-ship of CF-5s. We would be flying the first wave to Jimmy Lake, delivering modular practice bombs and CRV-7 rockets and honing our gun-strafing skills. The weather turned out to be perfect that day — clear skies, very light winds and the temperature was 5 below zero. Overnight temperatures were forecast to be minus 12. With these conditions, we were dressed in full winter gear.

All flight planning and preparations were completed, and no alternate was needed; if required, it would have been Edmonton, Alberta. Edmonton is just over 100 nautical miles to the west-southwest and would have required considerable fuel reserves.

Our four-ship was the first to launch that morning; taking off after us would be CF-18s and the venerable T-33s. On the surface this appeared to be a routine training mission flown by experienced pilots — all had completed at least one tour on the CF-18.

The sortie went as planned; the range work, procedures and radio calls were all completed to perfection. All that



Canadian Air Force photo

remained was to return to base (RTB) via the overhead break and, if gas permitted, a closed pattern or two. This was turning out to be one of those rare, near-perfect missions from start to finish.

On RTB we discovered all was not well at the airfield. As we tried to check in with the air traffic control (ATC) tower, we heard two CF-18s had diverted to Edmonton. The radio was extremely busy and there was much confusion. I distinctly remember hearing, "The airfield is blanketed by ice fog caused by departing CF-18s; all aircraft expect to divert to Edmonton." Conditions favorable for ice fog formation are air temperature below zero, a small temperature dew point spread (less than 2 degrees) and high humidity.

Immediately our four-ship climbed to 20,000 feet and slowed to max endurance. We switched to the instrument flight rules (IFR) recovery frequency. Again, the radio was busy with aircraft trying to recover to the base. We couldn't get a response from ATC since they were overwhelmed with IFR traffic. We knew our situation was bad, but not yet dire. We couldn't divert to Edmonton — Cold Lake was our only option. To make matters worse, the CF-5 had no instrument landing system (ILS) capability; we were PAR (precision approach radar) only for precision approaches at a Category E speed.

We held at max endurance and continued calling out to ATC. After what seemed like an inordinate amount of time, ATC directed their attention to us. At this point we had enough gas for only one approach, and our section was split into elements. On the radio we continued to hear that aircraft were diverting to Edmonton. The situation was now dire.

I knew from experience that PAR recoveries never put the CF-5 in a good position to land from decision height (DH). We usually ended up off-centerline or slightly high. The PAR controllers tried their best but, in the last two miles of the approach, the speed of the CF-5 caused the PAR controllers to fall behind on their corrections. I knew I had to fly a perfect PAR approach with careful attention paid to glide path calls. I couldn't do anything to correct for centerline errors other than follow the controllers' instructions.

As I led the second element, I had the benefit of hearing how the first element was being controlled. Unfortunately, and as expected, in the last two miles of their approach, I could sense the PAR controller was struggling. When the controller asked for our missed approach request, I heard a distinct change in the controller's voice when we requested ejection vectors as our missed approach.

Canadian Forces Base Cold Lake has two parallel runways. The inner runway is the longer of the two and is the dedicated IFR runway while the outer is for visual flight rules traffic. The lead element was approaching DH for the approach. As I listened carefully, I heard lead call "Visual between the runways; two take spacing." No. 2 very wisely not only took spacing, but immediately moved over to land on the outer runway as this was the closest runway to him and, due to IFR conditions, he knew the runway wasn't being used. This was an excellent decision as it allowed each pilot to land and use drag chutes to decelerate if necessary.

I expected the same situation would repeat itself for my element. We ended up at a similar DH between the runways. Like the element in front of us, I took the inner runway and my wingman landed on the outer runway — a successful ending to our mission.

I was reminded of a few valuable lessons on that cold, December day:

1. Everyone in aviation must work together; if something changes, like the weather, notify all concerned.

2. Our formation should have requested priority from ATC.

3. Cold weather flying requires proper preparations — respect the elements!

National Weather Service Weather Forecast Office

Omaha/Valley, NE

FrostBite and Hypothermia

Frostbite results from the body's survival mechanisms kicking in during extremely cold weather. The body's first imperative is to protect the vital inner organs, which it does by cutting back on circulation to your extremities: feet, hands, nose, etc. If these parts are exposed to the cold and receive less warming blood flow, they eventually freeze.

One way to avoid frostbite is to avoid going outside during severe cold, especially if the wind chill is -50 degrees F or below. If you must go, be sure to protect the exposed parts of your body, such as ears, noes, toes, and fingers. Mittens are more effective than gloves for warming your hands. Keep your skin dry. Stay out of the wind when possible. Drink plenty of fluids since hydration increases the blood's volume, which helps prevent frostbite. Avoid caffeinated beverages, however, as they constrict blood vessels and prevent warming of your extremities. Alcohol should be avoided since it reduces shivering, which is one of your body's ways of keeping warm. And be especially wary of smoking cigarettes in extremely cold temperatures. According to one physician, when you smoke, the blood flow to your hands practically shuts off.

Different Degrees of Frostbite

- First degree: ice crystals forming on your skin
- Second degree: your skin begins to feel warm, even though it is not yet defrosted.
- Third degree: your skin turns red, pale, or white.
- Fourth degree: pain lasts for more than a few hours, and you may see dark blue or black areas under the skin. See a doctor immediately if these symptoms arise. Gangrene is a real threat.

Frostbite First Aid

Have you heard that you should rub frostbitten skin with snow? That old-time remedy can cause permanent damage.

Never rub or massage, but do use your armpits, a warm companion, warm drinks, and warm clothes to thaw your frozen body parts. Remove rings, watches, and anything that is tight. Your goal is to get indoors as quickly as possible, without walking on a frostbitten foot if you can avoid it.

Once indoors, get in a warm (not hot) bath and wrap your face and ears in a moist, warm (not hot) towel. Don't get near a hot stove or heater, and don't use a heating pad, a hot water bottle, or a hair dryer. You may burn yourself before your feeling returns.

Your frostbitten skin will become red and swollen, and you'll feel like it's on fire. You may develop blisters. Don't break the blisters. It could cause scarring.

If your skin is blue or gray, very swollen, blistered, or feels hard and numb even under the surface, go to a hospital immediately.

Sources:
The Handy Weather Answer Book, Visible Ink, Detroit, 1997
The American Medical Association Encyclopedia of Medicine, Random House, New York, 1989
U.S. Pharmacist (21,1:31)

Hypothermia: the cold-blooded killer

You may have never heard of *hypothermia*, much less know how to get a handle on it. Here are the bone-chilling facts about this cold-blooded killer.

A body temperature below 96 degrees Fahrenheit is called hypothermia, and it doesn't take arctic temperatures to put you at risk. Even a moderately chilly air temperature of 60 degrees is low enough to trigger hypothermia if you aren't properly clothed.

The National Institute of Aging estimates that of the 28,000 people hypothermia kills every year, the largest percentage are older people. Some medicines, problems with circulation, and certain illnesses appear to reduce the older person's ability to resist hypothermia.

Also, the older you get, the less sensitive you are to cold weather. So, your body temperature could drop to a dangerously low level without you really being aware of it. In addition, older people don't seem to shiver very effectively, which is one of the ways the body warms itself up.

Remember these tips to help prevent hypothermia:

- Dress in layers
- Always wrap up well when going outside in the cold.
- Set your thermostat to at least a toasty 70 degrees during cold weather.
- Avoid extensive exposure to breezes and drafts.
- Keep plenty of nutritious food and warm clothes and blankets on hand to help ward off the winter chill. You'd also be wise to wear a warm hat during these months.
- Eat hot foods and drink warm drinks several times during the day.
- Ask a family member of neighbor to check on you often.
- Ask your doctor if any medicine you're taking increases your risk of hypothermia. Some drugs make it difficult for your body to stay warm. Drugs that may cause a problem include barbiturates, benzodiazepines, chlorpromazine, reserpine, and tricyclic antidepressants.

If your temperature is 96 degrees or less or you feel sluggish or recognize that you're having trouble

thinking clearly, see your doctor immediately or go to the nearest emergency room. It's better to be overly cautious than to die of a disorder that doesn't have to be deadly.

To help someone you suspect may be suffering from hypothermia, first call an ambulance. Then lie close to the person and cover both of you with thick blankets. The hotter you get, the more warmth you can give the other person. Don't rub the person or handle him or her roughly. That can make things worse.

