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GOOSE LAKE, MONTANA, 1964 ACCESSIBILITY FIELD METHODS AND LOGISTICS

by

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PREFACE

This report presents items of general interest associated with the Goose Lake, Montana, field study of the High Elevations Research Project, Materials Research Branch, U. S. Army Cold Regions Research and Engineering Laboratory (USA CRREL). This project was supported by the Director's In-House Laboratory Independent Research Program.

The material presented in this report is for information only and does not constitute official endorsement or rejection of any product. Any use of it for promotion or advertising purposes by any commercial interest is not authorized.

A more comprehensive study of certain aspects of the technical program at Goose Lake will be published separately.

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INTRODUCTION

This is not a scientific paper. It is a general outline and discussion of experience gained during the planning and execution of a research project to study the physical properties of snow in a high remote mountain cirque. The field site selected was at Goose Lake in the Beartooth Mountains of Montana, approximately 10 miles north of Cooke City (Fig. 1). The paper contains sections dealing with the geographical setting of the research area, problems associated with gaining access to that area, equipment and supplies, the nature of the research project, and a few comments on mountain safety. Inasmuch as this location will be used as a field site for USA CRREL projects during the next few years, this paper should also serve as a general "introduction" to the area and the problems one can expect to encounter there.

It should be stressed that this paper is not a final statement on the subject of alpine logistics nor will the techniques discussed here necessarily prove most successful. They should be considered solely as guidelines to assist in the planning of future research projects in mountainous areas.

GEOGRAPHICAL DATA

The Beartooth Mountains are located in southwestern Montana, directly north of Yellowstone Park, and are the northernmost range in the Middle Rocky Mountain Province. They are bounded on the west and north by the valley of the Yellowstone River and on the east and southeast by the Bighorn Basin. The largest city in the immediate vicinity is Billings, Montana, with a population of over 75,000, lying approximately 100 miles northeast of Cooke City via the Beartooth Highway. Billings is served by several major airlines and trucking firms, making it an excellent point of departure for work in the Beartooths. In addition, there is a General Services Administration car pool located in Billings where vehicles may be obtained.

From a distance, the most striking aspect of the Beartooth Mountains is the "subsummit surface," an area of generally low relief lying at an elevation of 10,000 to 12,000 ft above sea level, above which isolated peaks rise as monadnocks to a maximum elevation of 12,850 ft. On the north side of the range the relief is abrupt, the mountains rising as a wall from the floor of the Yellowstone Valley at less than 4000 ft above sea level to the subsummit surface. From the south the rise is much gentler and the average elevations of the valley floors are 7000 to 8000 ft, affording much easier access to the higher elevations in the interior of the range (Fig. 2).

The southern slope is a glacially rounded upland, liberally dotted with lakes ranging from over a mile to a few tens of feet in their longest dimension. The slopes are timbered up to approximately 9000 ft; above this altitude trees exist only in isolated patches. The surface above 9000 ft is similar in many respects to the arctic tundra, being composed of bogs and frostriven outcrops of metamorphic and igneous rocks. At the higher elevations, local relief is provided by "roches moutonnées" and narrow, steep-walled stream valleys which head at the major lakes.

ACCESSIBILITY

In the winter and spring, the research site at Goose Lake may be reached by motor toboggan (for a description of the vehicle used, see the section on "Oversnow Transport") from Cooke City by generally following old mining roads built about the

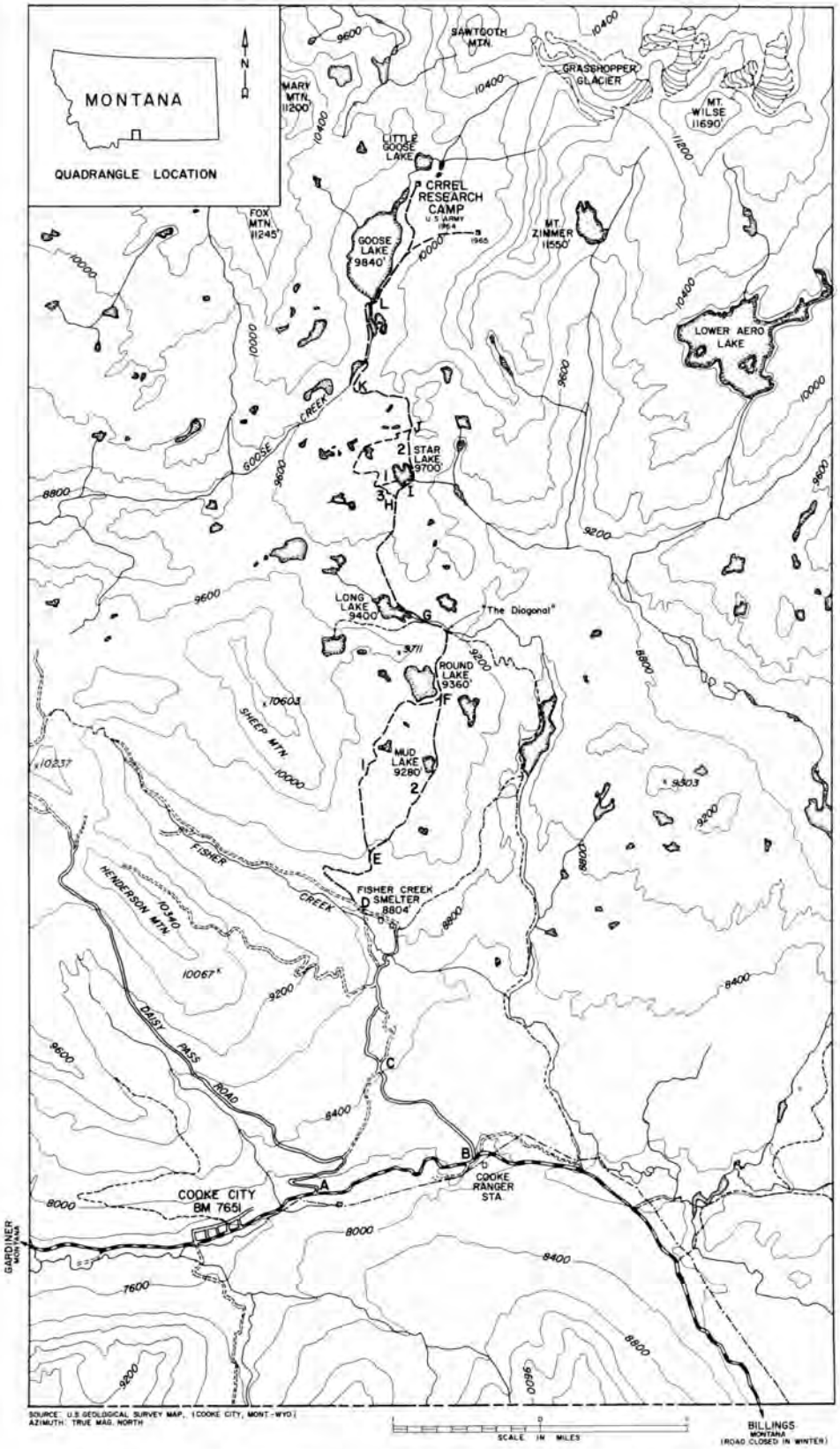

Figure 1. Cooke City – Goose Lake, Montana and vicinity.

Figure 2. Looking northeast across Mud Lake, Mt. Zimmer on the extreme left. A remnant of the dissected subsummit surface can be seen in the center of the picture.

turn of the century (see Fig. 1). For the first 5 miles one has a choice of two routes. It is possible to follow the Beartooth Highway (which is not plowed in the winter) east out of Cooke City approximately $1\frac{1}{2}$ miles to a point opposite the U. S. Forest Service Ranger Station just below the summit of Cooke Pass (Cooke City — A-B)*. At this point the road to the Fisher Creek Smelter (B-D) proceeds north from the main highway. This juction (B) is not immediately obvious in the winter due to the heavy snow accumulation. The Fisher Creek road gradually climbs through the timber on the lower slopes of Henderson Mountain until it reaches the top of a low, flat ridge overlooking Fisher Creek (Fig. 3) and the buildings comprising the smelter on the opposite valley wall.

A second much shorter, although steeper, approach to Fisher Creek is via the Daisy Pass road, which again leaves from the left hand (north) side of the main highway approximately $\frac{1}{2}$ mile east of Cooke City (A). At the top of the second switchback on the Daisy Pass road, a narrow path will be seen making a rising traverse of the slope to the right (east). This path (Fig. 4) joins the first route approximately 1 mile below the smelter (C).

