DESCENT

Volume 19 : No. 2 **Alaska Alpine Club** December 1988

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Contents

Page
Calendar of Events - 1
Editor's Message - 2
Climbing Class Poster (pass it on to anyone who may be interested) - - - - - - - - - 3
Valdez Ice-Climbing Festival - 1988 - 5
Peter MacKeith Expedition Climbing Grants - 6
Report from the top of the world by Bob Groseclose - - - - - - - - - - - - - - - - - 7
Carbon Monoxide Exposure in Mountaineers on Denali - - - - - - - - - - - - - - - - - 9
Alaska Mountain Safety Center & Alaska Avalanche School Schedule - - - - - - - - - - 12

Calendar

December 5	East Ridge of Hayes, Groseclose, Donofrio & Justice	Brooks 204	7:30 p.m.
January 25	Climbing Class Registration Frostbite Hypothermia Lecture	Brooks 204	7:30 p.m.
February 6	Monthly Meeting, Roger Siglin, Climbing in Peru	Brooks 204	7:30 p.m.
February 17 thru 20	Valdez Ice-Climbing Festival	Valdez	
March 6	Monthly Meeting	Brooks 204	7:30 p.m.
April 1	Glacier Rendezvous	T. B. A.	
April 3	Monthly Meeting	Brooks 204	7:30 p.m.
May 5	Reunion and Graduation Party	Yak Estates Commons	7:30 p.m.

The **DESCENT** is published 1 to 4 times a year on a hit or miss basis. Copies are sent to members of the Alaska Alpine Club. Non-members may receive **DESCENT** for $0.50 an issue.

Membership in the Alaska Alpine Club is open to anyone with an interest in the mountains. Meetings are open to the public and are normally the first Monday of the month, September to May, on the UAF campus. Tea and cookies are provided. The Alaska Alpine Club is a student organization of the University of Alaska, Fairbanks.

Editors Notes

Thanks to the efforts of Howard Ferren, Michael Harney, Dyan Seigel, Bob Groseclose, and others the Lower Canwell Hut has been renovated with cedar walls, insulation, bench, cook shelf, etc. The marmots did some damage over the summer but an unknown person cleaned up the mess. We have got to get rid of those critters.

Barb Powell donated all her climbing gear to the club as she was leaving to go to law school in Tennessee and due to bad knees knew she would not climb again. Some of the equipment will be useful for the climbing school such as the rope, ice axe, crampons, ice screws, etc. The avalanche transceivers could be used in a rental program such as Bob Groseclose suggested in the last Descent. Other gear such as boots, jumars, etc. should probable be sold to the highest bidder. Any suggestions?

A recent examination of the Thayer hut file found 24 letters from individuals in opposition to BLM selling the land to the club and 1 letter in favor of the sale. In addition there are pages and pages from Doug Buchanan in opposition. In response BLM had one of their investigators conduct a few interviews. BLMs' main concern was about our alleged opposition to snow machines and hunters. Examples of members with snow machines and those that hunt was provided. Apparently the conditions of the act under which we are trying to buy the land requires continued public use but in an attempt to satisfy some of the complaints BLM may include some stipulations that the hut shall remain open to the public.

Pawing deeper in the file to figure out who started us down this land purchase endeavor brought me to a letter of February 2, 1979 where the club asked for information on how to purchase BLM land ... signed by Doug Buchanan. Asking some of the old timers indicates that Doug was instrumental in starting this land acquisition action prior to the split of the clubs.

Discussions with a number of members finds a mix of opinions. There are a few members who support purchase but others who foresee much expense and many headaches with the responsibility of land ownership. If you wish to express your opinion on the issue there will probably be another comment period after the conclusion of the lawsuit which has stalled the action. Send to:

Gene Terland, District Manager
Bureau of Land Management
P.O. Box 42
Glennallen, Alaska 99588

For those of you who missed the November meeting and need a helicopter rescue someday ... your out of luck. The climbers who attended learned all about the 283 rd medical detachment from Bruce Bates. They fly out of Fort Wainwright or Fort Greely on 15 minutes notice. If a hoist is needed (no place to land) they take a bit longer to get airborne as the "bird" is heavier. If at all reasonable to do so move to a place where they can land. If you do need their medevac services call the State Troopers as they are the ones that usually dispatch them..

Stan Justice

SKI MOUNTAINEERING

Once again the Alaska Alpine Club will be offering instruction in ski mountaineering and climbing this spring. Two sessions will be offered.

Introduction to Ski Mountaineering For persons with cross-country skiing and cold weather camping experience. Will teach the basics of camping and ski travel in Alaskan mountains, including introductory crevasse rescue and safety topics.

Intermediate Ski Mountaineering and Climbing For persons having successfully completed the introductory course or with equivalent experience.

Tuition for each course is $20.00. Additional expenses include $17 for text, gas money, food, restaurant meals on field trips. Anyone in the Fairbanks community with appropriate experience is invited to participate. These courses are a great way to get into the mountains and meet other mountaineers! Safety is everyone's individual responsibility. The club carries no liability insurance.

The course consists of weekly lectures or discussion sessions held WEDNESDAYS at 7:30 P.M. in Brooks 204 on the UAF campus and weekend field trips some of which are long day trips and others are overnight excursions.