Sources:
Accidental hypothermia: a winter hazard for older people, National Institute on Aging, 1995
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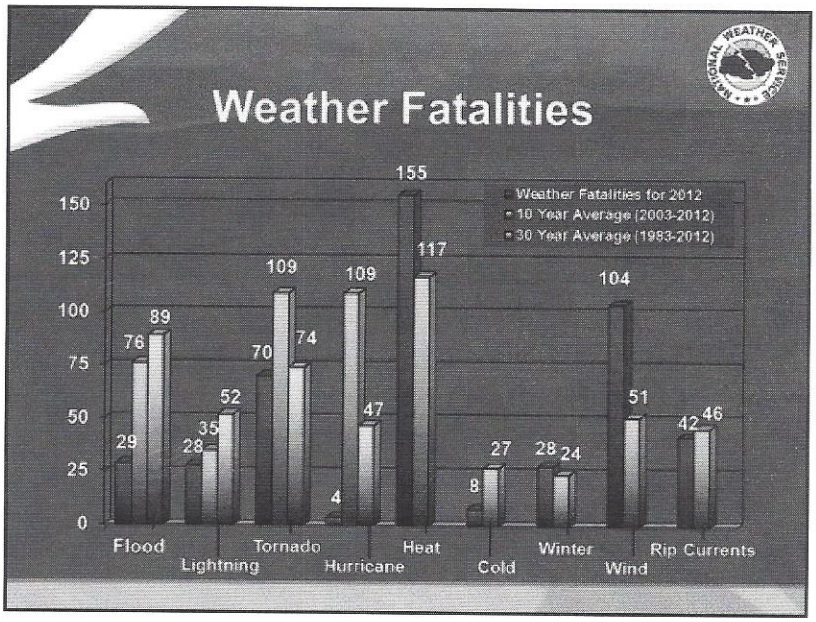
Natural Hazard Statistics

Statistics

- U.S. Summaries
- State Summaries
- Cold
- Flood
- Heat
- Lightning
- Tornado
- Tropical Cyclone
- Wind
- Winter Storm

Also available is the 73-Year List of Severe Weather Fatalities



Preliminary 2012 Statistics Now Online

The U.S. Natural Hazard Statistics provide statistical information on fatalities, injuries and damages caused by weather related hazards. These statistics are compiled by the Office of Services and the National Climatic Data Center from information contained in *Storm Data*, a report comprising data from NWS forecast offices in the 50 states, Puerto Rico, Guam and the Virgin Islands.

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Library Contents

Winter Flying Tips - P-8740-24
Author: *FAA* ***Date:*** *1996*

Introduction

Winter flying in most parts of the United States can adversely affect flight operations. Poor weather conditions with fast moving fronts, strong and gusty winds, blowing and drifting snow, and icing conditions are just part of the conditions that require careful planning in order to minimize their effects. Operation in this environment requires special winter operating procedures.

These pages are designed to refresh the pilot's memory in cold weather operations. Pilots should assure themselves that they have obtained adequate cold weather knowledge appropriate to the aircraft used and the geographical and weather environment. Winter flying is not particularly hazardous if the pilot will use a little extra caution and exercise good judgment in analyzing weather situations.

The material presented here has been taken from many discussions of winter flying techniques with highly qualified pilots in various parts of the United States. The experience gained in accident investigations has also been included in this guide.

This guide contains ideas and possible courses of action for the pilots to keep in mind while operating aircraft during winter months. It is produced in connection with the Federal Aviation Administration, General Aviation Accident Prevention Program, as a reference for pilots desiring information on winter flying.

About Winter Flying

Most pilots are familiar with winter conditions in their particular area; however, often a distance of a few miles may change the environment enough to present new problems to an inexperienced pilot. There are certain precautions that are significant to winter flying. Flight planning during winter months will require special knowledge in order to protect the aircraft as well as the pilot. Extra precautions should be used. Often roads that are well traveled during the summer months will be abandoned in the winter. To be forced down far from civilization may create a serious problem of survival. With today's extensive highway system, following a highway would not extend most flights in small aircraft by more than a few minutes. Even the vehicles on the road can give valuable information. You may see cars and trucks coming toward you with fresh snow adhering to the front of the vehicles. In most cases, you may as well start making a 180-degree turn due to reduced visibility ahead.

File a flight plan. A flight plan, in conjunction with an ELT, and a little knowledge on winter survival may save your life. Experience has shown that the advice of operators who are located in the area where the operation is contemplated is invaluable, since they are in a position to judge requirements and limitations for operation in their particular area.

When flying to a business appointment, always give yourself an out by informing your contact that you intend to fly and will arrive at a certain time, unless the weather conditions are unfavorable. ***You, the pilot, have complete responsibility for the GO or NO GO decision based on the best information available.*** Do not let compulsion take the place of good judgment.

Aircraft Preparation

If your home base is located in a warm climate area, you may not have familiarized yourself with the aircraft manufacturer's recommendations for winterizing your aircraft. Most mechanical equipment, including aircraft and their components, are designed by manufacturers to operate within certain temperature extremes. Manufacturers generally can predict their product's performance in temperature extremes and outline precautions to be taken to prevent premature failures.

Baffling and Winter Covers

Baffles are recommended by some manufacturers to be used in augmented tubes. Winter fronts and oil cooler covers are also added to some engine installations. FAA approval is required for installation of these unless the aircraft manufacturer has provided the approval. When baffles are installed on aircraft, a cylinder head temperature gauge is recommended, particularly if wide temperature differences are to be encountered.

Engine Oil

The oil is extremely important in low temperatures. Check your aircraft manual for proper weight oil to be used in low temperature ranges.

Oil Breather

The crankcase breather deserves special consideration in cold weather preparation. A number of engine failures have resulted from a frozen crankcase breather line which caused pressure to build up, sometimes blowing the oil filler cap off or rupturing a case seal, which caused the loss of the oil supply. The water, which causes the breather line freezing, is a natural byproduct of heating and cooling of engine parts. When the crankcase vapor cools, it condenses in the breather line subsequently freezing it closed. Special care is recommended during the preflight to assure that the breather system is free of ice. If a modification of the system is necessary, be certain that it is an approved change so as to eliminate a possible fire hazard.

Hoses

An important phase of cold weather preparation is inspection of all hose lines, flexible tubing, and seals for deterioration. After replacing all doubtful components, be certain that all clamps and fittings are properly torqued to the manufacturer's specifications for cold weather.

Cabin Heat

Many aircraft are equipped with cabin heater shrouds, which enclose the muffler or portions of the exhaust system. It is imperative that a thorough inspection of the heater system be made to eliminate the possibility of carbon monoxide entering the cockpit or cabin area. Each year accident investigations have revealed that carbon monoxide has been a probable cause in accidents that have occurred in cold weather operations.

Control Cables

Because of contraction and expansion caused by temperature changes, control cables should be properly adjusted to compensate for the temperature changes encountered.

Propellers

Propeller control difficulties can be encountered due to congealed oil. The installation of a recirculating oil system for the propeller and feathering system has proved helpful in the extremely cold climates. Caution should be taken when intentionally feathering propellers for training purposes to assure that the propeller is unfeathered before the oil in the system becomes congealed.

Batteries

Wet cell batteries require some special consideration during cold weather. It is recommended that they be kept fully charged or removed from the aircraft when parked outside to prevent loss of power caused by cold temperatures and the possibility of freezing.

Wheel Wells and Wheel Pants

During thawing conditions, mud and slush can be thrown into wheel wells during taxiing and takeoff. If frozen during flight, this mud and slush could create landing gear problems. The practice of recycling the gear after a takeoff in this condition should be used as an emergency procedure only. The safest method is to avoid these conditions with retractable gear aircraft. It is recommended that wheel pants installed on fixed gear aircraft be removed to prevent the possibility of frozen substances locking the wheels or brakes.

Operation of Aircraft

A thorough preflight inspection is important in temperature extremes. It is natural to hurry over the preflight of the aircraft and equipment, particularly when the aircraft is outside in the cold. However, this is the time you should do your *best* preflight inspection.

Fuel Contamination

Fuel contamination is always a possibility in cold climates. Modern fuel pumping facilities are generally equipped with good filtration equipment, and the oil companies attempt to deliver pure fuel to your aircraft. However, even with the best of fuel and precautions, if your aircraft has been warm and then is parked with half empty tanks in the cold, the possibility of condensation of water in the tanks exists.

Fueling Facilities

Another hazard in cold climates is the danger of fueling from makeshift fueling facilities. Fuel drums or "case gas," even if refinery sealed, can contain rust and somehow contaminants can find their way into the fuel. Cases are on record of fuel being delivered from unidentified containers which was not aviation fuel. As a precaution, we suggest:

- Where possible, fuel from modern fueling facilities; fill your tanks as soon as possible after landing, and drain fuel sumps to remove any water which may have been introduced.
- Be sure the fuel being delivered is, in fact, aviation fuel and is the correct grade (octane) for your engine.
- If you are not using modern fueling facilities, be sure to filter the fuel as it goes into your tanks. *NOTE: A funnel with a dirty worn out chamois skin is not a filter, nor will a new, clean chamois filter out water after the chamois is saturated with water. Many filters are available which are more effective than the old chamois. Most imitation chamois will not filter water.*
- Special precautions and filtering are necessary with kerosene and other turbine fuels. Manufacturers can supply full details on handling these fuels.