The Fisher Creek Smelter is important on three counts: (1) it marks the beginning of one of the few difficult sections of the trail, (2) it is the furthermost point on the trail that can be supplied by Weasel via route A-B-C-D , and (3) a cabin is located there, equipped with two beds and a stove, which may be used as an equipment dump and way station in the transporting of equipment to and from Goose Lake. The owner of the cabin has permitted USA CRREL personnel to use the facilities in the past and this can probably be arranged again during any future work in the area.

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* The letters and numbers refer to locations on Figure 1.

Figure 3. The Ski-Doo on top of the ridge west of Fisher Creek. The prominent landmarks in the background are Pilot and Index Peaks in the Absaroka Range.

Figure 4. A portion of the trail between Cooke City and Fisher Creek, looking south into the Absaroka Mountains Cooke City lies at the foot of Republic Mountain, the slopes of which are just visible at the extreme right.

Above the smelter, the trail climbs over the low, timbered ridge which forms the east wall of the valley of Fisher Creek. While this climb represents a rise of only 400 ft in elevation, it is impossible to approach it directly due to the abruptness of the rise. The trail climbs the ridge in one long switchback (D-E) which reduces the gradient to the point where loaded Ski-Doos can handle it easily. This switchback, however, introduces the problem of continually traversing a slope for a distance of approximately $\frac{1}{2}$ mile. A bit of shoveling is necessary to prepare the trail for the passage of loads. The trail to the top of the ridge is straightforward as there are no alternatives.

At the top of the ridge, however, it is possible to go in almost any direction as the country becomes quite open and park-like with limited local relief. The initial trail from the top of the ridge (E) to the next major landmark, Round Lake (F), bore generally off to the left (west) of the mining road into the high, open parks at the foot of Sheep Mountain. This route (E-1-F) was satisfactory under most conditions, but it climbed several hundred feet more than was necessary to reach Round Lake. This excess elevation was then lost quickly in a rather steep descent of the wall of the Round Lake basin. While this presented no problems on the inbound trip, occasionally a Ski-Doo coming out to the smelter would have difficulty climbing the slopes above the lake. This portion of the trail was therefore relocated soon after its establishment.

The new trail followed much more closely the trend of the mining road to Goose Lake (E-2-F). This presented another problem which could have become quite serious. As was mentioned, the country between the top of the switchback above the smelter and Round Lake is fairly open and the exact location of the mining road is never obvious in the winter. This section was traversed on a trial and error basis for several weeks at the beginning of the project. After that, all members of the party were sufficiently familiar with the landmarks to travel this route with reasonable security. In any future operation this section of the trail (E-2-F) should be well flagged to eliminate any question concerning its location.

Probably the single most difficult section of the trail lies just above Round Lake where the trail passes around the east side of a low ridge (Fig. 5) separating Round and Long Lakes and then makes a descending traverse of a high angle slope to reach the outlet of Long Lake. (This area is referred to as the "Diagonal;" see Figure 1, F-G.) In preparing the Diagonal for the movement of loaded Ski-Doos it was necessary to dig almost 200 yards of level trail into the steep hillside. This level shelf naturally collected any falling or sliding snow and consequently it was necessary to dig it out following each of the many storms which swept through the area in late April and early May. It is, therefore, essential to cache at least one shovel in the general area of the Diagonal. The terrain at this point is such that there is no choice of routes and future parties should be resigned to the effort of maintaining this stretch of trail.

Beyond this descending traverse, the trail passes around the right (northeast) side of Long Lake (Fig. 6), leaving the lake approximately two-thirds of the way from its south end to climb in a northerly direction through an obvious break, both in the terrain and the trees. At this point, timberline has almost been reached with the remaining trees occurring in small, widely scattered groups (Fig. 7). Here the trail is quite simple and easily followed in good weather, winding gradually higher among the groups of trees and the "roches moutonnées" (Fig. 8) until Star Lake, lying just at timberline, is reached. Mount Zimmer, which forms the east wall of the Goose Lake cirque, can now be seen to the north and on a clear day the problem becomes less one of general direction than of negotiating the rather extreme local relief formed by glacial erosion on the pre-Cambrian bedrock. The objective at this point is to reach the valley of Goose Creek (K) which can then be followed up to the outlet at the south end of Goose Lake (L). Three alternate routes were used at different times to traverse this section (Fig. 9) and while there may be other possi-

Figure 5. Round Lake, looking north. The trail goes to the right (east) around the rocky ridge in the background.

Figure 6. Trail at Long Lake, looking north. Note lack of tree cover and moderate local relief, typical of the south slope of the Beartooth Mountains above 9000 ft.

Figure 7. Portion of the trail between Long Lake and Star Lake, which lies over the low ridge on the horizon.

Figure 8. Trail approaching Star Lake. Low, snow-covered mounds to left of trail are "roches moutonnées. Beginning of trail by-passing Star Lake on the west is indicated by dotted line in the center.

Figure 9. Looking southwest over the basin of Star Lake. Lines indicate original trail (1) and 2nd and 3rd variants (2 and 3). The prominent mountain in the extreme upper right is Sheep Mountain.

bilities available, these are felt to offer the best chance of immediate success. Two of the routes began by dropping down (H-I) onto the ice cover of Star Lake. The first route (I-1-J) then goes to the left, around a prominent rock buttress which forms a 20 ft high cliff above the southwest corner of the lake and then up a gully leading generally to the west-southwest until sufficient elevation has been gained to surmount the low ridge above Goose Creek. The route then weaves through hummocky topography to point J. This approach was used during most of the field season in spite of its obvious drawbacks: its extreme circuitousness and the presence of several pitches which are at the upper limit of the pulling power of a loaded Ski-Doo. Later in the season, as an improvement on this route, a traverse (I-2-J) was made around the right (east) shore of Star Lake toward an open but very steep appearing slope which led directly to the top of the ridge behind (north of) Star Lake. It was found that the steepness of this slope was more apparent than real and that a Ski-Doo could, with a little help, climb it. This brought one out on the first variant at point J. The third variant (H-3-J) was adopted after it was felt that the ice cover of Star Lake was becoming unsafe to cross. This route left the main trail approximately 30 yards south of Star Lake and, following a rising traverse across the slopes to the left (west) of the lake, joined the first route (1) at the top of the gully. This last variant is not particularly suitable for loaded Ski-Doos and probably should not be used before the ice on Star Lake becomes unsafe.

From point J the route runs due north for approximately 0.2 miles following the "grain" of the local relief and thenturns west leading directly into Goose Creek (K) about $\frac{1}{2}$ mile from the lake outlet (L). This is the point where the angle of descent into Goose Creek is the shallowest. The location of the trail from K to the research site is quite obvious, following up Goose Creek to Goose Lake and then

Figure 10. Research camp in Goose Lake cirque. Roof of trailer is visible to the left of the tent. Little Goose Lake lies between trailer and low col in background.

around the right (east) side of the lake to the group of buildings visible at the north end of the lake (Fig. 10). On a clear day this presents no problems, but during fog or storm no attempt should be made to traverse this stretch of the trail unless it is very clearly marked with flags. The whiteout conditions which prevail in the Goose Lake cirque during storms completely obscure all landmarks.

In going from Goose Lake to Cooke City, fewer problems are encountered. This is primarily due to the fact that one is gradually losing elevation rather than gaining it. There are actually only two short sections of the trail which normally are difficult when traveling in this direction. These are: (1) the climb out of Goose Creek just above Star Lake and (2) the rising "Diagonal" traverse below Long Lake. The fact that they were negotiated during the 1964 field season under all snow and weather conditions is an indication that they are never absolutely impassable.

No avalanches were encountered on this route in 1964. Due to the nature of the terrain, their occurrence in the future is considered unlikely.

OVERSNOW TRANSPORT

In the mountains, unlike areas such as Greenland, one is faced with the problem of selecting a transport system which will function efficiently over a variety of terrain and snow types. In addition, because of the general remoteness of typical research areas and the desirability of simplicity in the support phase of any operation of this nature, it is best to select a motorized oversnow vehicle with an eye to ease of maintenance.

In approaching this problem for the Beartooth operation, it was felt that a certain latitude of choice should be allowed for unanticipated problems. It was therefore decided to take both skis and snowshoes for use around the immediate camp area and to depend upon the one-track Bombardier Ski-Doo as the primary means of transport (Fig. 11). The Ski-Doo is an open vehicle with a two-cycle, air-cooled engine which drives a continuous, 18 in. wide track. On packed snow, it is capable of

Figure 11. The single track Ski-Doo on the trail at Goose Creek.

speeds in excess of 20 mph and can pull one or two skiers plus 150-200 lb on a sled over moderate terrain.*

For the most part, problems with the Ski-Doo were of a minor nature and we were able to perform most of our own maintenance. We were fortunate, however, in having the services of a mechanic in Cooke City with some experience in the repair of Ski-Doos, otherwise our problems would have been greatly complicated. Since it is unreasonable to assume that all field parties will be this fortunate, it would be wise to be self-sufficient with regard to tools and spare parts so that any necessary repairs can be made by the project members themselves.