TEXT - "Mountaineering - The Freedom of the Hills" By The Mountaineers of Seattle (available at Clem's or REI)

CREDIT - Available for 3 credit hours as independent study.

SCHEDULE

Date	Class Topic	Weekend Trip
Introduction to Ski Mountaineering		
Jan 25	Register, Frostbite, Hypothermia	none
Feb 1	Gear-Make your own or buy	none
Feb 8	Snow Caves, Ice Axe, Crampons	Feb 11,12 Wickersham Dome Overnight
Feb 15	Prusik, Rappel, Z-pulley, Anchors	Feb 19 Skills workshop in town
Feb 22	Glacier Travel, Crevasse Rescue	Feb 25,26 Delta Glacier Ice
Mar 1	Avalanche safety	Mar 4 Panorama Area
Mar 8	First Aid, High Altitude Effects	Mar 11,12 Triangle Pk.
Intermediate Ski Mountaineering and Climbing		
		Apr 1,2 Glacier Rendezvous
Apr 5	Snow Climbing, Igloos, Fly ins	Apr 8,9 Panorama Peak Traverse
Apr 12	Ice Climbing	Apr 16 Healy Ice
Apr 19	Leadership, Expeditions	Apr 22,23 Institute Peak
Apr 26	Rock Climbing	Apr 30 Angel Creek Rocks

For further information contact Stan Justice 479-5017, Bob Groseclose 457-5498, Bob Thompson 455-6654 or, John Keller 479-3630 eve 474-6042 day.

1988 Climbing Class on Summit of McMallum

SIXTH ANNUAL
VALDEZ ICE-CLIMBING FESTIVAL - 1988

Sponsored by the Alaska Section of the American Alpine Club, and by the Valdez Alpine Club, the 1988 Ice-Climbing Festival will be held on the Washington's Birthday Weekend, Friday through Monday, February 17-20. The festival is an occasion when ice-climbers from all over Alaska gather, along with some out-of-state and foreign climbers. Originally just a sociable climbing weekend for members of the Alaska Section of the American Alpine Club, the event grew as interest spread. Past years have seen visits by Japanese, Austrians, Canadians and New Zealanders as well as those from Washington, Colorado, California, Kentucky, Arizona and elsewhere. Floor space, and use of kitchens and bathrooms, is available in the homes of several local residents, though there are motels available as well. During the weekend, climbing slide shows, films, and videos are shown, and a potluck spaghetti dinner is traditional on Saturday evening (participants should bring items to put in or go with spaghetti).

The appeal of Valdez is partly that it contains some of the best and most highly concentrated ice climbing anywhere on the world. For example, in or near the city limits there is more climbable ice than in all of Colorado, Montana and Wyoming, and as many routes as are listed in the guidebook for the entire Canadian Rockies. In addition, climbing conditions are exceptionally consistent, Moderate temperatures (20 to 30 F), sea-level location and lots of precipitation ensure thick, relatively plastic ice and greater comfort than in most places. Especially in Keystone Canyon, approaches are minimal (100 yards or less from the road). More than 160 routes have been climbed, so far, in or near the city limits, of all ranges of difficulty from the easiest to several of the harder routes anywhere. Several are longer than 600 feet, and there are new route possibilities. There is also some skiing available, both cross-country on a course up Mineral Creek, and downhill at Thompson Pass.

Those interested in coming to the Festival this year are encouraged to do so, and no registration is required. Those hoping to stay with local climbers must, however, call in advance as space is limited. Those wishing to check on conditions, should call ahead as well. The traditional center of activities (slide shows and films, mountaineering library, and sauna) has been the home of Drs. Andy Embick and Kathy Todd (see below). Other local contacts are John and Karen Weiland (835-2626), Bob Shelton (835-5127), and Brian Teale (835-5182). For motel reservations, contact the Village Inn (835-4445).

The actual ice climbing season is from some time in November or late October, to March or early April. Before February, thin, brittle ice, short days, cold and wind can be less than idyllic, but climbing is very feasible.

Andrew Embick M.D. / Festival Chairman / P.O. Box 1889 / Valdez, Alaska 99686 /
(907)835-4200(home) / (907)835-4811(work)

Peter MacKeith Expedition Climbing Grants

The "Peter MacKeith Memorial Endowment Fund for Climbing" was established in 1981 by the family of Peter MacKeith, late president of the Alaska Alpine Club, in honor of Peter's love for climbing and of his climbing achievements in Alaska, Afghanistan, Greenland, and Iceland. The Alaska Alpine Club was given the responsibility of distributing the earnings from the endowment for the purpose of supporting worthwhile mountaineering ventures by Club members in Alaska or elsewhere in the world.

Requirements for submitting a proposal:

1.) All expedition members must be Alaska Alpine Club members for at least a year prior to receiving the grant
2.) The proposal must contain the following:
   - a.) names, addresses, and resume of climbing experience for each expedition member.
   - b.) a description of the climbing objective.
   - c.) a description of how the party plans to carry out the climb and approximate dates of the cli[mb]
   - d.) a budget for the expedition explaining how a climbing grant will be used.
3.) DEADLINE for submitting a proposal is March 1 of each year.