Fuel Filters and Sumps

Fuel filters and sumps (including each tank sump) should be equipped with quick drains. Sufficient fuel should be drawn off into a transparent container to see if the fuel is free of contaminants. Experienced operators place the aircraft in level flight position, and the fuel is allowed to settle before sumps and filters are drained. All fuel sumps on the aircraft are drained including individual tank sumps. Extra care should be taken during changes in temperature, particularly when it nears the freezing level. Ice may be in the tanks which may turn to water when the temperature rises, and may filter down into the carburetor causing engine failure. During freeze-up in the fall, water can freeze in lines and filters causing stoppage. If fuel does not drain freely from sumps, this would indicate a line or sump is obstructed by sediment or ice. There are approved anti-ice additives that may be used. Where aircraft fuel tanks do not have quick drains installed, it is advisable to drain a substantial amount (1 quart or more) of fuel from the gascolator; then change the selector valve and allow the fuel to drain from the other tank. Advisory Circular (AC) 20-43C, *Aircraft Fuel Control, (http://www.airweb.faa.gov/Regulatory_and. . .89790036862569C3004BA88B?OpenDocument)* contains excellent information on fuel contamination. Paragraphs 10 and 11 are especially pertinent to many light aircraft and include a recommendation for periodic flushing of the carburetor bowl.

Aircraft Preheat

Low temperatures can change the viscosity of engine oil, batteries can lose a high percentage of their effectiveness, instruments can stick, and warning lights, when "pushed to test," can stick in the pushed position. Because of the above, preheat of engines as well as cockpit before starting is considered advisable in low temperatures. *Use extreme caution in the preheat process to avoid fire. The following precautions are recommended:*

- Preheat the aircraft by storing in a heated hangar, if possible.
- Use only heaters that are in good condition and do not fuel the heater while it is running.
- During the heating process, do not leave the aircraft unattended. Keep a fire extinguisher handy for the attendant.
- Do not place heat ducting so it will blow hot air directly on parts of the aircraft; such as, upholstery, canvas engine covers, flexible fuel, oil and hydraulic lines or other items that may cause fires.
- Be sure to follow the manufacturer's procedures.

Engine Starts

In moderately cold weather, engines are sometimes started without preheat. Particular care is recommended during this type of start. Oil is partially congealed and turning the engines is difficult for the starter or by hand.

There is a tendency to overprime, which results in washed-down cylinder walls and possible scouring of the walls. This also results in poor compression and, consequently, harder starting. Sometimes aircraft fires have been started by overprime, when the engine fires and the exhaust system contains raw fuel. Other fires are caused by backfires through the carburetor. It is good practice to have a fireguard handy during these starts.

Another cold start problem that plagues an unpreheated engine is icing over the spark plug electrodes. This happens when an engine only fires a few revolutions and then quits. There has been sufficient combustion to cause some water in the cylinders but insufficient combustion to heat them up. This little bit of water condenses on the spark plug electrodes, freezes to ice, and shorts them out. The only remedy is heat. When no large heat source is available, the plugs are removed from the engine and heated to the point where no more moisture is present.

Engines can quit during prolonged idling because sufficient heat is not produced to keep the plugs from fouling out. Engines which quit under these circumstances are frequently found to have iced-over plugs.

After the engine starts, use of carburetor heat may assist in fuel vaporization until the engine obtains sufficient heat.

Radios

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Radios should not be tuned prior to starting. Radios should be turned on after the aircraft electrical power is stabilized, be allowed to warm up for a few minutes, and then be tuned to the desired frequency.

Ice, Snow, and Frost

A common winter accident is trying to take off with frost on the wing surface. It is recommended that all frost, snow, and ice be removed before attempting flight. It is best to place the aircraft in a heated hangar. If so, make sure the water does not run into the control surface hinges or crevices and freeze when the aircraft is taken outside. Don't count on the snow blowing off on the takeoff roll. There is often frost adhering to the wing surface below the snow. Alcohol or one of the ice removal compounds can be used. Caution should be used if an aircraft is taken from a heated hangar and allowed to sit outside for an extended length of time when it is snowing. The falling snow may melt on contact with the aircraft surfaces and then refreeze. It may look like freshly fallen snow but it usually will not blow away when the aircraft takes off.

If an aircraft is parked in an area of blowing snow, special attention should be given to openings in the aircraft where snow can enter, freeze solid, and obstruct operation. These openings should be free of snow and ice before flight. Some of these areas are as follows:

- Pitot tubes
- Heater intakes
- Carburetor intakes
- Anti-torque and elevator controls
- Main wheel and tail wheel wells, where snow can freeze around elevator and rudder controls.

Fuel Vents

Fuel tank vents should be checked before each flight. A vent plugged by ice or snow can cause engine stoppage, collapse of the tank, and possibly very expensive damage.

Taxi

Braking action on ice or snow is generally poor. Short turns and quick stops should be avoided. Do not taxi through small snowdrifts or snow banks along the edge of the runway. Often there is solid ice under the snow. If you are operating on skis, avoid sharp turns, as this puts torque on the landing gear in excess of that for which it was designed. Also for ski operation, make sure safety cables and shock cords on the front of the skis are carefully inspected. If these cables or shock cords should break on takeoff, the nose of the ski can fall down to a near vertical position which seriously affects the aerodynamics efficiency of the aircraft and creates a landing hazard. If it is necessary to taxi downwind with either wheels or skis and the wind is strong, get help or don't go. Remember, when you are operating on skis, you have no brakes and no traction in a crosswind. On a hard-packed or icy surface, the aircraft will slide sideways in a crosswind and directional control is minimal particularly during taxiing and landing roll when the control surfaces are ineffective.

Takeoff

Takeoffs in cold weather offer some distinct advantages, but they also offer some special problems. A few points to remember are as follows:

- Do not overboost supercharged engines. This is easy to do because at very low density altitude, the engine "thinks" it is operating as much as 8,000 feet below sea level in certain situations. Care should be exercised in operating normally aspirated engines. Power output increases at about 1% for each ten degrees of temperature below that of standard air. At -40 degree F, an engine will develop 10 percent more than rated power even though RPM and MP limits are not exceeded.
- If the temperature rises, do not expect the same performance from your aircraft as when it was operated at the lower density altitudes of cold weather.
- Use carburetor heat as required. In some cases, it is necessary to use heat to vaporize the fuel. Gasoline does not vaporize readily at very cold temperatures. Do not use carburetor heat in such a manner that it raises the mixture temperature barely to freezing or just a little below. In such cases, it may be inducing carburetor icing. An accurate mixture temperature gauge is a good investment for cold weather operation. It may be best to use carburetor heat on takeoff in very cold weather in extreme cases.

If your aircraft is equipped with a heated pitot tube, turn it on prior to takeoff. It is wise to anticipate the loss of an airspeed indicator or most any other instrument during a cold weather takeoff -- especially if the cabin section has not been preheated.

During climbout, keep a close watch on head temperature gauges. Due to restrictions (baffles) to cooling air flow installed for cold weather operation and the possibility of extreme temperature inversions, it is possible to overheat the engine at normal climb speeds. If the head temperature nears the critical stage, increase the airspeed or open the cowl flaps or both.

En Route

Weather

Weather conditions vary considerably in cold climates. In the more remote sections of the world weather reporting stations are generally few and far between and reliance must be placed on pilot reports. However, don't be lured into adverse weather by a good pilot report. Winter weather is often very changeable; one pilot may give a good report and five or ten minutes later VFR may not be possible.

Remember, mountain flying and bad weather don't mix. Set personal limits and stick to them.

Snow showers are, of course, quite prevalent in colder climates. When penetration is made of a snow shower, the pilot may suddenly find himself without visibility and in IFR conditions. Snow showers will often start with light snow and build. Another hazard which has claimed as its victims some very competent pilots is the "whiteout." This condition is one where within the pilot's visibility range there are no contrasting ground features. Obviously the smaller the visibility range the more chance there is of a whiteout; however, whiteout can occur in good visibility conditions. A whiteout condition calls for an immediate shift to instrument flight. The pilot should be prepared for this both from the standpoint of training and aircraft equipment.