Three major breakdowns were experienced during the field season. These were, in the order of their occurrence, a torn track, a broken gas line, and a cracked cylinder. Under normal circumstances, any one of these would have been sufficient to render the Ski-Doo inoperative for the balance of the field season. The torn track occurred during the initial stages of the move into Goose Lake and was probably caused by a lack of proper adjustment of the track alignment. It is possible to prevent this by constantly watching the track adjustment. Following replacement of the torn track, we had no further trouble of this nature. The broken gas line was probably caused by the vibrations associated with a two-cycle engine. In this particular instance, the problem was solved by brazing the line, but under more normal circumstances a complete replacement of the gas line would have been the best solution. The cause of the cracked cylinder is not known and, at any rate, this is not considered a field repair operation.

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* The Ski-Doo is one of a class of motor toboggans with varying performance characteristics. This section should not be construed as an implication that the Ski-Doo is the only acceptable vehicle of this type.

It is believed that the number and extent of the breakdowns during the field season were exceptional, primarily due to the fact that the vehicle had been operated extensively in Greenland the previous season and had not been thoroughly overhauled before being sent to the field again. Also, the demands made upon a vehicle of this type in an alpine region are quite extreme and its performance limits may have been exceeded at times. The most satisfactory solution to this problem is the acquisition and use of a minimum of two of the larger Ski-Doos, thereby diminishing the amount of work any one vehicle is required to perform. In addition, this should insure, insofar as is possible, at least one operable vehicle at all times.

For minor field repairs, the following represent the minimum tool requirements:

2 6-in. crescent wrenches,
1 spark plug wrench,
1 pair needle-nosed pliers,
1 thickness (feeler) gauge,
2 6-in. flared tip screwdrivers,
1 small wire brush,
A metal rod, $\frac{1}{2}$ in. diam by 18 in. long (for cleaning snow out of the track),
Operator's manual.

The spare parts kit should include at least one replacement for any item which can be replaced in the field. In particular, these are:

1 complete carburetor assembly,
1 complete automatic rewind starter assembly,
1 track,
2-3 drive belts,
4 fan bolts,
and
3-4 spark plugs

A list of spare parts used in 1964 will be found in Appendix A, section F.

The operation of tracked vehicles over snow covered mountain terrain presents certain problems which are not normally encountered in the polar regions. Of these, two are significant enough to warrant some discussion: (1) the importance of crusts in oversnow movement and (2) cross slope travel.

Travel was possible but extremely difficult immediately following a heavy snowfall or after a period of intense radiation on an established snow crust. The problem of oversnow movement in the mountains, therefore, appears to be intimately linked to the amount of intergranular cohesion in the top few centimeters of the snowpack. This problem needs considerable investigation but at the present time the following generalizations appear to hold.

1. Travel is extremely difficult immediately following a storm. The deep (50 cm +), low-density (.15 - .20) snow which is deposited by the storms in this area has only a limited bearing capacity which is well below that needed to support either a skier or a tracked vehicle.

2. Crust-dependent travel is possible on sunny days only until about 1 hour after the sun first strikes the snow surface and then only if the overnight temperature has been low enough to promote crust formation. A crust which has the surface characteristics of concrete at 6:00 a.m. can deteriorate by 10:00 a.m. into a cohesionless mass which makes any sort of reasonable travel difficult.

Every traveler in the mountains will eventually encounter the necessity of traversing a slope. While this is by no means an insurmountable problem it does preclude the use of most oversnow vehicles for extensive intermountain travel. In general, oversnow vehicles are designed to travel over relatively flat snow surfaces that have fairly high bearing capacities. Under less favorable conditions problems develop. For example, in traversing a slope the driving action of the track tends to make the vehicle slide sideways down the slope. The natural tendency of the driver

is to correct for this by steering slightly uphill. This invariably leads (depending upon such factors as slope length, gradient, and number and size of obstacles) to one of several end results. These are: (1) the vehicle will continue to turn under the influence of steering and gravity until it is pointed straight up the slope (at this time forward motion usually ceases as a result of the tracks digging themselves into the snow until the vehicle is resting on its undercarriage), (2) the vehicle will continue to slide sideways down the slope until it reaches the bottom or (3) it will encounter an obstruction, such as a tree, and will jam itself against it. With the standard tracked oversnow vehicles now in use on the polar ice caps it is believed that the only present solution to the above problem is the construction of a level shelf, wide enough to allow passage of the vehicle, across each slope which must be traversed.

With vehicles of the Ski-Doo type used in the 1964 field work, it was found that this problem could be solved in a less strenuous fashion. While the establishment of a permanent trail did require a certain amount of digging at critical points to allow for the passage of loaded sleds, traversing slopes with the Ski-Doo could be accomplished by adjusting the center of gravity of the vehicle so that a majority of its weight rested on the inner edge of the track. This had the effect of leveling the vehicle and lessening the tendency to slide sideways. One can accomplish this with all Ski-Doo type vehicles by simply standing on the uphill side and leaning away from the vehicle. The amount of lean is some function of the slope angle and the condition of the surface snow. This approach can, of course, only succeed when lightweight, open vehicles are being used. In this way, we became able to traverse slopes which were too steep for the Ski-Doo to climb directly and, in some cases, to reach points indirectly which would have otherwise been inaccessible.

The above represents a problem to which attention should be given if the Army is to achieve any degree of mobility in the mountains. There is no doubt that it would have proven impossible to get a "Weasel" or weasel-type vehicle over the 10 miles of trail from Cooke City to Goose Lake even though, as a cross-country mountain trail, this route was extremely simple.

Sled design is an area in which vast improvements can be made over currently available models. Three different types of sleds were used by the project to haul equipment. These sleds were used mainly during the initial and final phases of the program when the project equipment was being moved between Cooke City and the Goose Lake research site. Our sleds consisted of one 200-lb "boatsled" and one 100-lb "boatsled." These were supplemented during crucial periods by a toboggan and a sled mounted on two runners. None of these designs proved particularly satisfactory. A significant portion of the trail between Goose Lake and the staging area at the Fisher Creek smelter involved traverses across moderately steep slopes. It was at these points that we most needed a sled which would follow quite closely the movements of the towing vehicle. None of our sleds did. They all had a tendency to slide sideways while traversing slopes, occasionally pulling the towing vehicle backwards off the trail. Even more of a problem arose when the sled, due to the characteristics of the load, rolled over downhill. Not infrequently this caused the dumping of an entire load down a slope from which recovery was difficult. In addition, the two "boatsleds" were designed to be pulled by a length of rope tied through an eye on the underside of the sled. This undoubtedly works well when one is crossing a flat surface at a uniform rate of speed but in the mountains it led to a great many problems, particularly when traveling down steep slopes. A more rigid towing arm is essential.

Before further field work is accomplished, an improved sled should be designed and built. Such a sled should incorporate most of the following features if it is to perform satisfactorily over alpine terrain. It should run on skis equipped with a medial fin on the lower surface to improve the tracking performance. In order to lower frictional resistance, the body of the sled should be supported above the skis, where it will not normally be in contact with the snow surface. The entire sled should be constructed of aluminum or a similar metal in order to have a high strength-weight ratio. The sled should have removable side panels so that various load

configurations can be accomodated. The towing arm should be rigid and designed to permit the sled to turn over without damage either to the towing hitch or the arm. This could probably best be accomplished by the use of a swivel arrangement in the hitch assembly.

Considerable thought was given to the type of ski and ski binding which would be most suitable for an operation of this type. It was finally decided that the primary requisites for the skis were durability and ease of use. The Head ski, made by the Head Manufacturing Co. of Timonium, Maryland, seemed to best meet our requirements and, consequently, one pair of the "standard" model, 6 ft 6 in. in length, was purchased for each member of the group. These skis functioned very satisfactorily with one minor exception. Head skis are made with either stiff or limber tips. The stiffer ski allows greater control when skiing over a relatively hard surface but is more difficult to handle in deeper powder snow. The model we purchased was the stiffer variety but, as it turned out, most of the cross-country skiing was done in powder snow. While the more flexible tip tends to climb upward when pushed ahead in powder snow, the stiff tip has a tendency to remain at a constant depth or to dig deeper into the snow. Since, from the standpoint of energy expenditure, it takes less effort to control a "soft" ski on a hard surface than to push a "hard" ski through soft snow, it is felt that if additional Head skis are acquired for this type of work they should be the most flexible model of the "standard" ski or perhaps the "deep-powder" model.