Obligations of the expedition upon receiving a grant:

1.) Use the grant money for the original climbing expedition described in the proposal or return the money to the Alaska Alpine Club.

2.) Provide an acknowledgement that the expedition has received a Peter MacKeith Climbing Grant from the Alaska Alpine Club.
3.) Submit an article (with pictures if possible) about the climb for the Club's publication DESCENT.
4.) Present a slide show about the climb for the Alaska Alpine Club.

(NOTE: These obligaions hold even when the objective of the climb is not attained.)

General:

1.) Grants will be awarded at the March Annual Meeting of the Alaska Alpine Club.
2.) Expeditions are not limited to Alaska or the United States
3.) Expeditions are not limited to first ascents or climbs of unusual difficulty although these aspects will be taken into consideration.
4.) The financial need of the expedition's climbers will be given high priority.
5.) The Alaska Alpine Club does not assume any liability for the expedition.
6.) In any given year, the Club may distribute the entire earnings of the endowment, part of it, or none of it, depending on the merits of the proposals. Grants may be awarded to one or several expeditions.

Report from the top of the world

By Bob Groseclose

A British climber once observed that "men do not conquer a big mountain, they wait until the mountain is napping and sneak up on it." On June 3-4, 1988, the highest point of North America, Denali (a/k/a Mt. McKinley) was taking a breather from the storms and high winds characteristic of its summit. After three weeks, including 5-6 "storm days," I and six others from our 9 person group snuck to the top. "Napping" though it was, Denali still greeted us with -10 degrees F temperature and dished out far worse we counted our good fortune in being able to stand atop this 20,320 feet peak, regarded by many as the highest climb in the world because of the 13,000 vertical elevation gain from the 7,000 base camp to the top.

For those accustomed to the serenity and solitude of climbing Alaska's remote mountains, climbing Denali is quite different—an experience often approaching a visit to an international KOA campground. Except that on Denali there are no electrical hook-ups, "showers" are limited to non-liquid precipitation, and toilet paper is not provided. And like travel south of the border, be careful about drinking the water. "Yellow fever" is best avoided by consuming only snow of the white variety.

Denali offers not only the "big mountain" challenge, but also a cultural experience generally reserved for U.N. delegates. During my three weeks on the mountain from May 16 to June 7, I encountered climbers from France, Switzerland, Austria, Britain, Italy, Spain, Canada, Germany, Korea, Japan, and New Zealand. In fact, foreigners appear to make up at least half (maybe more) of the 500 climbers who attempt Denali annually. I found myself speaking nearly as much broken French and German as during my last trip to Europe. Pantomining and charades were often the only common "language" to communicate with some of the foreign climbers encountered on the popular West Buttress route.

Much to the dismay of mountaineers steeped in the credo of "help yourself or die," a number of foreign climbers didn't have much difficulty learning the word "help" and of using it even when circumstances later proved it unwarranted. The helicopter evacuations of three Koreans in two, separate rescue efforts from the 18,000-19,000 foot levels of the Cassin Ridge of Denali (one of the more difficult approaches to the summit), led to the inevitable bad taste jokes in our climbing team, which happened to have three attorney members:

Q: What's the difference between three Koreans and three attorneys in trouble on Denali?

A: The Koreans get rescued.

If you have a climber's bent, Denali is both a memorable and challenging experience. Realizing that not everyone finds enjoyment in going without a shower for three weeks, in sharing a communal crapper in full view of the universe (see photo), in testing the limits of one's endurance, or in living at altitude (nausea, headaches, shortness of breath, general malaise), nevertheless here is a boiled down recipe for a successful Denali climb.

NOTE: For those readers without a climber's dementia, who find neither joy nor challenge in climbing a flight of stairs, much less a 20,000 foot mound of dirt, rock, and ice, kindly proceed to the next article, however mundane and trivial though it may be. For those bracing for a Denali climb, read on.

1. A "successful" climb is getting back safe and sound. You want to live to climb again, hug your child, insult your adversary, or even write your memoirs. There's no point in killing yourself to prove a point, namely, that you're a mere mortal and that the mountain is bigger and meaner than you. Getting to the top must be of secondary importance.

2. Get in shape. In addition to the spa and your Jane Fonda workout,

After descending from the summit, the author basks at the 14,000-foot camp with more than a vertical mile of Denali looming in the background. The summit clouds indicate high winds aloft.

*nearly 30 mph winds. Given Denali's capacity to getting in a number of early season mountain climbs will better prepare you for toting a 50-plus pound pack up Denali. As Seattle climber and attorney Jim Wickwire aptly put it, "the best way to get in shape to climb mountains is by climbing mountains." Several early season climbs also hone your mountaineering skills, build confidence, and enable you to field test your equipment.

3. Learn to climb and camp out in the winter. The essence of a Denali climb is coping with the cold. It might have been Sam McGee's "awful dread of the icy grave," but it need not be yours. Modern equipment and clothing take much of the dread out of winter camping. Still, you need to have enough winter camping experience to learn what clothing and sleeping bag combination work best for you. Some people sleep warmer than others. Don't bank on manufacturers' ratings on sleeping bags—field test your equipment and draw your own conclusions.