Carburetor Ice

Three categories of carburetor ice are:

- ***Impact ice*** - Formed by impact of moist air at temperatures between 15 and 32 degrees F on airscoops, throttle plates, heat valves, etc. Usually forms when visible moisture such as rain, snow, sleet, or clouds are present. Most rapid accumulation can be anticipated at 25 degrees F.
- ***Fuel ice*** - Forms at and downstream of the point where fuel is introduced, and occurs when the moisture content of the air freezes as a result of the cooling caused by vaporization. It generally occurs between 40 and 80 degrees F, but may occur at even higher temperatures. It can occur whenever the relative humidity is more than 50 percent.
- ***Throttle ice*** - Forms at or near a partly closed throttle valve. The water vapor in the induction air condenses and freezes due to the venturi effect cooling as the air passes the throttle valve. Since the temperature drop is usually around 5 degrees F, the best temperatures for forming throttle ice would be 32 to 37 degrees F although a combination of fuel and throttle ice could occur at higher ambient temperatures.

In general, carburetor ice will form in temperatures between 32 and 50 degrees F when the relative humidity is 50 percent or more. If visible moisture is present, it will form at temperatures between 15 and 32 degrees F. A carburetor air temperature (CAT) gauge is extremely helpful to keep the temperatures within the carburetor in the proper range. Partial carburetor heat is not recommended if a CAT gauge is not installed. Partial throttle (cruise or letdown) is the most critical time for carburetor ice. The recommended practice is to apply carburetor heat before reducing power and to use partial power during letdown to prevent icing and overcooling the engine.

To prevent carb ice:

- Use carb heat ground check
- Use heat in the icing range
- Use heat on approach and descent

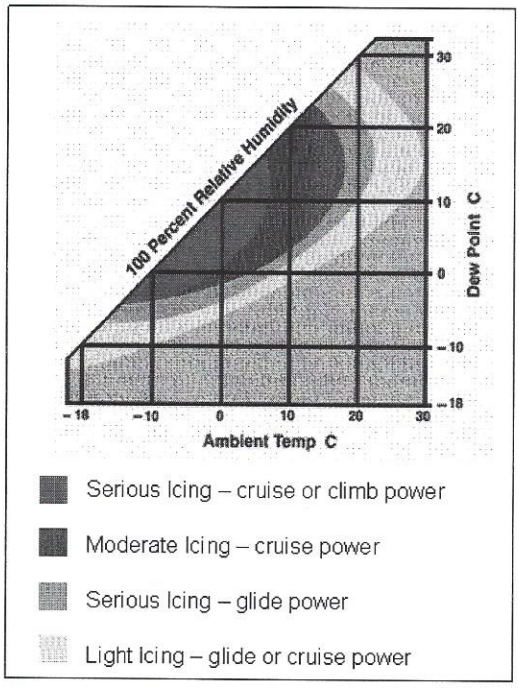
Warning signs of carb ice include:

- Loss of rpm (fixed pitch)
- Drop in manifold pressure (constant speed); rough running

Pilot response to warning signs should be:

- Apply full carb heat immediately (may run rough initially for short time while ice melts)

In the chart below, the curves encompass conditions known to be favorable for carburetor icing. The severity of this problem varies with different types, but these curves are a guide for the typical light aircraft. Light icing over a prolonged period may become serious. When you receive a weather briefing, note the temperature and dewpoint and consult this chart.



Carbon Monoxide Poisoning

Don't count on symptoms of carbon monoxide to warn you: It's colorless, odorless, and tasteless, although it is usually found with exhaust gases and fumes. If you smell fumes or feel any of the following symptoms, you should assume that carbon monoxide is present.

Initial symptoms include feelings of sluggishness, warmth, and tightness across forehead, followed by headache, throbbing, pressure at the temples and ringing in the ears. Severe headache, nausea, dizziness, and dimming of vision may follow. If any of the above conditions exist, take the following precautions:

- Shut off the cabin heater or any other opening to the engine compartment.
- Open a fresh air source immediately.
- Don't smoke.
- Use 100 percent oxygen if available.
- Land as soon as possible.
- Be sure the source of the contamination is corrected before further flight.

Spatial disorientation can also be expected any time the pilot continues VFR flight into adverse weather conditions. Flying low over an open body of water during low visibility and a ragged ceiling is another ideal situation for disorientation.

Letdown

Engine Operation

During letdown, there may be a problem of keeping the engine warm enough for high power operation, if needed. It may be desirable to use more power than normal, which may require extension of landing gear or flaps to keep the airspeed within limits. Carburetor heat may also be necessary to help vaporize fuel and enrich the mixture.

Blowing Snow and Ice Fog

Blowing snow can be a hazard on landing, and a close check should be maintained throughout the flight as to the weather at destination. If the weather pattern indicates rising winds, then blowing snow may be expected which may necessitate an alternate course of action.

Ice fog is a condition opposite to blowing snow and can be expected in calm conditions about -30 degrees F and below. It is found close to populated areas, since a necessary element in its formation is hydrocarbon nuclei such as found in automobile exhaust gas or the gas from smokestacks.

Both of the conditions described above can form very rapidly and are only a few feet thick (usually no more than 50 feet) and may be associated with clear en route weather. Pilots should always make a careful check of the current and forecast weather, as well as make a preflight plan for alternate courses of action.

Landing

A landing surface can be very treacherous in cold weather operations. In addition, caution is advised regarding other hazards such as snow banks on the sides of the runways and poorly marked runways. Advance information about the current conditions of the runway surface should be obtained. If it is not readily available, take the time to circle the field before landing to look for drifts or other obstacles. Be aware that tracks in the snow on a runway do not ensure safe landing conditions. Often snowmobiles will use runway areas and give a pilot the illusion that aircraft have used the airport and the snow is not deep.

Ski wheel combinations are popular and very convenient; however, forgetting to use the landing gear appropriate to the runway surface can be embarrassing.

In level flight, due to their relatively "dirty" profile, skis will cut cruising speed to some extent. In addition to some loss of aerodynamic efficiency, skis have other disadvantages. They require more care in operating because bare spots must be avoided to keep from wearing the bottom coating of the skis, although the bottom coating must be renewed on some skis periodically. There is now an anti-friction tape that is very useful for this purpose. Skis equipped with the anti-friction coating do not freeze to the surface like those that expose bare metal to the snow. Another method of keeping skis from freezing to the snow is to taxi the aircraft up onto poles placed across and under the skis. This prevents them from touching the snow for most of their length.

Extra care in use of skis during takeoff and landing is also recommended. Rutted snow and ice can cause loss of ground control, even failure of skis or landing gear parts. Deep powder snow can adversely affect ski operation. Prolonged takeoff runs in deep powder are expected and it may be deep enough that no takeoff is possible under existing conditions. In this case, experienced operators pack a takeoff path with snowshoes, or taxi back and forth until an adequately packed runway is available.

Post-Flight

The following are items to consider before leaving the aircraft after the flight:

- As soon as possible fill the tanks with the proper grade of c-lean aviation fuel, even if the aircraft is going into a heated hangar.
- If the aircraft is to be left outside, put on engine covers and pitot covers.
- If the weather forecast is for snow or clear and colder, put on rotor, or wing covers and save yourself from a snow or frost removal job in the morning.
- Control locks or tied controls are suggested if the aircraft is left outside, and there is a chance of high wind conditions. Tiedowns are also suggested in high winds.
- If the aircraft is equipped with an oil dilution system, consider the advisability of dilution of the engine oil. If it is decided to dilute, manufacturer's recommendations should be carefully followed commensurate with the temperature expected.
- During engine shutdown, a good practice is to turn off the fuel and run the carburetor dry. This diminishes the hazard of a fire during preheat the next morning.

Survival

After a crash landing, it is best to leave the aircraft as soon as possible. Take time to analyze the situation and help others. Take care of any injuries first. Stay away from the aircraft until all gasoline fumes are gone. Sit down and think. Keep in mind that survival is 80 percent mental, 10 percent equipment, and 10 percent skills. Since mental factors are the number one problem, establish a goal to conquer regardless of the consequences. Don't have "give-up-itis" or a "do-nothing attitude." Don't run off without taking time to think out each problem. Don't imagine things that are not there. There are basic fears in each of us. They are:

- Fear of the unknown
- Fear of darkness
- Fear of discomfort
- Fear of being alone
- Fear of animals
- Fear of death
- Fear of punishment
- Fear of personal guilt

Points to remember:

- Your MIND is the best tool for survival. USE IT!
- The number one enemy is yourself.
- The number two enemy is injuries.
- The number three enemy is temperature.
- The number four enemy is disease.