In the planning stages of this operation, little thought was given to ski poles as it was assumed that they would be used solely as an aid in traversing the snow on skis. As it turned out, this was an unwarranted assumption. A ski pole lends itself admirably to a variety of tasks around a mountain camp which can only be performed with a long metal rod. Our poles were aluminum with a tubular construction which, once bent, could not be straightened. Several of the poles were bent while being used for purposes for which they were never designed and this ended their usefulness. It would seem that, in the future, rather than attempt to keep a constant watch over the poles to ensure that they were not used for something other than their primary purpose, it would be best to purchase poles made of a solid steel rod which, while heavier, would be a great deal stronger.

Ski bindings present a problem which may well be insolvable in a fashion satisfactory to all. There are a number of criteria which must be considered when selecting a binding and, at least in some cases, these criteria are mutually exclusive. General purpose bindings generally do not give the skier maximum control over the skis, while at the same time a binding which will allow one to closely control the skis will generally accept only one type of boot, that to which it was initially fitted. None of the standard so-called "safety" bindings are particularly adaptable to cross-country skiing, which constitutes a majority of the ski use. On the other hand, the use of a more rigid binding always poses the possibility of a broken leg which could be very serious under isolated field conditions such as those encountered in Montana.

The binding finally selected for the Beartooth project consisted of a "Marker" toepiece, a triangular block of metal under which the toe of the ski boot is placed. This block swivels from side to side on a post when the leg is torqued past a limit determined by a set screw. This binding has the advantage of simplicity coupled with the fact that the amount of torque necessary for release can be determined by the individual skier after a very short period of trial and error. Used in conjunction with this toepiece were so-called "touring attachments." These are aluminum plates which screw onto the ski immediately behind the toepiece and are essentially a modification of the old "beartrap" binding. Their primary advantage is that they can be removed when not in use (that is, during downhill skiing), reducing the danger of fractures without lessening the effectiveness of the binding. The binding was completed by a front throw cable assembly which could be used either in a downhill or touring position simply by changing its position with regard to semicircular hooks. One set of hooks was attached by screws on either side of the ski beneath the front of the heel and one set on either side slightly forward of the ball of the foot.

This type of binding did not prove wholly satisfactory. It was found, for instance, that the aluminum touring attachments were not strong enough to withstand the stresses imposed upon them by numerous falls either during downhill skiing or while the skier was being towed behind the Ski-Doo. In addition, it was not always feasible to remove the touring attachment for downhill runs. Because much of the terrain negotiated was rolling in nature a great deal of time would have been spent taking skis off and putting them on again. This, in effect, largely negated the safety aspects of the swivel toepiece.

It was found that a ski-mountaineering boot (that is, a boot which is designed to be used either as a skiing or a hiking boot) is, like most compromises, not particularly successful for either purpose. It would therefore seem, on the basis of the Montana experience, that the binding should be designed around whatever type of footwear is finally selected for the party rather than allowing the ski binding to dictate the type of boot used. Future parties might consider using a "safety" touring binding such as the Ramy-Securus which would appear to be satisfactory for almost any boot provided it has a grooved heel.

As was mentioned above, snowshoes were also taken as a substitute for the skis. During the planning stages of the project, it was felt that skis would be the primary means of non-motorized locomotion and, consequently, little thought was given to the type of snowshoe to be used. We simply took what was readily available. This was the "bearpaw" type of shoe which had been used quite successfully on the rather hard snow surface in Greenland but which was found to be quite unacceptable in the deep, soft snow in the mountains. In the future, it would seem best to give the same careful consideration to the choice of snowshoes as to the choice of skis since it was found that, under certain conditions, they could be profitably used on an interchangeable basis. It is believed that the most desirable snowshoe for use in snow such as was encountered at Goose Lake would be one of the so-called "trail" models, 4-5 ft in length, slightly cambered parallel to the short axis with a strongly up-turned toe. The standard snowshoe harness was quite satisfactory.

TRAIL MARKERS

One might assume that in mountainous terrain there would be an abundance of naturally occurring landmarks which would render the use of trail markers superfluous. In actual practice the need for markers is as great as on the polar ice caps for two reasons. Below timberline, one is faced with a multitude of trees, all of which look alike. Because they block off the view of the surrounding terrain, the problem is not a lack of landmarks but an embarrassment of them. In addition, the continually falling snow buries and alters the aspect of the trail almost on a day to day basis. These factors combine to make the use of trail flags or marked trees mandatory below timberline.

Above timberline, a problem quite similar to one experienced in Greenland and the Antarctic exists, although with certain differences. On the polar ice caps the horizon is generally flat with a featureless, snow-covered foreground. In the mountains, on the other hand, there are objects on the horizon by which it is possible to orient oneself. Difficulties arise when the horizon is obscured by a storm or clouds. Then all that can be seen is a featureless, snow-covered foreground. While this does not occur frequently, it can occur with a suddenness which makes it dangerous for a traveler using only the surrounding mountains as points of reference.

In Montana we used dowels, 3 ft x $\frac{3}{8}$ in. diam, painted black on the ends, as markers. These worked fairly well but had two major drawbacks. After insertion in the snow, only about 2 - 2 $\frac{1}{2}$ ft was visible. Therefore the snow accumulation during one major storm was enough to bury these markers. Also, in the mountains the apparent color of any dark object not composed of snow is black in relation to the intense glare from the snow. Consequently, a black trail marker tends to blend in very nicely with any vegetation or rock in its immediate vicinity and, conversely, small exposures of rock or vegetation, when seen from a distance, can be mistaken for trail markers. The following is therefore recommended.

The marker should consist of a pole, preferably bamboo, which projects a minimum of 6 ft above the surface of the snow. (During the 1964 season, a total accumulation of approximately 10 ft of new snow was experienced during April and May. However, not all of this was on the ground at any one time.) A brightly colored flag should be attached to the top of the pole. This flag serves two purposes. The bright color helps to differentiate it from either white or black backgrounds while the movement of the flag in the wind attracts the traveler's attention. Even below timberline, where a good deal of bough motion exists during windy periods, a fluttering object could be distinguished at some distance. All trails used should be marked in this fashion at whatever interval seems proper (maximum of 50 yards).

EQUIPMENT AND SUPPLIES

For the most part our equipment proved to be reasonably well suited to our project needs and with only minor modifications would undoubtedly serve to support any field party working under alpine conditions. Because previously published equipment and project lists (Benson, 1955; unpublished notes available at USA CRREL) were of considerable help to us in planning our field program, we are enclosing our equipment and food lists in Appendix A.

Clothing

As has been pointed out in numerous publications, clothing designed for use in the mountains must be adaptable to a wide range of environmental extremes. It must give protection at temperatures ranging down to -30F with accompanying high winds and at the same time be light enough to be carried during periods when it is not in use. Radiation temperatures equivalent to over 90F were encountered in the Beartooth Mountains. During these periods it would have been very uncomfortable to be burdened with clothing which would not fit easily into a small knapsack. For this reason, clothing fabricated primarily of down and nylon was chosen.

Specifically, the following items were used.

Mountain parka. Made of nylon quanto cloth in a pullover style, the mountain parka was found to be one of our most useful items of clothing. It is completely windproof, eliminating one of the primary chilling factors in the extremely dry mountain air. It is also sufficiently lightweight to be worn during periods of moderate to high insolation. When not in use it can be carried in a hip pocket.

Down parka. The Eddie Bauer "Karakoram" model down parka, while somewhat heavier (3 lb) than the standard bivouac models (2 lb 10 oz), was sufficiently rugged to permit its use during activities which might have damaged lighter models. This jacket, combined with the nylon parka, gave sufficient protection under the most severe conditions encountered in 1964. Yet together they weighed less than 4 lb and could easily be carried in a small pack when not in use.

Field pants. "Gerry" mountain pants made of Burlington 90-10 Orlon whipcord provided the warmth of wool without many of its undesirable features. They are double thickness to the knees in front and back and the pockets can be closed with a snap flap. For complete comfort in deep snow, it is necessary to use some type of gaiter to close the gap between the bottom of the pant leg and the boot. The only undesirable feature of these pants was that when they were used without wind pants during periods of heavy snowfall, the amount of snow adhering to the pants was excessive.

Underwear. Net underwear was chosen for its ventilating and and insulating qualities. It can be used either alone, for maximum ventilation, or under a cotton "T" shirt for additional insulation.

Wind pants. Standard army arctic shells made of tightly woven nylon were used. For the most part, these were quite satisfactory but some improvements for mountain use could be made. The pant itself is two to three times heavier than commercially available models, thereby complicating the storage problem. Its dark color also promotes absorption of radiant energy causing considerable melting of the snow which accumulates on the surface of the material. Adding to this problem is the fact that these pants are not at all waterproof. Future parties might do well to consider one of the commercial models available.