Learning and practicing such mountaineering skills as crevasse rescue, use of an ice axe, and climbing in snow and ice are also essential. It's too late to learn how to get out of a crevasse once you're in one. Also, the best way to stay out of a crevasse is knowing how to avoid falling in one. Basic mountaineering courses are available in Anchorage through the community college. In Fairbanks, a local climbing club, the Alaska Alpine Club, offers a climbing course commencing in January. Also, some of the guiding concessionaires on Denali offer a "mountaineering seminar" component to their guided climbs.

4. Get a medical examination. You don't want to discover a heart murmur at altitude. Medical evacuations are no fun, neither for the victim nor the rescue team.

5. Budget ample time. Sometimes even your clients and the court might have to wait. Climbing Denali is on

cessful in summiting might have had a more rewarding experience if they weren't rushing their climb. Although there are instances of well-honed groups having summited within two weeks, a minimum three-week time schedule enhances the chances of success. You then have both the time to acclimate as well as to sit out the random storm.

On the subject of time, the months of May and June are regarded as the climbing season for Denali. Although the weather and storm intensity varies from season to season, May and June are generally optimal for avoiding excessive cold (below -30 degrees), avalanches, softening bridges over crevasses, and stormy periods.

6. Climb with a team. Unless you're able to recruit your own climbing team, which is difficult given the commitment required, you have essentially two options (solo climbing is not a serious option):

A) Hang around Talkeetna or Kahiltna base camp long enough and you're bound to find a climbing partner, or preferably a climbing team. This leaves too much to chance for my liking. I know of climbers ascending Denali by this approach but they run the risk of not finding a team or of finding a team which shuns some time-tested safety techniques.

For example, despite the history of climbers who have met their fate traveling unroped, many climbing parties still travel unroped on parts of Denali. This seems to be more common of foreign climbers who either don't know better or simply don't care. Because of the National Park Service lecture video, which is required viewing for Denali's climbers, it is hard to understand climbers not knowing better.

Be selective about your climbing companions and insist on safe practices.

B)There are six guides and guiding services authorized by the National Park Service to guide climbers on

any particular degree of climbing/-guiding competence. Although utilizing a guide is not the fiercely independent, Alaskan approach, it has distinct advantages in an ascent of Denali. In addition to the obvious advantage of being with a person who "has been there before" and, hence, just might know more than the average climber, you also are spared much of the planning and logistical drudgery of a "big mountain" climb. Have you ever assembled food supplies for a three week outing, much less one where the rudimentary chore of cooking has its quirks at altitude?

For between $2,000 and $2,500 you can contract with a guiding service to climb Denali. When you consider

The communal commode at the 7,000-foot Kahiltna Base Camp, complete with operating instructions in 7 languages.

that the price covers food, round-trip airfare from Talkeetna to the base camp on the Kahiltna glacier, and all common equipment (tents, ropes, stoves and fuel, radio, shovels, etc.), the price is well worth it.

The principal drawback to utilizing a guiding service is the risk of being thrown in with people with whom you might not otherwise choose to spend three weeks of your life. Traveling in a large group (9 to 12 people) of varying climbing and out-

ever, because of the need to acclimate during a high altitude climb, speed in breaking camp and travel is not so critical. You quickly learn on Denali to view distances differently than you might otherwise. It is roughly 20 miles from Kahiltna base camp to the summit of Denali. What took me nearly three weeks to climb took scarcely one day to descend. Climbing Denali safely is no race.

I climbed with Alaska-Denali Guiding Inc. (Brian and Diane Okonek of Talkeetna). The risk of being placed with incompatible people was largely eliminated by their application and screening process. I was pleased to learn that the guides insisted on knowing something about me, such as my climbing and outdoor background, level of fitness, and that they required a doctor's certificate as to my medical fitness.

Be selective about choosing a guide. The better ones do not exceed a ratio of three clients per guide. You can obtain a list of the Denali guides through the National Park Service.

7. Go prepared. A detailed discussion of equipment and supplies for a Denali climb can be found in "Surviving Denali," Jonathan Waterman (1983 American Alpine Club). You obviously don't want to be underequipped, and by the same token you don't want to cripple yourself hauling unnecessary items.

If you are considering a Denali climb and want to know more about my experience, give me a call, phone 452-1855 (work) or 457-5498 (home).

When not pursuing outdoor adventures, Bob Groseclose practices law in Fairbanks with the firm of Staley, DeLisio, Cook & Sherry, Inc. He is also president of the Alaska Alpine Club.

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Carbon Monoxide Exposure in Mountaineers on Denali

By W.A.Turner[1], M.A. Cohen[2], S. Moore[3], J.D. Spengler[2], M.D., and P.H. Hackett[4], M.D.

ABSTRACT

Carbon monoxide (CO) poisoning is a particular hazard for persons camping in cold, stormy, high altitude locations such as Mt. McKinley (Denali). Recently, two climbers were killed by CO on Denali while cooking in a tightly sealed tent. CO has also contributed to high altitude illness. To assess exposure in various shelters we measured CO levels with a portable monitor in a mountaineering tent, igloos and snow caves during an ascent of Denali.

Concentrations measured at altitudes between 2000 and 5200m usually exceeded the U.S. Environmental Protection Agency's 1-hour standard of 35ppm, reaching a mean value as high as 165ppm in a snow cave. Based on the data from this preliminary study, the use of a larger vent hole, approximately the size of a ski pole basket, appears to provide enough ventilation to maintain CO levels at more acceptable levels in snow caves and igloos.