Whether to stay with the aircraft or start out on foot may be a major decision. Did you file a flight plan? If you did, it may be best to let them find you. Is your emergency locator transmitter operating? Do you have a survival kit? Don't fight a storm. Stay put and find shelter. Most storms are of short duration. What do you have in the aircraft that can be used to aid in survival? Other tips:

- The compass will keep you going in one direction.
- Gasoline will help make a fire.
- Oil can be used for smoke signals.
- Seat upholstery may be used to wrap around feet or hands.
- Wiring may be used for tie strings.
- The battery may be used to ignite fuel.
- Use whatever is available to protect the body from the loss of heat; don't waste body heat by eating snow.
- Make a fire and heat water before drinking.
- You can conserve energy to last three weeks if you have water and stay dry -- body heat can escape 240 times faster from wet clothing than from dry clothing.
- It is best to eat small amounts of sugary foods to replace the energy lost through body heat.

A good survival kit is well worth its weight. The following would be a useful kit; however, you can assemble an inexpensive survival kit of your own.

First you need a metal container with a lid. This container can be used to heat water, make tea, use as a digging tool or polished as a signal mirror. In addition, you need:

- Boy Scout knife.
- Small candle.
- Box of matches (wrapped in plastic).
- Leaf bag (pull over head, cut hole for face).
- Garbage bag (step in, pull up and tuck in pants or tie around waist). You now have body protection from heat loss.
- Sugar cubes (wrap in plastic, 6 to 12 cubes).
- Plastic tape.

The list above is only a sample of what can be done. Use your own innovation and remember that survival depends upon you.

About This Series

The purpose of this series of Federal Aviation Administration (FAA) Aviation Safety Program publications is to provide the aviation community with safety information that is informative, handy, and easy to review. Many of the publications in this series summarize material published in various FAA advisory circulars, handbooks, other publications, and various audiovisual products developed by the FAA and used in its Aviation Safety Program.

Some of the ideas an materials in this series were developed by the aviation industry. The FAA acknowledges the support of the aviation industry and its various trade and membership groups in the production of this series.

Comments regarding these publications should be directed to the National Aviation Safety Program Manager, Federal Aviation Administration, Flight Standards Service.

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WINTER STORMS

THE DECEPTIVE KILLERS

A PREPAREDNESS GUIDE

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

DECEMBER 2001

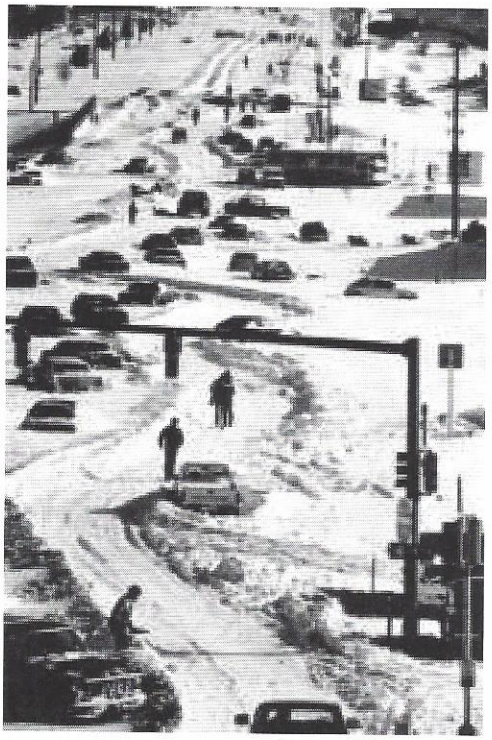
American Red Cross

Winter Storms
The Deceptive Killers

This preparedness guide explains the dangers of winter weather and suggests life-saving action YOU can take. With this information, YOU can recognize winter weather threats, develop an action plan and be ready when severe winter weather threatens. Remember...your safety is up to YOU.

Why Talk About Winter Weather?

- Each year, dozens of Americans die due to exposure to cold. Add to that number, vehicle accidents and fatalities, fires due to dangerous use of heaters and other winter weather fatalities and you have a significant threat.
- Threats, such as hypothermia and frostbite, can lead to loss of fingers and toes or cause permanent kidney, pancreas and liver injury and even death. You must prepare properly to avoid these extreme dangers. You also need to know what to do if you see symtoms of these threats.
- A major winter storm can last for several days and be accompanied by high winds, freezing rain or sleet, heavy snowfall and cold temperatures.
- People can become trapped at home or in a car, without utilities or other assistance.
- Attempting to walk for help in a winter storm can be a deadly decision.
- The aftermath of a winter storm can have an impact on a community or region for days, weeks or even months.
- Extremely cold temperatures, heavy snow and coastal flooding can cause hazardous conditions and hidden problems.



James Wiesmueller

For More Information

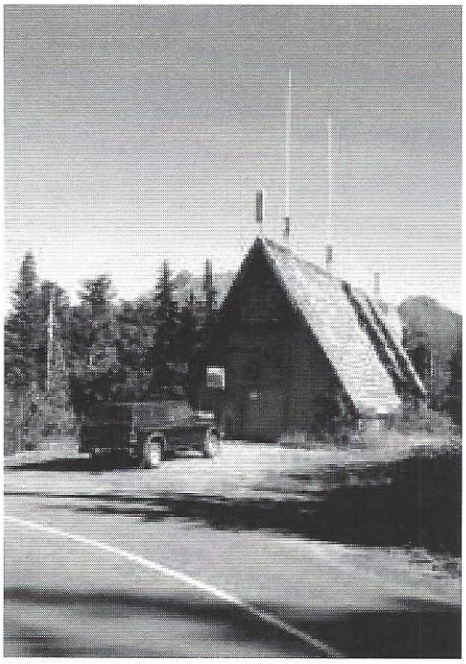
Contact your local National Weather Service (NWS) office, American Red Cross chapter or local emergency management agency for more weather-related brochures.

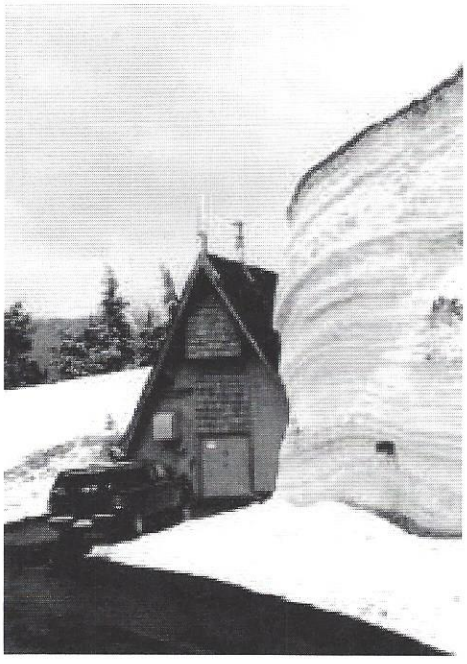
You can find more information on flash flooding in the *Flash Floods and Floods...The Awesome Power* brochure. Contact your local Red Cross chapter or NWS office for copies. You can download a copy at the NWS Web site below. To find additional materials on winter safety, try the following Web sites:

NWS: www.nws.noaa.gov
FEMA: www.fema.gov
Red Cross: www.redcross.org

Heavy Snow

Heavy snow can immobilize a region and paralyze a city, stranding commuters, closing airports, stopping the flow of supplies, and disrupting emergency and medical services. Accumulations of snow can cause roofs to collapse and knock down trees and power lines. Homes and farms may be isolated for days and unprotected livestock may be lost. In the mountains, heavy snow can lead to avalanches. The cost of snow removal, repairing damages, and the loss of business can have severe economic impacts on cities and towns.





Before and after photo at Mt. Baker, WA, Ski Summit. Early June snow depth in 1999 measured 228 inches. The world record seasonal snowfall of 1,141 inches was recorded at Mt. Baker that year. Photos courtesy of Mt. Baker Ski Area.

BLIZZARD: Winds of 35 mph or more with snow and blowing snow reducing visibility to less than ¼ mile for at least 3 hours.

BLOWING SNOW: Wind-driven snow that reduces visibility. Blowing snow may be falling snow and/or snow on the ground picked up by the wind.

SNOW SQUALLS: Brief, intense snow showers accompanied by strong, gusty winds. Accumulation may be significant.

SNOW SHOWERS: Snow falling at varying intensities for brief periods of time. Some accumulation is possible.

SNOW FLURRIES: Light snow falling for short durations with little or no accumulation.

Injuries Due To Ice and Snow

- About 70% result from vehicle accidents
- About 25% occur in people caught out in a storm
- Most happen to males over 40 years old

An avalanche is a mass of tumbling snow. More than 80 percent of midwinter avalanches are triggered by a rapid accumulation of snow, and 90 percent of those occur within 24 hours of snowfall. An avalanche may reach a mass of a million tons and travel at speeds up to 200 mph.

