Avalanche

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AVALANCHE CONFERENCE

Santa Fe, N. M.
April 15-16, 1960

REPORT OF AVALANCHE CONFERENCE
Santa Fe, New Mexico
April 15-16, 1960

By
Herbert C. Storey, Director
Division of Watershed Management Research
Forest Service, U. S. Dept. of Agriculture
Washington, D. C.

A conference was held April 15 and 16, 1960, in Santa Fe, New Mexico, to consider the avalanche problem in this country and Canada. Representatives of some 10 agencies, including two from Canada, assembled at the invitation of the U. S. Forest Service to discuss, first, what the different agencies were doing towards meeting their various avalanche problems, what studies were underway to improve basic knowledge and develop better techniques of avalanche hazard forecasting, avalanche control and protection. And second, to determine what steps should be taken to improve the coordination of avalanche control activities of various agencies and in general strengthen the overall effort towards meeting this common problem.

It was agreed by the conference that the avalanche problem is increasing in importance as more and more people go into avalanche hazard areas for winter recreation, also as more important lines of communication are built through such areas, and as more thought is given to the effects of avalanches on military operations in case of war.

A number of subjects were discussed to establish what is being done to meet avalanche problems and what is the state of knowledge concerning avalanches and their control. Attached is a list of the subjects discussed and the lead-off discussers; also attached are some of the discussions presented.

The conferees decided that the overall avalanche problem could best be met by activities in four general categories: (1) Basic Research, (2) Technical Improvements, (3) Control and Safety Operations, (4) Avalanche Defense Structures and revegetation.

The conferees considered each of these categories and established certain needs and made specific recommendations. The needs and recommendations are presented to the interested agencies for such action as is appropriate and feasible.

Needs and Recommendations

Overall

The conference recognized the need for a continuing means of correlating the activities of the various agencies concerned with avalanche activities, recommending needed projects, providing for exchange of information, and maintaining liaison between agencies and projects. The conference further agreed that the Forest Service is the leading agency in avalanche studies and control in the U. S. In view of the overall need, the conference addressed a recommendation to the Chief, U. S. Forest Service, that he consider the desirability of taking appropriate action towards establishment of a permanent interagency Avalanche Committee for the purpose of recommending projects, maintaining liaison, providing for exchange of information, and correlating activities.

Basic Research

The conference affirmed that basic research is essential and pointed to the following needs:

1. The types of research projects needed are those concerned with the physical principles of snow and snow behavior.

2. Basic research can be accomplished in a cooperative manner through participation of several agencies who furnish equipment, facilities, and manpower according to their ability, or through joint studies, or through closely integrated research projects.

3. A research program should be of a continuing nature, adequately staffed and financed.

4. Types of studies needed should include:

    a. Snow physics and mechanics

    b. Energy exchange and meteorological studies

    c. Terrain and vegetation effects.

5. The present collection of snow-weather-avalanche data is of importance to both basic research and operations and should be continued and strengthened.

6. There should be close liaison between all research groups for exchange of information and research results.

Technical Improvements

The conference agreed that there is a need for technical improvements and recommended the following projects:

1. Improvement in instrumentation, including but not limited to: de-icing systems for wind measuring equipment, temperature telemetering equipment, improved penetrometer, and snow settlement gages.

2. Explosives experimentation and testing, including but not limited to: type and quantity of explosive to use in various situations, suitability of rockets.

3. Search and rescue equipment and techniques, including but not limited to: high-span lift evacuation equipment, toboggans for evacuation of injured, avalanche probes.

4. Development of improved techniques of winter sports area planning and management, classification of ski trails, and ski-slope maintenance.

5. Development of improved snow control structures, as distinguished from avalanche defense structures.

6. That the fine work done by the Air Force in cooperation with the National Park Service in the use of the sonic boom to stabilize avalanches be continued and expanded to give more knowledge as to the potentialities and limitations of this technique.

Control and Safety Operations

The conference recognized that there are numerous agencies, public and private, involved in avalanche hazard control and that public safety is a matter of concern wherever avalanche hazard exists. The conference recommended that:

1. At winter recreation areas on public land, the land managing agency be responsible for and carry out avalanche hazard forecasting and control operations.

2. Agencies concerned with public safety be encouraged to prepare rescue plans and organize, train and equip rescue crews.

3. A countrywide, cooperative rescue plan be developed for back country rescues.

4. There be adequate provision for training in avalanche safety including the preparation of training films, other training aids, and the translation of appropriate foreign publications.