INTRODUCTION

Ever since the early polar explorers began using portable kerosene stoves to cook and melt snow for water, numerous accounts of people being poisoned by the exhaust gases from such stoves have been published (1-3). One such account comes from the journey of Stefansson to the North Pole. He reported that while using a Primus stove (a small kerosene stove) in a snow house, the walls "became iced and impervious to gases," whereupon two of his companions collapsed in the house while he and the fourth member of the party managed to extinguish the stove and escape before collapsing: "An hour later three of the party members were well enough to go into the house again..." (1).

In the modern era, we have the advantage of considerable research on topics such as emission rates of carbon monoxide (CO) from stoves and lanterns (2,4), the concentrations of CO that can be found in tents and snow houses (1-5), and the amount of carboxyhemoglobin (COHb) found in the blood after carbon monoxide exposure (3). The acute health effects of exposure to carbon monoxide are well established (6). Most recently, Cohen (4), using a combination of laboratory work and computer modeling predicted that high levels of CO could be attained in tents when a cooking stove was used even for periods less than 30 minutes if ventilation were inadequate.

Despite considerable knowledge in this area, morbidity and mortality from CO poisoning persists on Mt. McKinley (Denali). In 1986, two Swiss climbers died on Denali while cooking in a tightly sealed tent at 4400m, ironically, only a few meters from the medical research camp. The purpose of this study was to better define the exposure to CO on Denali under typical mountaineering conditions in typical shelters and to test various methods of reducing the hazard by changing shelter ventilation.

Measurements were made during and after the use of the stove for meal preparation. The data indicate that CO exposure may reach toxic levels in all types of shelter and that adequate ventilation in snow shelters can be established by larger vent holes.

METHODS

Two of the authors (WT and SM) made the measurements during a climb of Denali in June of 1985. Measurements were made in three types of shelters used for mountaineering: tent, igloo, and snow cave (Figure 1). Because climbers often encounter temperatures well below freezing and strong winds, these shelters are designed to be small in volume and to have low ventilation rates. The tent was nylon, designed for two persons, with double-wall construction and a vestibule for cooking that was open to the inside of the tent. Igloos were made with cut snow blocks, and the cooking and sleeping level was higher than the entrance. Snow caves were also constructed with the living area higher than the entrance to help maintain warmth.

Carbon monoxide (CO) measurements were made using a calibrated CO monitor (Gas Tech Portable, Model CO-82). The instrument was zeroed before and after each series of measurements. A calibration standard of 180ppm CO was used at 90m, 2600m, 3400m, and 4300m above sea level to define a relationship between the instrument's response to the standard and the altitude. When plotted, an altitude correction function was derived and applied to the data. (The instrument reads low at high altitude due to decreased partial pressure of gas.) This was preferred over adjusting the instrument at each altitude. Readings of the CO instrument were recorded at approximately 10-minute intervals during monitoring.

Three different stoves with similar fuel consumption rates were used during the testing. These were an Optimus 111B, an Optimus 8R, and a MSR Firefly. All stoves burned white gas and were in good operating condition. None had special jets for high altitude, and no attempts were made to alter the air/fuel ratios. The maximum fuel consumption rate for two of the three stoves (111B and 8R) has been measured to be approximately 210 grams/hour and is estimated to be less for the Firefly.

Measurements were made during the preparation of the meals in each of the dwellings. These periods typ-

Harriman Associates, Auburn, Maine;
Harvard School of Public Health, Cambridge, Massachusetts;
Perini Corp, Framingham, MA;
Denali Medical Research Project, University of Alaska, Anchorage, Alaska. Institutional Affiliation: Harvard School of Public Health.
Reprint Requests: Peter H. Hackett, M.D., 742 K Street, Anchorage, Alaska, 99501.