NWS

Ice

Heavy accumulations of ice can bring down trees and topple utility poles and communication towers. Ice can disrupt communications and power for days while utility companies repair extensive damage. Even small accumulations of ice can be extremely dangerous to motorists and pedestrians. Bridges and overpasses are particularly dangerous because they freeze before other surfaces.

Rain	Freezing Rain	Sleet	Snow
Frozen precipitation melts into rain	Frozen precipitation melts in warm air... ...rain falls and freezes on cold surfaces as a sheet of ice	Frozen precipitation melts... ...refreezes into sleet before hitting ground	Snow falling into cold air never melts

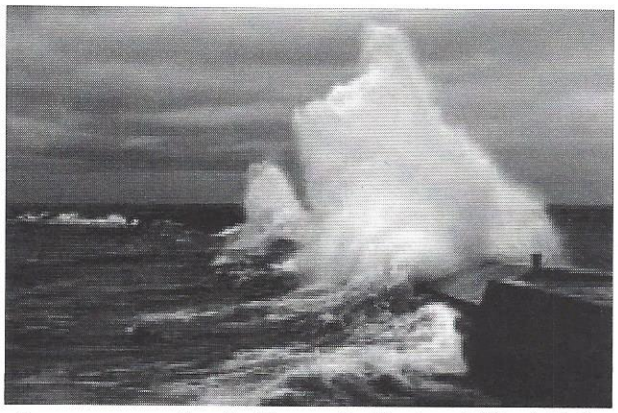
Winter Flooding

Winter storms can generate coastal flooding, ice jams and snow melt, resulting in significant damage and loss of life.

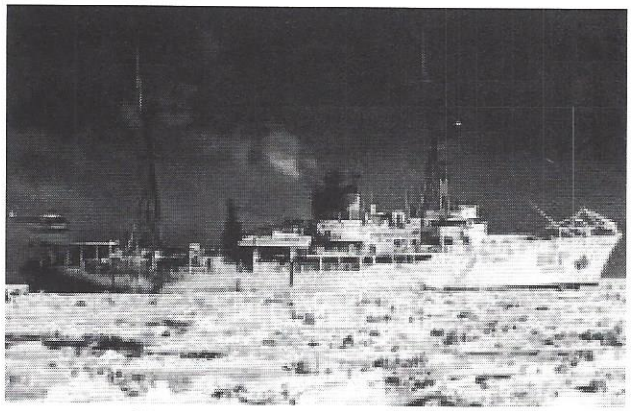
COASTAL FLOODS: Winds generated from intense winter storms can cause widespread tidal flooding and severe beach erosion along coastal areas.

ICE JAMS: Long cold spells can cause rivers and lakes to freeze. A rise in the water level or a thaw breaks the ice into large chunks which become jammed at man made and natural obstructions. Ice jams can act as a dam, resulting in severe flooding.

SNOW MELT: Sudden thaw of a heavy snow pack often leads to flooding.



Large wave action in Marquette Harbor, MI/Jack Pellet



Ship survey of ice in shipping channels/NOAA

Wind Chill Chart

Wind (mph) \ Temperature (°F)	Calm	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
5		36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57	-63
10		34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66	-72
15		32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71	-77
20		30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74	-81
25		29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78	-84
30		28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80	-87
35		28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82	-89
40		27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84	-91
45		26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
50		26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95
55		25	18	11	4	-3	-11	-18	-25	-32	-39	-46	-54	-61	-68	-75	-82	-89	-97
60		25	17	10	3	-4	-11	-19	-26	-33	-40	-48	-55	-62	-69	-76	-84	-91	-98

Frostbite Times: 30 minutes | 10 minutes | 5 minutes

$$\text{Wind Chill (°F)} = 35.74 + 0.6215T - 35.75(V^{0.16}) + 0.4275T(V^{0.16})$$

Where, T = Air Temperature (°F) V = Wind Speed (mph) Effective 11/01/01

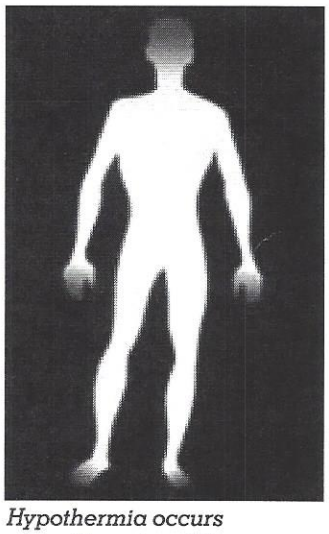
NOAA

Exposure to cold can cause frostbite or hypothermia and become life-threatening. Infants and elderly people are most susceptible. What constitutes extreme cold varies in different parts of the country. In the South, near freezing temperatures are considered extreme cold. Freezing temperatures can cause severe damage to citrus fruit crops and other vegetation. Pipes may freeze and burst in homes that are poorly insulated or without heat. In the North, extreme cold means temperatures well below zero.

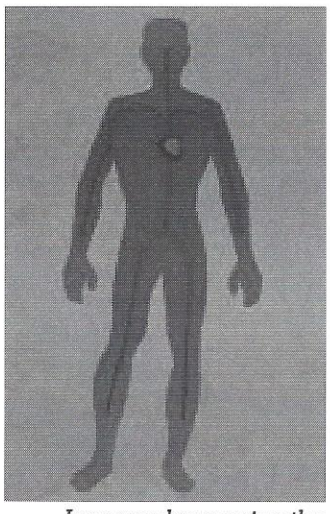
Wind Chill is not the actual temperature but rather how wind and cold feel on exposed skin. As the wind increases, heat is carried away from the body at an accelerated rate, driving down the body temperature. Animals are also affected by wind chill; however, cars, plants and other objects are not.

Injuries Related to Cold

- 50% happen to people over 60 years old
- More than 75% happen to males
- About 20% occur in the home



Hypothermia occurs when the extremities are excessively cold (blue)



Improperly warming the body will drive cold blood from the extremities to the heart, leading to heart failure

Frostbite is damage to body tissue caused by extreme cold. A wind chill of -20° Fahrenheit (F) will cause frostbite in just 30 minutes. Frostbite causes a loss of feeling and a white or pale appearance in extremities, such as fingers, toes, ear lobes or the tip of the nose. If symptoms are detected, get medical help immediately! If you must wait for help, slowly rewarm affected areas. However, if the person is also showing signs of hypothermia, warm the body core before the extremities.

Hypothermia is a condition brought on when the body temperature drops to less than 95°F. It can kill. For those who survive, there are likely to be lasting kidney, liver and pancreas problems. Warning signs include uncontrollable shivering, memory loss, disorientation, incoherence, slurred speech, drowsiness and apparent exhaustion. Take the person's temperature. If below 95°F, seek medical care immediately!

If Medical Care is Not Available, warm the person slowly, starting with the body core. Warming the arms and legs first drives cold blood toward the heart and can lead to heart failure. If necessary, use your body heat to help. Get the person into dry clothing and wrap in a warm blanket covering the head and neck. Do not give the person alcohol, drugs, coffee or any hot beverage or food. Warm broth is the first food to offer.

Annual Mean S

Midwest and Plains

- Heavy snow
- Strong winds/Blizzards
- Extreme wind chill
- Lake-effect snow
- Ice storms

West Coast

- y precipitation
- winds
- tal flooding
- h erosion

Mid-At to New

- Heavy sn
- Ice storm
- Strong w
- Coastal f
- Beach er
- Extreme

The Rockies

- Heavy snow
- Mountain-effect snow
- Strong winds
- Avalanches
- Extreme cold
- Blizzards