Gloves. Leather finger shells with woolen inserts were quite satisfactory under most conditions. In the future rubber gloves into which woolen liners can be inserted should be included for work involving the handling of wet snow.

Hats. Hats were furnished by each individual and varied accordingly. In general, two factors must be taken into account when choosing headgear; protection from cold and from solar radiation. These two factors cannot generally be resolved in one design and it is best, therefore, to take two types of hats: a woolen stocking cap for protection from cold, and some type of broad-brimmed hat for ratiation protection.

Socks. Norwegian Ragg socks were used but any heavy wool sock should be satisfactory. Sufficient numbers should be provided to insure that a dry pair is available at all times. We found that five pairs per man was adequate.

Eye protection. A combination of high radiation intensity and high surface albedo make it extremely uncomfortable to work in the open in the mountains without some type of dark glasses. This problem was handled at Goose Lake by having each member of the party bring one pair of dark glasses of the type he preferred and furnishing, as a spare, a pair of "racing type" ski goggles with three interchangeable lenses. Standard dark glasses proved to be much more satisfactory than the ski goggles because of the latter's tendency to fog up on the inside of the lens.

Boots. Two types of boots were taken: a lightweight, insulated rubber boot for general use in the vicinity of the research site and a ski-mountaineering boot for traveling on skis or over exposed rock. Both performed sufficiently well as not to be a hindrance but in the future considerable improvement in the choice of footgear can be made. The ski-mountaineering boot was chosen because it seemed to be a compromise between two conflicting requirements. That is, it would permit us to use standard ski safety bindings without modification and at the same time permit normal walking without discomfort. This, unfortunately, did not prove to be the case, at least to the degree anticipated. The boot proved to be too stiff for comfortable walking for any distance, either on or off skis. A primary boot should be selected mainly for its comfort during normal walking and climbing and then bindings suitable for that boot placed on the skis.

The insulated rubber boot served its purpose quite well. However, one slight modification would be desirable. The model used was made with an absorbent inner liner which, after becoming wet, dried very slowly. If this were replaced with a waterproof liner which could be wiped dry after use, the usefulness of the boot would be extended.

Gaiters. Gaiters were found to be essential in the deep, soft snow encountered in the mountains. They are made of tightly woven, heavy duty nylon, tubular in design, and are used to close the gap between the bottom of the pant leg and the boot top. The ones used in Montana reached to just below the knee and so served also to keep this portion of the pant leg free of snow.

Camp equipment

As with clothing, camping equipment which is used in the mountains must be designed for that environment because of the weight restrictions imposed by transport problems. One must balance the desire for comfort against the effort required to establish and maintain a truly comfortable camp. Some reasonable compromise which provides something above the bare minimum required for existence and at the

same time does not require an inordinate amount of time or effort is undoubtedly the best solution. The following paragraphs contain a short description of the compromise which was achieved between these two conflicting objectives during the 1964 field season. With minor modifications, this approach could probably be used in any area where weight was considered more important than comfort.

Tents. The tent used was the Blanchard "Draw-tite" type, manufactured by the Eureka Tent and Awning Company of Binghamton, New York. This tent comes in a variety of models—the two types chosen for this trip were the two-and four-man "Alpine" design. This tent consists of a body made from tightly woven, heavy duty cotton hung from an external aluminum frame. The two-man model has a floor space of approximately 35 ft^2, is 4 ft high at its highest point and weighs 12 lb; the four-man tent has a floor space of 80 ft^2, is 6 ft high at its highest point and weighs 35 lb. Both of these tents roll up into bundles suitable in size for any form of transportation including back packing.

In practice, the four-man tent was used primarily for storage of food and equipment while the two-man model was used for sleeping. It was possible to store all the project food and that equipment which was not immediately in use in one of the larger tents without excessive crowding. The two-man tent, on the other hand, proved to be a bit small for even one man to live in under any but fairly minimal conditions. It is felt that, in the future, its use should be restricted to camps which will only be occupied for short periods. It would be more advantageous, both from the standpoint of party morale and efficiency, to take no tents smaller than the four-man model for use over extended periods. The slight increase in weight would be more than compensated for by the general utility value of the floor space and by the interchangeability of the sections of the external frame.

Only one serious problem was encountered with the tents. During a period of high wind shortly after the initial establishment of the Goose Lake camp, both four-man tents were blown down and extensively damaged. To avoid a repetition of this, it was necessary to guy the tents from the top of the external frame to stakes (6-ft ablation stakes were used) driven their full length into the snow. This method prevented the tents from being blown down again even in the highest winds that were experienced ($\sim$70 mph).

Beds. During the planning stages, it was felt that food and sleep would be prime factors in the morale of the party. For sleeping, a combination of camp cot, foam pad and down sleeping bag was adopted. The camp cot consisted of a down-insulated canvas platform, 2 x 6.5 ft, supported by four spring-steel legs. The down insulation was hung beneath the canvas and served to prevent heat loss at that point. A foam pad, 1.5 in. thick, 2 ft wide and 6 ft long was placed between the sleeping bag and the cot to prevent heat loss through the bottom of the bag.

The sleeping bag finally chosen was the Bauer "Karakoram" mummy-type bag. This bag contains 3.5 lb of goose down and weighs a total of 6 lb 12 oz. There are lighter bags on the market but one generally sacrifices either durability or warmth in their use. This combination functioned extremely well during the coldest temperatures experienced (-15F).

Cooking equipment. A nesting, four-man cook set of heavy gauge aluminum was used for most of the cooking and performed quite satisfactorily. For baking, a folding oven designed to be used with the stoves gave generally good results and most baking failures were undoubtedly more a function of the cook than of the oven. In the future, for any cooking to be done at elevations above 10,000 ft, it would be well to include some type of pressure cooker as the low boiling point of water at and above that elevation makes it rather difficult to fully cook some foods.

Stoves. Two-burner Coleman stoves, using white gasoline as a fuel, were the principal source of heat. These stoves were not satisfactory and, if possible, should be avoided in the future. The difficulties in procuring white gasoline and the

sensitivity of the stove to any impurities in the gas made their use a constant problem. At one time it was necessary to abandon the research camp for a period of 3 days due to a stove malfunction caused by impurities (presumably condensed water) in the gas. While this was not considered a serious matter at the time, under different weather conditions it could have proven quite unpleasant. Subsequent experience has indicated that this problem may be circumvented by straining all gasoline through felt, which is impermeable to water but not to gasoline. In any case, due to the problems involved in attempting to ship fuel via private commercial carriers, the primary criterion used in the selection of the stoves should be the types of fuel available in the vicinity of the research area.

In spite of certain obvious disadvantages (ratio of container weight to fuel weight and reduced caloric output), propane or butane may prove to be quite acceptable fuels for an isolated research station. This type of fuel is more convenient to use, generally more reliable, and probably safer than containers of gasoline. It is also becoming quite generally available. During the 1965 field season, it is planned to use propane as the primary fuel for both cooking and heating, which should allow an evaluation of the relative merits of propane and gasoline to be made.

Lanterns. The Coleman two-mantle lantern, burning white gasoline, was used with good results. Apparently this lantern is not as sensitive to impurities contained in the fuel as is the stove and no problems were experienced. It is suggested that a plentiful supply of mantles, several spare generators, and one or two spare globes be taken as all are relatively fragile and may need replacement. Since obtaining fuel for the lantern is often a problem, some thought should be given to the use of lanterns burning propane or a similar gas. These are now available commercially.

Miscellaneous items. In the day-to-day activities of a camp of the sort described in this report there is a constant need for a variety of small pieces of equipment for which there is generally no suitable substitute. Several hundred feet of lightweight nylon cord was used at Goose Lake for purposes such as lashing loads on sleds, guying down tents and, for a short time, holding the Ski-Doo together. A whisk broom is almost essential to brush snow off clothing as one enters a tent and to sweep the tent floor. A hammer, pliers, adjustable wrenches, several sizes of screwdrivers, and nails were all needed at one time or another during the season.

Rations

In addition to filling immediate nutritional requirements, the menu was designed to allow an evaluation of a variety of foods which might be used under more primitive living conditions. When planning a menu for field use, one is confronted with two partially conflicting requirements. On the one hand, an elaborate menu requires that considerable time, which could better be devoted to the research program, be spent in the preparation of meals. Conversely, a simple menu is frequently monotonous and can be very hard on the morale of the party. While it is fairly apparent that the best way to reconcile this conflict of interest is by compromise it is by no means immediately apparent what the nature of this compromise should be. To some extent, recent developments in the preparation and packaging of lightweight foods have solved this problem but not to the extent which one might assume from a casual reading of the claims of the manufacturers. While it is true that weight and bulk have been largely eliminated, the problem of preparation remains much the same.