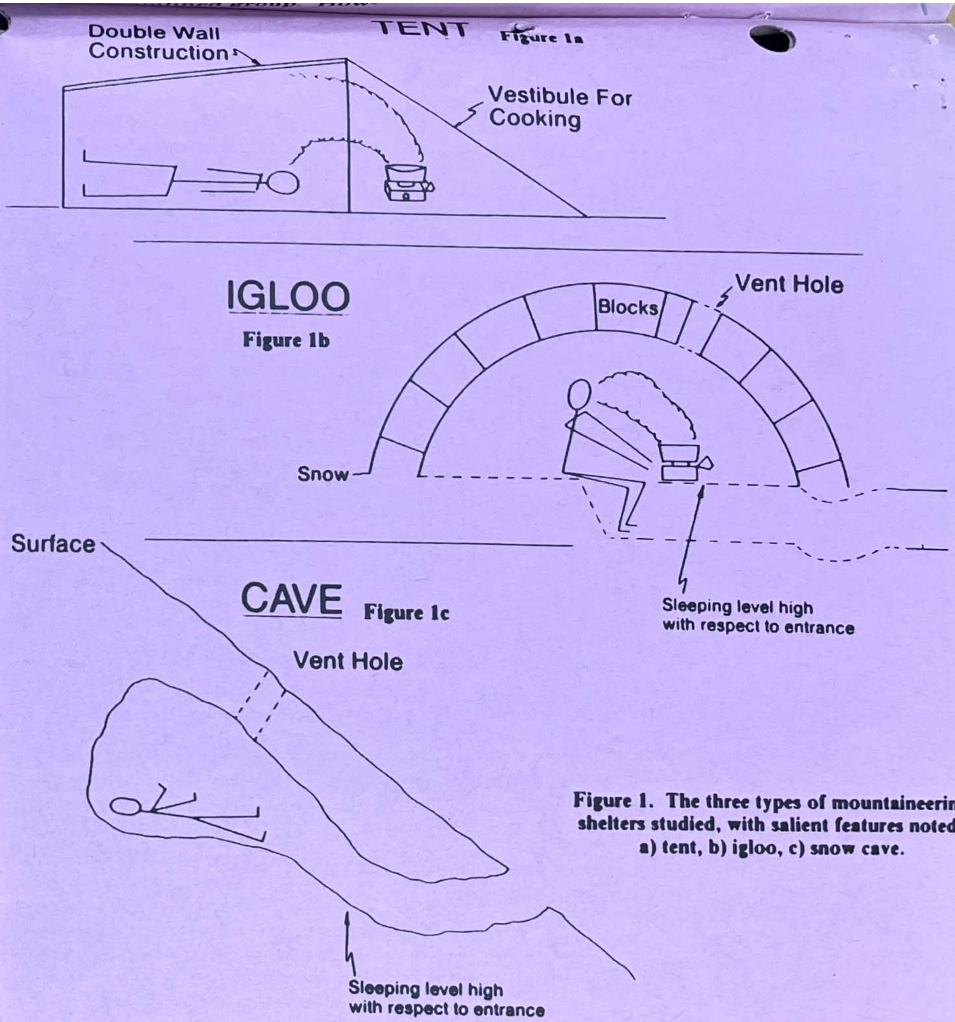

Figure 1. The three types of mountaineering shelters studied, with salient features noted: a) tent, b) igloo, c) snow cave.

- 6 -

ically lasted between one and two hours and consumed 150-300 grams of fuel. The detector was located in the breathing zone of the occupants, approximately 1.5 to 2 meters horizontally from the cookstove and approximately 1 meter vertically, depending on the particular shelter. Efforts were made to standardize this sampling location. CO measurements were also made after the stove was turned off to calculate ventilation rates. Assuming exponential decay, the ventilation rate (air exchange rate of the dwelling) is the slope of the logarithm of CO concentration plotted against time. A more in-depth study of this method and its assumptions can be found in American Society of Testing and Materials (ASTM) (7). In snow caves, all measurements were repeated with different sized ventilation holes. Ventilation area was changed in the tent by partially opening or closing the zippered door. The reported CO concentrations have been corrected for altitude.

RESULTS

Tent

Table 1 gives the data that was taken inside the tent at 2300m using the 111B stove. During the last two runs, the CO concentrations were notably higher than the first two runs and were above the toxic level (50ppm). The outdoor wind speed during the first run was 7m/s, while there was no detectable wind during the following measurements. This explains the high ventilation rate in run 1 as measured by CO decay rate.

Igloo

The results from using the 111B and 8R stoves in the igloos at 2600 and 4300m are presented in Table 2. CO reached toxic levels in all tests when the stoves were burning for more than fifteen minutes. The first test was made while the snow blocks were still fresh and porous, which may have led to the relatively high air ventilation rate (air exchange rate) observed. The last three runs were made in igloos that had relatively less permeable walls due to glazing and accumulated snowpack. There was a decrease in ventilation rate for the later tests.

Snow Cave

Table 3 summarizes the results for the snow caves at 5000 and 5300m using the 8R and MSR stoves. While in these snow caves, the highest CO concentration was recorded (190ppm). Therefore, we investigated the relationship between concentration and the vent size.

Vent Area Versus Ventilation Rate

In a snow cave, vent holes of different sizes were made to test the relationship between air exchange rate and the size of the hole. The size of the vent area does not include the opening at the cave entrance, since the floor of the cave is higher than the entrance. Three basic sizes were tested: an ice axe shaft hole (approximately 10cm²), a ski basket hole (approximately 50cm²), and a hole made with the handle of a shovel (approximately 80cm²). The relationship between vent area and the ventilation (air exchange) rate is shown in Figure 2. In this limited data set the ventilation rate closely correlates with the gross vent area (R^2=0.903). A hole of 50cm² more than doubled the ventilation rate, and also kept CO concentrations below the EPA standard of 35ppm for one hour.

Air Exchange Versus Dwelling Type

Air exchange rates in the three shelters were determined by decay of CO over time with the source off. Figure 3 shows typical decay rates for the tent, the igloos, and the snow caves with holes. For the tent, the entrance door was half open. Even without perceptible wind, the ventilation rate was calculated at 65 air exchanges/hr (ACH). The inside vs outside temperature difference was about 6°C. CO concentrations reached background ambient values in three minutes. For the igloo, with a vent hole of approximately 45cm², a typical air exchange rate was five air changes/hour, and the CO concentration had not reached ambient levels after 30 minutes. For the cave with a vent hole of approximately 20cm², a typical air exchange rate was 3.6 air changes/hour, and after 45 minutes the CO concentration was still relatively high.