5. Agency programs include adequate provision for public education in avalanche safety.

6. Arrangements be made whereby military weapons and ammunition, surplus to military needs, are available to appropriate government agencies for avalanche control operations.

Avalanche Defense Structures and Revegetation

The conference recognized that considerable information in this field is available and yet is not being fully used and therefore recommends that:

1. The Western Association of State Highway Officials be asked to include avalanche hazard on its agenda at its forthcoming Portland, Oregon, meeting.

2. Progress in the field of avalanche defense be brought to the attention of groups such as: The Highway Research Board, American Society of Civil Engineers, etc.

3. Available engineering data on avalanche defense structures be compiled in a handbook.

4. Reforestation be considered in the planning of all avalanche defense systems and provided for where appropriate.

5. Avalanche hazard be considered in timber harvest operations in steep snowpack areas.

In conclusion, the conferees agreed enthusiastically as to the value of the conference and that additional conferences should be held in the future.

Topics Discussed at the Avalanche Conference, Santa Fe, New Mexico April 15-16, 1960

Avalanche Investigations by the U. S. Forest Service
Ed La Chapelle, U. S. Forest Service

Related Work of the Snow, Ice and Permafrost Establishment, U. S. Corps of Engineers
R. O. Ramseier, SIPRE, U. S. Corps of Engineers

Avalanche Investigations for Canadian Highways
Peter Schaerer, National Research Council of Canada

Avalanche Control Activities in Glacier National Park
Max E. Edgar, U. S. National Park Service
Lt. Walter J. Schob, Jr., U. S. Air Force
Capt. Henry West, U. S. Air Force

Investigations of Snow Conditions Causing Avalanches
Whitney M. Borland, National Ski Patrol

Drifting of Snow
Mario Martinelli, U. S. Forest Service

Snow Accumulation Studies in the Sierra Nevada
Henry Anderson, U. S. Forest Service

Summary of Current European Avalanche Work
R. O. Ramseier, SIPRE, U. S. Corps of Engineers

National Ski Patrol Avalanche Program
Wm. R. Judd, National Ski Patrol

Physics of Snowpack
Ed La Chapelle, U. S. Forest Service

Weather Observations and Measurements of Snowpack Conditions
M. M. Atwater, U. S. Forest Service

Avalanche Hazard Forecasting
Ed La Chapelle, U. S. Forest Service

Avalanche Control and Prevention Through Use of Explosives, Stabilization by Skiing, etc.
M. M. Atwater, U. S. Forest Service

Avalanche Protection and Prevention Through Use of Terrain Modification, Structures, and Vegetation
Peter Schaerer, National Research Council of Canada

Avalanche Training and Safety Program on Winter Sports Areas
John Herbert, U. S. Forest Service

Resolution Adopted by the Avalanche Conference Held in Santa Fe, New Mexico, April 15-16, 1960

WHEREAS, the Avalanche Conference at Santa Fe, New Mexico, April 15 and 16, 1960, was attended by representatives of ten organizations with a direct interest in the problems of avalanche hazard and control, and

WHEREAS, this Conference was called by the Forest Service for the purpose of exchanging information and views and making recommendations concerning the future of avalanche research and avalanche control techniques, and

WHEREAS, the Forest Service is the leading agency in avalanche studies and avalanche control in the U. S., and

WHEREAS, uses of mountainous areas in winter where avalanches are a threat to public safety and property is increasing rapidly, and

WHEREAS, there is a need for an integrated program of avalanche research and avalanche control,

THIS CONFERENCE RECOMMENDS to the Chief, U. S. Forest Service, that:

1. He establish a policy to the effect that the Forest Service will continue to perform avalanche control work on lands under its jurisdiction and will engage in avalanche research and technical development as is feasible and appropriate.

2. He consider the desirability of establishment of an interagency Avalanche Committee to recommend projects, maintain liaison, provide for exchange of information, and correlate activities.

Resolution Adopted by the Avalanche Conference Held in Santa Fe, New Mexico, April 15-16, 1960

WHEREAS, the Avalanche Conference conducted on April 15-16, 1960, in Santa Fe, New Mexico, has been of great value in achieving a better understanding of the importance and nature of the avalanche problem and the need for closer cooperation of all agencies concerned, and

WHEREAS, the organization and success of the Conference is due mainly to the leadership of the U. S. Forest Service in this field, now

BE IT RESOLVED, that the conferees express their deep gratitude and appreciation to the U. S. Forest Service for its initiative and hospitality in planning, arranging, and conducting the Avalanche Conference.