The menu discussed here was planned largely around the use of "freeze-dried" foods. At present, these are produced primarily by Armour and Company under the brand name "Star-lite" and consist of a variety of foodstuffs from which all the moisture has been removed while in a frozen state. For any field operation where weight is the primary consideration, this type of ration should certainly be considered. A complete meal for four people weighs less than 1 lb which means that it is possible to eat well in the field on a maximum of $1\frac{1}{2}$ lb per day. In actual practice, it was found that roughly 4 man-hours were required each day to restore the "freeze-dried"

foods to a state of edibility. This included the melting of water (which can be considered as almost a certainty in planning for any winter mountain operation), rehydration and cooking. An additional 2 man-hours were generally required in the cleaning-up process which followed each meal due to the many utensils required in the rehydration and cooking. Toward the end of the field season, more and more cooking was done by the "one-pot" technique to the exclusion of variety. In this method, all meals are organized around a "stew" into which the principal ingredients of the meal have been placed. This not only speeds up the cooking process, since rehydration and cooking can go on simultaneously, but it also lessens the number of pots which must be washed following the meal. Its only real disadvantage is that one soon tires of an endless succession of mostly undefinable tastes and the unchanging consistency and texture of the meals. This can be relieved from time to time, however, by a fired or baked meal which becomes even more enjoyable by comparison. In addition, the work of menu planning is vastly simplified since, if the finished product is generally the same irrespective of its ingredients, there is really little point in unnecessary complications during the planning stages.

In practice, the basic menu (a list of which is given in Appendix A) was supplemented with fresh fruits, vegetables and meats purchased locally. It would probably be possible to do this in almost every area where research was to be conducted and at least 25% of the food budget should be allowed for this purpose.

RESEARCH PROGRAM

As the results of the research program will be published elsewhere, this only represents a brief outline of the program as it was envisioned and as it was actually carried out. The Goose Lake operation had two specific goals to accomplish"..., to attempt to determine, through the measurement of certain selected parameters, changes in the physical properties of an alpine snowfield during the period of spring melt" and "...to...serve as pilot study for later work at extremely high elevations" (Alford and Weeks, 1964).

The following paragraphs compare the objectives and the results obtained so that certain conclusions reached by the field workers may benefit those working under similar conditions in the future.

Snow mechanics

A series of generally interrelated tests were planned which would give some insight into the strength characteristics of the alpine snow pack. A number of snow samples, varying both in depth and time, were to be taken from pit walls and broken on an unconfined compression apparatus to determine the vertical and temporal variation in unconfined compression strength. "In-situ" measurements of shear strengths were to be made using a vane type shear strength apparatus and correlated with results obtained from specimens which were removed from the pack and sheared in a shear box. The centrifugal tensile strength of selected specimens also was to be determined. In actual practice, because the density of the snow in a seasonal alpine snow pack is invariably lower (< 0.4 g cm^{-3}) than it is in those areas (e.g. Greenland) where it has been more extensively studied, a number of the "standard" snow tests were unsuccessful.

During the entire field period, no satisfactory results were obtained using the unconfined compression apparatus. All samples which were tested tended to mush out on the ends rather than break cleanly. This was in spite of the relatively high densities (0.45 - 0.50) which were reached at the end of the season. It is believed that the unconfined compression apparatus is, in general, not a satisfactory research tool in the study of alpine snow: in the winter the snow density is too low while later in the spring when the density increases to where testing might be possible (> 0.40 g cm^{-3}), vapor transfer in the pack results in a lack of intergranular bonding. Therefore the snow rarely is strong enough for this test to be successful.

The "in-situ" shear vane apparatus used in the field was a modification of an earlier model adapted from soil mechanics for use in snow studies by Haefeli and Brandenberger. It consisted of a number of meter-long rods, 2.5 cm in diameter, which could be screwed into one another to accomodate a variety of snow depths. Attached by a threaded coupling to the lower end of the bottom segment of the rod was an assembly consisting of two vanes at right angles to one another. There were two separate vane designs, one with the vane dimensions 3 cm x 3 cm and the other 3 cm x 1 cm (Fig. 12). These vanes were sharpened on all leading edges with the exception of the upper to lessen the disturbance to the snow being tested. The shearing force was applied at the upper end of the rod with a torque wrench. A number of problems were encountered in the use of this apparatus. First and foremost is the fact that the strength of the snow toward the end of the field period exceeded that of the instrument with resultant damage to the vanes and couplings. Three of each of the two vane designs were taken to provide spares in case of damage. At the completion of the 1964 field season, all of the 1 cm x 3 cm vanes were bent to such an extent that they were unusable. In addition the couplings on all rod sections, consisting of a solid piece of threaded stock inserted into and riveted to lengths of stainless steel tubing, had undergone sufficient torsional deformation as to be unserviceable. While a comparative study has not yet been made of the results obtained with the two vane designs, it is felt that, if at all possible, future work should be performed primarily with the larger vane (3 cm x 3 cm). To avoid the problem of deformation within the rod itself, future models should be constructed on a more unitized basis, eliminating those points of weakness encountered in the first model. All couplings in the future should be the spring-loaded type found in the Rammsonde extensions. The screw type couplings were often quite difficult to uncouple following a test involving high shear strengths and at best it was a time-consuming operation.

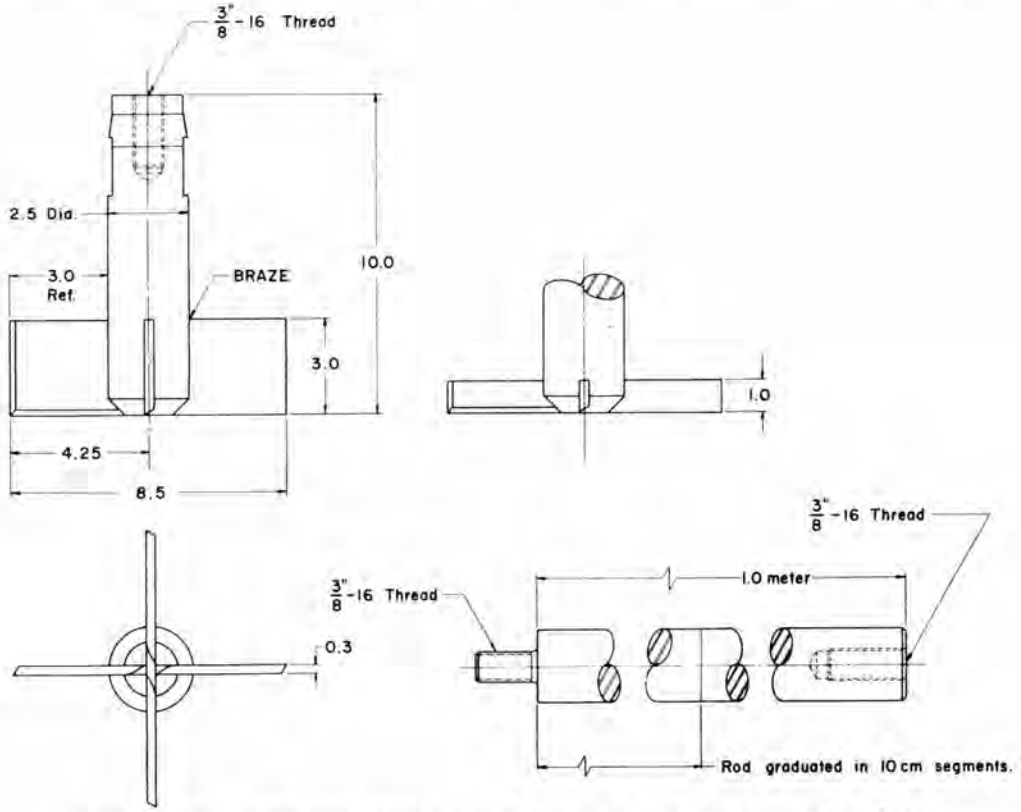

Figure 12. The two shear vane designs that were used. All dimensions in centimeters unless otherwise noted.

The shear vane was maintained at the desired depth by the use of a sliding ring equipped with a set screw which could be positioned at any point on the rod and which then rested upon a flat aluminum plate 25 cm x 25 cm x 1 cm through which the rod passed. This plate was used as a reference datum, its upper surface assumed to coincide with that of the snow. The head of the set screw should be large enough so that it can be manipulated while wearing gloves, and the threaded portion sufficiently strong to withstand the stresses imposed upon it.