DISCUSSION

The observations and experiments performed on Denali between 2000m and 5200m were made under typical snow camping conditions. The stoves and shelters are all common to mountaineering. The snow burn times were actual meal or water preparation times required to support two or three climbers. It is important to note that 8 of the 13 sets of measurements of CO exceeded 50ppm during stove use. Our data, though limited, indicate that mountain climbers on Denali who cook in shelters may be at risk of acute carbon monoxide poisoning and that increasing shelter ventilation effectively reduces the risk.

Average CO concentration ranged from 15ppm to 165 ppm, varying primarily with shelter ventilation rates but also with fuel consumption and stove type. The air

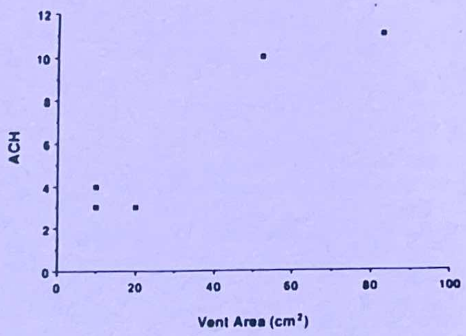

Figure 2. Air exchange rate (ACH) vs. size of vent area in a snow cave. A vent greater than 50 cm sq resulted in higher exchange rates.

Table 1

TENT				
Stove Type	111B	111B	111B	111B
Altitude (meters)	2300	2300	2300	2300
Delta temp. (degrees C)	11	6	8	6
Wind Speed (m/s)	7	none	none	none
Burn Time (hrs)	.75	.5	.5	.5
CO conc (ppm)				
# Points	10	5	6	6
Max.	40	40	80	110
Mean	25	35	50	70
Min.	15	25	15	55
Gross Ventilation (cm²)	4500	19400	2600	19400
Ventilation Rate (air exchange/hr)	150	65	13	38
# of points in decay curve	3	15	10	9

Table 2

IGLOO				
Stove Type	111B	111B	8R	8R
Altitude (meters)	2600	4300	4300	4300
Delta temp. (degrees C)	17	23	23	23
Wind Speed (m/s)				
Burn Time (hrs)	1	1	.5	25
CO conc (ppm)				
# Points	8	14	5	4
Max.	85	140	80	40
Mean	80	120	70	35
Min.	70	80	60	30
Gross Ventilation (cm²)	none porous	45 glazed walls	45 glazed walls	45 glazed walls
Ventilation Rate (air exchange/hr)	13	5	4	14
# of points in decay curve	17	22	10	10

exchange rates were determined to be lowest in igloos and snow caves where the walls are more impervious to air flow and ventilation holes limited. We confirmed similar CO levels and ventilation rates during March 1986 in snow caves at 1000m and 1500m in the Presidential Range of the White Mountains of New Hampshire (unpublished observation).

The plot of the CO concentration decay suggests that the mechanism for ventilation in the snow caves and igloos is relatively similar, while the tent may differ. Wind is one factor expected to exert much more influence on ventilation in a tent compared to snow shelters, especially once an interior ice-glazed surface is formed. It should be noted that during the first experimental run inside of the tent, a wind of approximately 7m/s was blowing outside. This run resulted in an air exchange value of 150 per hour. Subsequent measurements were in calm conditions, and air exchange rates were closer to the other two shelters but still generally higher for the tent. The much larger vent area of the tent appears to be a distinct advantage. It should be noted that tightly sealed tents, however, could also form an ice glazed interior surface in the absence of wind or be covered with snow on the outside; even tents have the potential for low air exchange rates, as demonstrated by the recent deaths on Denali.

The effectiveness of using larger vent holes in snow caves is an important finding. We found the relationship between the air exchange rate in the snow cave and the vent area was relatively linear, implying only a small contribution to the ventilation rate was made by diffusion of air through the semi-porous snow and ice. In order to make a rough estimate as to what vent size would be required to keep the CO concentration below a certain level, the CO concentration was also plotted against the vent size. We recommend a minimum of $50 cm^2$ vent in a snow cave, which seems to be adequate even if the snow walls are glazed.

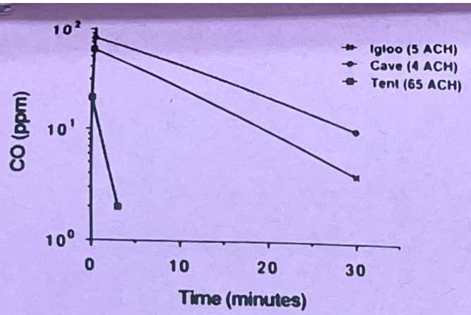

Figure 3. Carbon monoxide concentration in parts per million over time for the three different shelters. The shelter with high air exchange rate (ACH) had the most rapid decline in CO after the stove was turned off.

The emission rate (or source strength) of the cooking stove also influenced the level of CO. Based on fuel consumption rates determined for the 111B and 8R and boiling times for all three stoves, it appeared that the MSR Firefly had a lower fuel consumption rate and thus possibly a lower emission rate.