Southeast and Gulf Coast

- Ice storms
- Crop-killing freezes

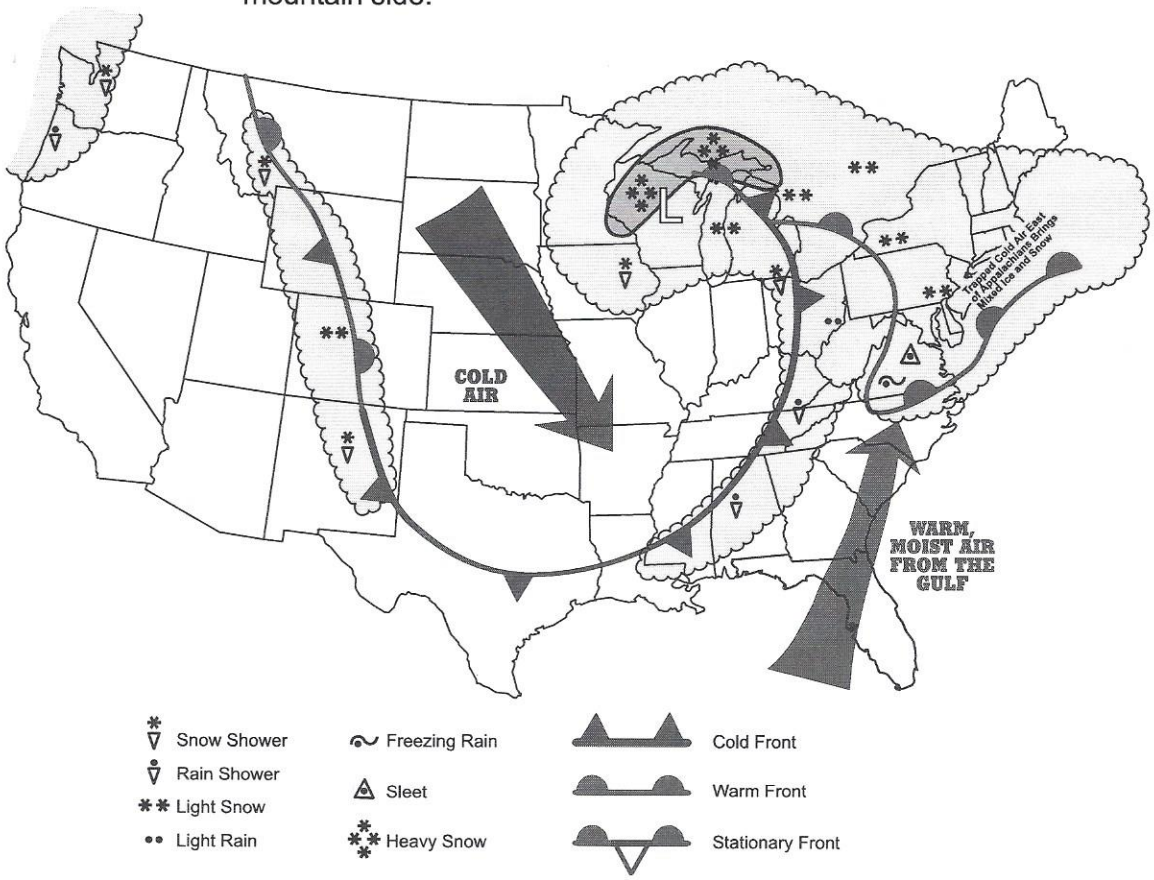
How Winter Storms Form

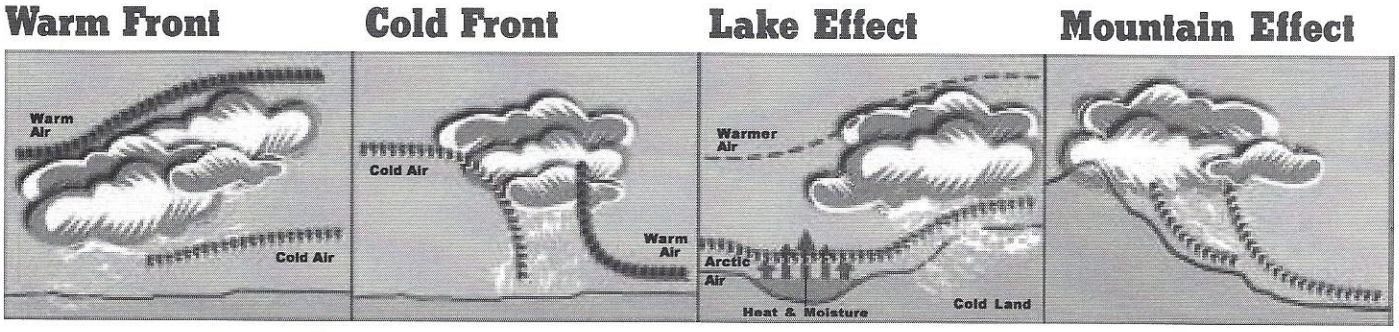
There are many ways for winter storms to form; however, all have three key components.

COLD AIR: For snow and ice to form, the temperature must be below freezing in the clouds and near the ground.

MOISTURE: Water evaporating from bodies of water, such as a large lake or the ocean, is an excellent source of moisture.

LIFT: Lift causes moisture to rise and form clouds and precipitation. An example of lift is warm air colliding with cold air and being forced to rise. Another example of lift is air flowing up a mountain side.





Stay Informed!

KEEP AHEAD OF THE STORM by listening to NOAA Weather Radio, commercial radio and television for the latest winter storm warnings, watches and advisories

Electronic equipment available to receive weather information/NOAA (Weather Radio, Radio, TV, Pager, Cell Phone, Two-Way Radio)

NOAA Weather Radio is the best means to receive warnings from the National Weather Service. The National Weather Service continuously broadcasts warnings and forecasts that can be received by NOAA Weather Radios, which are sold in many stores. The average range is 40 miles, depending on topography. Purchase a radio that has a battery back-up and a Specific Area Message Encoder feature, which automatically alerts you when a watch or warning is issued for your county or parish.

What to Listen For

The National Weather Service issues outlooks, watches, warnings and advisories for all winter weather hazards. Here's what they mean and what to do. Use the information below to make an informed decision on your risk and what actions should be taken. Remember to listen to your local officials' recommendations and to NOAA Weather Radio for the latest winter storm information.

OUTLOOK:	Winter storm conditions are possible in the next 2-5 days. Stay tuned to local media for updates.
WATCH:	Winter storm conditions are possible within the next 36-48 hours. Prepare now!
WARNING:	Life-threatening severe winter conditions have begun or will begin within 24 hours. Act now!
ADVISORY:	Winter weather conditions are expected to cause significant inconveniences and may be hazardous. If you are cautious, these situations should not be life threatening.

Be Prepared!

Before the Storm Strikes

At Home and Work

Primary concerns are loss of heat, power and telephone service and a shortage of supplies if storm conditions continue for more than a day.

Have available:

Flashlight and extra batteries.

Battery-powered NOAA Weather Radio and portable radio to receive emergency information. These may be your only links to the outside.

Extra food and water. Have high energy food, such as dried fruit, nuts and granola bars, and food requiring no cooking or refrigeration.

Extra medicine and baby items.

First-aid supplies.

Heating fuel. Refuel before you are empty. Fuel carriers may not reach you for days after a winter storm.

Emergency heat source: fireplace, wood stove, space heater.

- Use properly to prevent a fire.
- Ventilate properly.

Fire extinguisher, smoke alarm.

- Test smoke alarms once a month to ensure they work properly.

Make sure pets have plenty of food, water and shelter.

In Vehicles

Plan your travel and check the latest weather reports to avoid the storm!

Fully check and winterize your vehicle before the winter season begins.

Carry a WINTER STORM SURVIVAL KIT:

- Mobile phone, charger, batteries
- Blankets/sleeping bags
- Flashlight with extra batteries
- First-aid kit
- Knife
- High-calorie, non-perishable food
- Extra clothing to keep dry
- Large empty can to use as emergency toilet. Tissues and paper towels for sanitary purposes
- Small can and waterproof matches to melt snow for drinking water
- Sack of sand or cat litter for traction
- Shovel
- Windshield scraper and brush
- Tool kit
- Tow rope
- Battery booster cables
- Water container
- Compass and road maps.

Keep your gas tank near full to avoid ice in the tank and fuel lines.

Avoid traveling alone.

Let someone know your timetable and primary and alternate routes.

NOAA

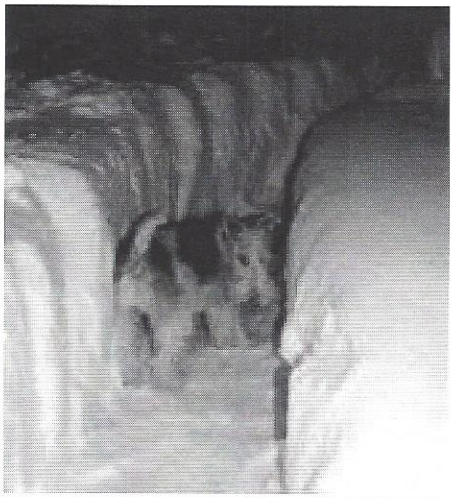
On the Farm/Pets

Move animals to sheltered areas. Shelter belts, properly laid out and oriented, are better protection for cattle than confining shelters, such as sheds.

Haul extra feed to nearby feeding areas.

Have water available. Most animals die from dehydration in winter storms.

Make sure pets have plenty of food, water and shelter.