It is not possible at this time to comment upon the value of the shear vane apparatus in the study of snow. This must await a reduction of the data which is not yet complete. The tests using the shear vane apparatus were designed to allow an analysis of total sample variance both as a function of the operator and of the properties of the snow pack. The test plots were located on the basis of a random number table and profiles were obtained from each plot. An analysis of the data should show not only the variation in shear strength between the individual snow layers but also the effectiveness of the apparatus in measuring this parameter.

The tensile strength apparatus (Bucher, 1948; Butkovich, 1956) consisted of a standard 500-cm^3 sample tube rotated about a vertical axis by a variable speed motor (50-3000 rpm). A tachometer measures the speed, which is slowly increased until the snow specimen in the sample tube breaks due to the centrifugal force. The entire assembly is mounted in a box approximately 50 cm x 30 cm x 30 cm and is powered by 110-volt a c which in this case was derived from a portable generator. This unit performed quite well but it contained an inherent flaw which soon put it out of operation. In order for the results obtained from this apparatus to be interpreted properly, it is necessary that the tachometer reading be convertible to revolutions per minute with a high degree of accuracy. Unfortunately the reduction gears between the sample tube and the tachometer were fabricated from a porous, fibrous material, which tended to swell when wet by condensation induced by the warm, humid interior of the living quarters. This changed the gear ratio sufficiently to invalidate the laboratory calibration. At about the middle of the field season, it was decided that the values given by the tensile apparatus were no longer reliable and its use was discontinued. This problem can, of course, easily be solved by changing the gear material.

Pit studies

The pit work involved no radical departures from those techniques which have been used successfully in Greenland and the Antarctic in the past. Little would be gained here by a lengthy description of them. Density, temperature, Rammsonde and shear strength profiles were made at each pit and the gross stratigraphy was described. During the period when the tensile strength apparatus was functioning, it was used to test each of the density samples.

Only one major problem was encountered with regard to the pit studies but it was sufficient to cause considerable difficulty in the application of the pit technique to studies of alpine snow. On days when the incoming radiation level was high (i.e. all days without a heavy overcast) the temperature of any metal object exposed to either direct or reflected radiation rose rapidly. In addition, as a result of decreased circulation, the air temperature in the pit rose well above the ambient. These factors caused considerable difficulty in the measurement of density profiles using the standard 500-cm^3 snow sample tubes. Even if these tubes were kept constantly in the shaded portion of the pit, their temperature would rise to the point where they became quite warm to the touch. When they were inserted into the pit wall, the strong negative temperature of the pack combined with the positive temperature of the tube caused the formation of a considerable thickness of ice on both the inner and outer surfaces. This made removal of the snow sample very difficult, and reduced the accuracy of the density measurement. The positive air temperature experienced in the pits also caused severe changes in the properties of the exposed snow in a few

minutes time, making it very difficult to perform adequate tests. It would be possible to avoid this problem by completing all pit studies while the sun is below the horizon. While this approach is possible and was adopted toward the end of the field period, it is by no means satisfactory. Attempts should be made to devise alternate methods of obtaining the data, which currently come from pit studies, in areas of intense solar radiation such as are found in the higher mountains.

Meteorological measurements

In the mountains, in addition to instrumentation problems, the adequate specification of micrometeorological parameters is made extremely difficult by the apparent wide range of values which may be obtained within an area of limited geographical extent. The problems associated with defining and then making meaningful measurements were felt to be outside the province of this project and consequently only a minimum of data, necessary to the proper interpretation of the snow studies, were gathered.

In the deep, soft snow generally found in the mountains it is quite difficult to establish a stable platform on which to mount the various sensors, many of which require precise, controlled orientation. The existence of this problem was recognized prior to departure for the field and various platform designs were considered. The design criteria were lightness, stability and an absence of structural features which might interfere with the radiation sensors. The final platform was composed of two H-shaped end pieces connected at the cross piece mid-point by a horizontal member (Fig. 13). It was built from 10-ft sections of 2 in. diameter rigid aluminum conduit and was designed so that the horizontal member could be moved vertically on the upright corner posts by simply loosening four set screws, thereby permitting the placement of instruments at any desired height above the surface of the snow up to a maximum of 10 ft. This height could be extended in the future if desired by the addition of lengths of conduit.

It was hoped that sufficient support would be provided by the four vertical posts at the corners of a 10 x 10 ft square to render the use of guy wires unnecessary. For the most part, this was the case. Some difficulty was encountered due to conduction of heat from the upper portion of each upright, which was heated by the sun, into the snow with subsequent melting. Other than this, the platform performed as expected and a reorientation of the radiation sensors, which must be constantly facing the zenith, was required only one time, about midway through the field period.

On this platform were mounted two Eppley pyrheliometers at the mid-point of the horizontal conduit, one measuring incident short wave radiation and the other, facing downward with the sensing element parallel to the snow surface, measuring reflected radiation. Two aspirated radiation shields containing one thermocouple each were mounted 1 and 2 meters respectively above the snow surface and were used to measure the air temperature profile through that distance. It was found that the unaspirated radiation shield alone was not sufficient to insure an accurate air temperature reading. Aspirated and non-aspirated readings separated in time by 10 minutes varied by as much as 20C.

Both the thermocouples and the pyrheliometers were read with a Rubicon potentiometer several times each day. The method is not wholly satisfactory and the use of recorders should be considered in the future.

Ablation studies

It was desired that some data be collected concerning the processes contributing to the gradual metamorphism and eventual melting of the snow in the spring. These were to be quite general studies, designed primarily to define the nature of the problem and were to include a study of the ways in which mass is lost by the pack prior to the runoff period, the changes of the temperature gradients within the pack itself, and the reaction of the snowpack to these factors.

Figure 13. The meteorological tower, showing location of the Eppley pyrheliometers and thermocouple radiation shields.

It was assumed that mass would be lost from the cold pack primarily in two ways: by evaporation from surface or near-surface layers and by limited percolation due to radiational melting at or near the surface. To measure evaporative losses, pans with a capacity of 144 in.^{3} were to be filled with snow, weighed, and placed with their upper surface flush with that of the snow. Unfortunately, our largest balance had a maximum capacity of only 1 kilogram, less than the weight of a snow-filled pan. Since it was impossible to obtain absolute values from this test, it was decided to attempt a qualitative study in its stead. The pans were placed as above but without being weighed, and the loss was estimated at the end of each day. The results of this study seem to indicate that mass loss by evaporation is quite significant in the Goose Lake cirque and should be examined in more detail.

The investigation of the possibility of mass loss as a result of surface melting due to solar radiation and subsequent runoff also was largely qualitative. It was found, however, that mass is lost in this fashion during that time when the body of the snowpack is still several degrees below the melting point and that this melt water percolates laterally near the surface of the pack toward points of maximum topographic depression. For the most part, shallow pits and fuchsine dye, an organic dye which turns red in the presence of water, were used to determine the existence of this near-surface runoff and future studies are planned to determine its magnitude and significance.

The temperature profile of the snow pack was measured with a series of 13 thermocouples placed 50 cm into the wall of a pit at 15-cm intervals, after which the

pit was refilled with snow. The presence of the backfilled pit undoubtedly modified the thermal regime of the snowpack in the vicinity of the thermocouple string to some extent but short of placing the thermocouples in the fall and allowing them to be buried naturally, there seems to be no reasonable alternative. The temperature readings were consistent during the period of observation and no anomalous gradients were recorded, indicating that the thermocouples functioned with a reasonable degree of accuracy.

It is felt that our present results strongly indicate the need for a thorough re-examination of available field testing techniques for low density snow. It is hoped that new, rapid, simple, readily portable and more sensitive techniques can be developed which should greatly facilitate the study of snow at remote field sites.

SAFETY

As is the case everywhere, safety in the mountains is mostly a matter of a prudent approach combined with a realistic assessment of the hazards which may be encountered. There is no reason why an operation in the mountains cannot be conducted with complete safety as long as one is willing to make allowances for the nature of the environment. Broadly, hazards in the mountains can be grouped under two general headings: weather and terrain.

Weather

Mountain weather presents a safety hazard, not so much due to its severity as to its variability. Mountains are a natural focal point for storms, due largely to their effect on the air masses which must cross them. Warm, moist air coming in contact with a mountain range, or, on occasion, an individual mountain, gives rise to localized but turbulent weather. Quite commonly storms, instead of originating elsewhere and moving into the mountains, are produced locally. Therefore there is frequently little warning of an impending storm and it is not uncommon to go from "summer" to "winter" conditions in the space of a half hour. The limited horizon caused by surrounding peaks also allows a storm to develop on one side of a ridge without giving any indication of its presence to a person on the other side. This storm may then suddenly move across the ridge producing rather unpleasant consequences for people caught without the proper equipment.