Table 3

SNOW CAVE					
Stove Type	8R	8R	MSR	MSR	8R
Altitude (meters)	5000	5000	5000	5300	5300
Delta temp. (degrees C)	8	11	14	11	5
Wind Speed (m/s)					
Burn Time (hrs)	1 hr.	1	2	1	.25
CO conc (ppm)					
# Points	10	6	11	4	3
Max.	190	35	95	65	30
Mean	165	30	70	50	28
Min.	70	25	60	38	25
Gross Ventilation (cm^2)	11	52	20	11	81
Ventilation Rate (air exchange/hr)	4	10	3	3	11
# of points in decay curve	18	4	6	11	5

The concentrations of CO recorded in the various shelters are high enough to produce significant toxicity. Of the 13 total experiments, eight showed mean concentrations of 50ppm or higher. Fifty ppm CO results in a carboxyhemoglobin level of about 8%, assuming the kinetics of uptake and equilibration remained the same as sea level. There is some evidence, however, that CO uptake is increased because of the hyperventilation induced by the hypoxia of high altitude (8,9). Although 8% COHb is not considered toxic at sea level, such a level will exacerbate the altitude hypoxia. The normal arterial oxygen saturation (SaO2%) of a climber on Denali after two days acclimatization to 4400m is 80%. A decrease in oxygen carrying capacity of 8% to an effective SaO2% of 72% due to COHb would result in a very significant drop in oxygen transport, rendering the climber at a "physiologically" higher altitude and could easily precipitate acute mountain sickness. In 1985, two Denali climbers required rescue because of severe acute mountain sickness induced by CO exposure (10). Low-level CO exposure may thus contribute to altitude illness. Further evidence for an additive effect of CO and altitude hypoxia was a study by Vollmer *et al.* (11). Four of seventeen healthy subjects at a simulated altitude of 4725m collapsed when COHb reached 9% to 19% (9), values not associated with collapse at sea-level. The EPA has more recently reviewed the combined effects of CO and altitude (12).

The higher CO concentrations recorded in our study are clearly in the range to cause CO toxicity, depending mostly on the exposure time. Symptoms of CO poisoning are identical to those of acute mountain sickness; i.e., headache, nausea, dizziness and lassitude. Therefore, differentiating the two may be impossible. Also, because of the lower inspired oxygen pressure, the rate of elimination of CO from hemoglobin may be impaired.

Two climbers found dead of CO poisoning from cooking in a tightly sealed tent on Denali in 1986 had COHb levels of 65.6% and 56.9% at autopsy, levels considered lethal even at sea level. Although the interactions of CO and altitude hypoxia need further investigation, it is clear that CO poisoning poses a serious risk when using stoves in shelters at high altitudes.

SPECIFIC RECOMMENDATIONS

As a result of the measurements obtained, the authors recommend that tents, igloos and snow caves always be vented when combustion appliances are used. We suggest that mountaineers adopt the practice of creating a vent hole in igloos and snow caves that is at least the diameter of a ski pole basket whenever a stove is in use, especially at high altitude. This vent should be located in the vicinity of stove operation and as high as possible in the dwelling. To maintain vital warmth offered by the shelter without risk of physical impairment from CO poisoning, the vent hole may be plugged with snow after finishing use of the stove. Using this method, the authors on this McKinley climb were able to maintain temperature within properly constructed igloos and caves in the range of 15 to 20°C above ambient except when the vent was open.

In light of the recent mountaineering deaths and illness attributable to CO poisoning and increasing activity of high altitude mountaineering, further research is needed in this area. Altitudes above 4000m are sufficiently hostile without the added danger of carbon monoxide.

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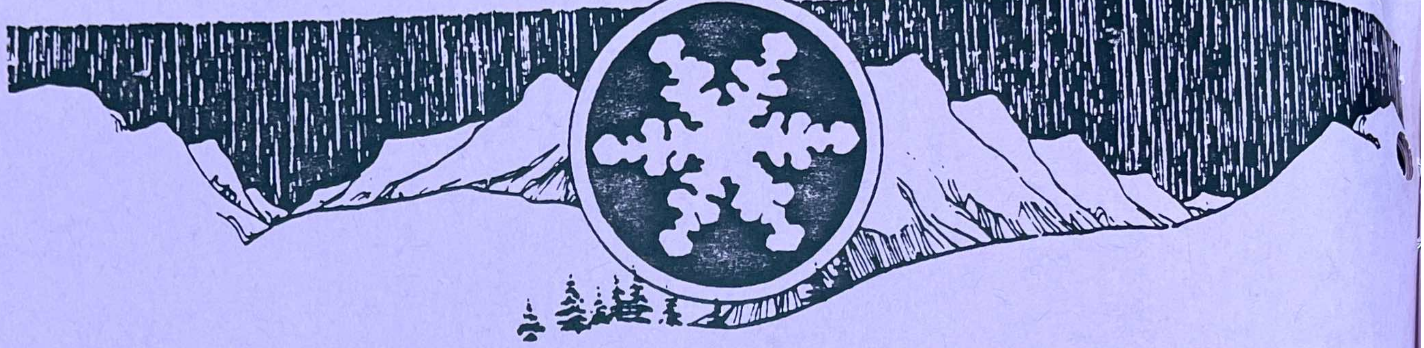

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