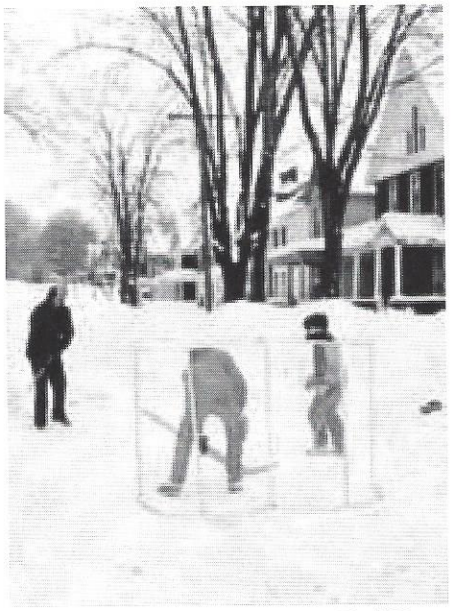


Glenn Field/NOAA

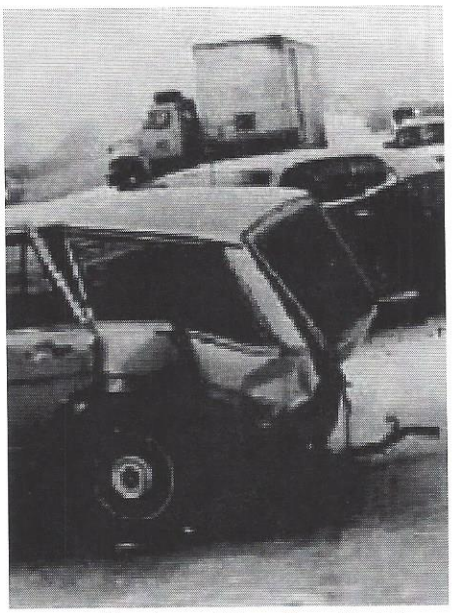
Dress for the Season

Wear loose, lightweight, warm clothes in layers. Trapped air insulates. Remove layers to avoid perspiration and subsequent chill. Outer garments should be tightly woven, water repellent, and hooded. Wear a hat. Half your body heat loss can be from the head. Cover your mouth to protect your lungs from extreme cold. Mittens, snug at the wrist, are better than gloves. Try to stay dry.

When Caught in a Winter Storm



Courtesy of American Red Cross



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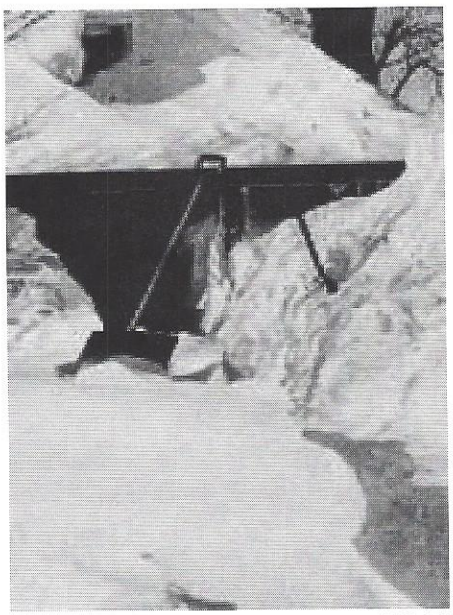

NOAA

Outside

Find shelter:

- Try to stay dry.
- Cover all exposed body parts.

No shelter:

- Build a lean-to, windbreak or snow cave for protection from the wind.
- Build a fire for heat and to attract attention.
- Place rocks around the fire to absorb and reflect heat.

Melt snow for drinking water:

- Eating snow will lower your body temperature.

In a Vehicle

Stay in vehicle:

- You will become quickly disoriented in wind-driven snow and cold.
- Run the motor about 10 minutes each hour for heat.
- Open the window a little for fresh air to avoid carbon monoxide poisoning.
- Make sure the exhaust pipe is not blocked.

Be visible to rescuers:

- Turn on the dome light at night when running the engine.
- Tie a colored cloth, preferably red, to your antenna or door.
- After snow stops falling, raise the hood to indicate you need help.

Exercise:

- From time to time, move arms, legs, fingers and toes vigorously to keep blood circulating and to keep warm.

Inside

Stay inside:

- When using alternate heat from a fireplace, wood stove, space heater, etc., use fire safeguards and properly ventilate.

No heat:

- Close off unneeded rooms.
- Stuff towels or rags in cracks under doors.
- Cover windows at night.
- Eat and drink. Food provides the body with energy for producing its own heat. Keep the body replenished with fluids to prevent dehydration.
- Wear layers of loose-fitting, lightweight, warm clothing. Remove layers to avoid overheating, perspiration and subsequent chill.

AVOID OVEREXERTION, such as shoveling heavy snow, pushing a car or walking in deep snow. The strain from the cold and the hard labor may cause a heart attack. Sweating could lead to a chill and hypothermia. Take Red Cross Cardiopulminary Rescue (CPR) and Automated External Defibrillator (AED) training so you can respond quickly to an emergency.

FAMILY DISASTER PLAN

Prepare for hazards that affect your area with a Family Disaster Plan. Where will your family be when disaster strikes? They could be anywhere at work, at school or in the car. How will you find each other? Will you know if your children are safe? Disasters may force you to evacuate your neighborhood or confine you to your home. What would you do if basic services – water, gas, electricity or telephones – were cut off?

Steps to Take

I **Gather information about hazards.** Contact your local National Weather Service office, emergency management office, and American Red Cross chapter. Find out what type of disasters could occur and how you should respond. Learn your community's warning signals and evacuation plans. Assess your risks and identify ways to make your home and property more secure.

II **Meet with your family to create a plan.** Discuss your plan with your family. Pick two places to meet: a spot outside your home for an emergency, such as fire, and a place away from your neighborhood in case you can't return home. Choose an out-of-state friend as your "family check-in contact" for everyone to call if the family gets separated. Discuss what you would do if advised to evacuate.

III **Implement your plan.**

1. Post emergency telephone numbers by the phone.
2. Install safety features in your home, such as smoke alarms and fire extinguishers.
3. Inspect your home for potential hazards (items that can move, fall, break or catch fire) and correct them.
4. Have your family learn basic safety measures, such as CPR, AED and first aid; how to use a fire extinguisher; and how and when to turn off water, gas and electricity in your home.
5. Teach children how and when to call 911 or your local Emergency Medical Services number.
6. Keep enough supplies in your home for at least 3 days. Assemble a disaster supplies kit. Store these supplies in sturdy, easy-to-carry containers, such as backpacks or duffle bags. Keep important documents in a waterproof container. Keep a smaller disaster supplies kit in the trunk of your car.

A Disaster Supplies Kit Should Include:

- A 3-day supply of water (one gallon per person, per day)
- Food that won't spoil
- One change of clothing and shoes per person
- One blanket or sleeping bag per person
- First-aid kit
- Prescription medicines
- Emergency tools
- Battery-powered NWR
- Portable radio
- Flashlight with extra batteries
- Extra set of car keys
- Cash and a credit card
- Special items for infant, elderly or disabled family members.

IV **Practice and maintain your plan.** Ensure your family knows meeting places, phone numbers and safety rules. Conduct drills. Test your smoke alarms monthly and change the batteries at least once each year. Test and recharge your fire extinguisher(s) according to manufacturer's instructions. Replace stored water and food every 6 months. Contact your local National Weather Service office, American Red Cross chapter or emergency management office for a copy of "Your Family Disaster Plan" (L-191/ARC4466).

Local Sponsorship:

ARC 4467 December 2001 NOAA/PA 200160

WATER AND WIND CHILL FACTORS (Concl.)

COOLING POWER OF WIND ON EXPOSED FLESH EXPRESSED AS AN EQUIVALENT TEMPERATURE

ESTIMATED WIND SPEED (IN MPH)	ACTUAL THERMOMETER READING (F)												
	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60	
	EQUIVALENT TEMPERATURE (F.)												
Calm	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60	
5	48	37	27	16	6	-5	-15	-26	-36	-47	-57	-68	
10	40	28	16	4	-9	-24	-33	-46	-58	-70			
15	36	22	9	-5	-18	-32	-45	-58	-72				
20	32	18	4	-10	-25	-39	-53	-67					
25	30	16	0	-15	-29	-44	-59						
30	28	13	-2	-18	-33	-48	-63						
35	27	11	-4	-20	-35	-51	-67						
40	26	10	-6	-21	-37	-53	-69						
WIND SPEEDS GREATER THAN 40 MPH HAVE LITTLE ADDED EFFECT.	LITTLE DANGER (FOR PROPERLY CLOTHED PERSON) MAXIMUM DANGER OF FALSE SENSE OF SECURITY.				INCREASING DANGER: DANGER FROM FREEZING OF EXPOSED FLESH.			GREAT DANGER					

SOURCE: NAVMED BULLETIN 5052-29