Sensible temperatures in the mountains are always very much a function of the sun and one should never allow the apparent warmth of a day to persuade one to leave camp without sufficient clothing to provide protection through a 100 F effective temperature range. This certainly represents the minimum which can be expected on a typical spring day in the mountains. This is not to say that the air temperature actually fluctuates this much but a 15-degree drop in actual air temperature coupled with the disappearance of the sun and an increase in wind velocity amounts to the same thing so far as the individual is concerned.

In summary then, if one is always prepared for rapid deterioration of the weather in the mountains, the chances of being unpleasantly surprised are greatly lessened.

Terrain

The primary problems associated with alpine terrain are: the ease with which a point may be reached from which there is no easy retreat and the existence of impassable obstacles in an otherwise straightforward route. Either alone or together, these two factors have in the past been responsible for a large portion of all mountain accidents. While it might initially be assumed that the above applies only to those phases of mountain travel which are generally considered the province of mountain-climbers, this is far from the case. One may start down a steep slope with a tracked vehicle only to find halfway down that a low cliff bars further progress. If the slope is too steep for the vehicle to reclimb, the situation can become quite difficult. A long journey over moderate terrain can be interrupted near its end by a narrow, steep-walled stream valley which cannot be crossed. Certainly, the best solution for

these problems is to carefully study, on maps, air photographs and, if possible, on the ground, any new or doubtful terrain over which a traverse is intended.

Aside from the above factors, neither of which is unique to the mountains but both of which perhaps exist to a greater degree there, the problem of living and working safely is much the same as at any other field station and should not need discussion here. If a margin is allowed for the inevitable errors in judgement which will occur in even the most experienced parties, problems should be minimized. In the mountains, it is generally when one has not anticipated the unexpected that "accidents" occur.

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APPENDIX A: EQUIPMENT AND FOOD LISTS

I. General utility equipment

A. Transportation

1 Bombardier "Ski-Doo," series RS, single track model
4 pr Metal skis, safety bindings
4 pr Ski poles
4 pr Snowshoes

B. Trail equipment

1 200-lb cap. sled
1 100-lb cap. sled
2 Nylon climbing rope, 7/16 in. x 150 ft
2 Piton hammers
10 Carabiners, aluminum
10 Pitons, angle
10 Pitons, horizontal
10 Pitons, vertical
5 Pitons, ice screw
4 Pack frames w/sacks
100 Willow wands

C. Camping equipment

2 Four-man, Blanchard type tents
2 Two-man, Blanchard type tents
4 Down-filled sleeping bags
4 Collapsible canvas cots
4 Nylon-covered foam pads, 2 x 6 ft
2 Coleman stoves, two-burner model
4 Coleman lanterns, two-mantle model
1 Heavy-gauge aluminum nesting cook kit
2 Whisk brooms
6 Plastic gasoline cans, 5 gal (white gas and Ski-Doo fuel)
2 Spades, short handle

II. Scientific instruments and equipment

A. General pit equipment

2 Shovels, square point, short handle
1 Ladder, 16 ft, aluminum
1 Saw, pruning, 24 in.
1 Tape, steel whiteface, 15 m

B. Equipment for density measurements

12 Snow sampling tubes, 500-cm^3, w/2 rubber caps
2 Trimming plates, stainless steel
1 Triple beam balance
1 Spring balance
2 Whisk brooms
1 Trowel, dry wall
6 Grain size cards

C. Equipment for snow temperature measurements

8 Thermometers, Weston dial, -40 to +25 w/case
2 Thermocouple strings, 16 thermocouples w/selector switch
1 Rubicon potentiometer
1 Standard cell
1 Dewar flask, 1 pt capacity

D. Equipment for hardness measurements
- 1 Rammsonde penetrometer, complete, w/case
- 1 Canadian hardness kit, complete

E. Equipment for meteorological measurements
- 9 Rigid aluminum conduit sections, 10 ft x 2 in. diam
- 4 Rigid aluminum conduit sections, 5 ft x 2 in. diam
- 4 T-joints, aluminum w/set screws
- 2 Thermometers, maximum-minimum, six type
- 1 Thermograph
- 1 Actinograph
- 1 Psychrometer, Assman
- 1 Psychrometer, sling
- 4 Thermometers, for sling psychrometer
- 4 Radiation shields, aspirated
- 2 Thermocouple strings
- 1 Rubicon potentiometer, model 2735-S
- 1 Dewar flask, 1 pt cap.
- 1 Generator, Homelite, model 35A, 115-V, 50-cycle, single phase

F. Equipment for snow mechanics studies
- 1 Tensile strength apparatus
- 1 Unconfined compression apparatus
- 1 Ro-tap shaker, portable, hand operated
- 1 Set sieves, nested
- 1 Shear vane apparatus
- 1 Torque wrench set
- 3 Vanes for shear vane apparatus, 9 cm^2
- 3 Vanes for shear vane apparatus, 3 cm^2
- 3 Proving rings, ass't.
- 2 Indicators, dial, model LC-2B, range 0.200 in.
- 1 Generator, portable, 1.5 kw cap.

G. Equipment for snow ablation studies
- 50 Poles, wood, 1 in. x 1 in. x 6 ft
- 1 Bottle fuchsine dye
- 1 Mt. Rose snow sampling kit, complete
- 6 Meter sticks

H. Equipment for photography
- 1 Camera, 35 mm Leica w/50 mm lens
- 1 Meter, exposure, GE model PR-3
- 1 Tripod, quick-set hi-boy
- 1 Camera, 4 x 5 Speed Graphic
- 1 Adapter, 120 roll film, for 4 x 5 camera
- 10 Rolls 35 mm color film
- 20 Rolls 120 black and white film

I. Equipment for recording and storing data
- 8 Field books, level book, Bruning, 749F
- 2 Green record books, (10 $\frac{1}{2}$ x 8 $\frac{1}{3}$)
- 2 Clipboards
- 24 Pencils, 4H w/eraser
- 1 Sandpaper board
- 1 Box staples
- 10 Manila file folders
- 2 Erasers, gum

III. Food inventory

	Quantity	Unit
A. Beverages		
Lemonade	40	1-oz pkg
Pineapple-grapefruit	10	1-oz pkg
Milk, dried	10	No. 2 can
Cocoa	10	No. 2 can
Coffee, instant	10	lge btl
Tea, instant	10	lge btl
B. Dried fruit		
Dates	40	lb
Peaches	10	lb
Apricots	20	lb
C. Soups		
Chicken noodle	10	pkg *(8)
Split pea	10	pkg (8)
Potato	10	pkg (8)
Tomato	10	pkg (8)
Vegetable	10	pkg (8)
Cream of mushroom	10	pkg (8)
D. Freeze dried foods		
Pork chop dinner	48	pkg (2)
Ranch style breakfast	132	pkg (4)
Beef steak	48	pkg (2)
Gravy/sliced beef	24	pkg (4)
Vegetable-beef stew	12	pkg (4)
Chili w/beans	24	pkg (4)
Shrimp creole	12	pkg (4)
Swiss steak dinner	48	pkg (4)
Beef patties	20	can (1-2)
Bacon bar	10	bar (1-2)
Meat bar	10	bar (1-2)
E. Other items		
Jam	40	tube
Chipped beef	30	btl (4)
Rice, instant	10	lb
Puddings, ass't	40	pkg
Salt	5	lb
Sugar	10	lb
Jello	60	pkg
Potatoes, dried	50	$\frac{1}{2}$ lb
Noodles	20	$\frac{1}{2}$ lb
Macaroni	20	$\frac{1}{2}$ lb
Gravy, dehydrated	25	pkg (4)
Spaghetti sauce	25	pkg (4)
Honey	5	pt
Peanut butter	5	lb
Pepper, blk	1	can
Cooking oil	10	qt
Catsup	5	btl
Mustard	5	btl
Bisquick	10	lb

* (8) indicates number of 1 man-meal servings per package

Shortening	2	2 lb
Butter	10	lb
Cheese, ass't	15	lb
Cereals, ass't	5	pkg

This list was supplemented with the purchase of a variety of perishable items in the field.

F. Fuels, lubricants and spare parts

Item	Quantity Used
Gasoline, leaded	60 gal
Gasoline, white	25 gal
Oil, SAE 10 (for engine)	12 pt
Oil, SAE 10 (for spot lub.)	4 oz
Ski-Doo track	1
Rear bogey assembly	1
Spark plugs, "Champion" D-9	5
Link plate spring	1
Rewind starter	1
Contact and breaker points	0
Fan bolt	3
Spark plug protector	1
Fuel line adapter at tank	1
Drive belt	2
Throttle cable assembly	1
Brake cable assembly	1