Attendance
Avalanche Conference, Santa Fe, New Mexico
April 15-16, 1960

Name	Agency	Location
M. D. Hoover	U.S.F.S.	Ft. Collins, Colo.
Henry A. Sawchuk	U.S. Bureau of Public Roads	Washington, D.C.
D. H. Long	U.S.F.S.	Santa Fe, N.M.
J. M. Herbert	U.S.F.S.	Ogden, Utah
H. W. Camp	U.S.F.S.	Washington, D.C.
John E. Stephenson	U.S.F.S.	Santa Fe, N.M.
David C. Stevens	U.S.F.S.	Albuquerque, N.M.
Paul V. Wykert	National Park Service	Box 1728, Santa Fe, N.M.
Henry W. Anderson	Pac. SW Forest Exp. Station	Box 245, Berkeley, Calif.
Paul E. Packer	Int. For. and Range Exp. Station	Ogden, Utah
M. Martinelli, Jr.	U.S.F.S.	Fort Collins, Colo.
Ed La Chapelle	U.S.F.S.	Alta, Utah
E. G. Dunford	U.S.F.S., PNW For. & Range Exp. Sta.	Portland, Ore.
Henry Tiedemann	U.S.F.S., Arapahoe NF	Golden, Colo.
Whitney M. Borland	National Ski Patrol, SIPRE	Denver, Colo.
Geo. W. Peak	Soil Conservation Service	P.O. #699, Casper, Wyo.
R. A. Work	SCS (Snow Surveys)	209 SW 5th, Portland, Ore.
M. M. Atwater	U.S.F.S.	Box 4, Tahoe City, Calif.
Morlan W. Nelson	SCS	Box 1247, Boise, Idaho
N. C. Gardner	Snow Research & Avalanche Warning Section - National Parks Branch	Glacier, B.C., Canada
Peter Schaerer	National Research Council of Canada Div. of Building Research	Ottawa 2, Ont., Canada
D. C. Harrington	Reg. 9, U.S.B.P.R.	Denver, Colo.
Robert Bursiel	B. of P. R., Avalanche Research	Anchorage, Alaska
Richard W. Wilke	U.S.F.S.	Washington, D.C.
C. E. Remington	U.S.F.S.	Bldg. 85, Federal Center, Denver, Colo.
J. M. Usher	U.S.F.S.	Washington, D.C.
Max E. Edgar	N.P.S., Glacier National Park	West Glacier, Mont.
W. N. Parke	U.S.F.S.	Washington, D.C.
R. O. Ramseier	SIPRE	Wilmette, Ill.
V. H. Anderson	independent glaciologist	367 W. Whitney, Sheridan, Wyo.
Peter Totemoff	U.S.F.S.	Santa Fe, N.M.
Eugene L. Peck	U. S. Weather Bureau	Salt Lake City, Utah
Lt. Walter J. Schob, Jr.	Geiger Field, U.S. Air Force	Spokane, Wash.
Capt. Henry West	Geiger Field, U.S. Air Force	Spokane, Wash.
H. C. Storey	U.S.F.S.	Washington, D.C.
Wm. R. Judd	National Ski Patrol System	Denver, Colo.

Avalanche Conference: Santa Fe, N.M., April 1960

WEATHER OBSERVATIONS AND MEASUREMENT OF SNOWPACK CONDITIONS

By
M. M. Atwater, USFS

Mt. Shuksan

Nothing is more essential to control of avalanche hazard than forecasting or recognizing the hazard in time to do something about it. Hazard forecasting in turn depends upon accurate and comprehensive observation of the factors that lead to avalanches. Hazard forecasting itself is the subject of your next speaker. My function is introductory: to describe for you the observation methods we have developed and how we hope to improve them.

Over a period of years we have identified certain contributory avalanche factors and have observed them continuously to the best of our ability. These observations are the basis for the technique of avalanche hazard forecasting. Any improvement in that technique will of necessity be preceded by better methods of observation. The contributory avalanche factors we have identified and observed are as follows:

1. The nature of the base.
2. The amount, type and density of new snowfall.
3. Snowfall intensity.
4. Precipitation intensity.
5. Wind action.
6. Snow settlement.
7. Temperature.

The mere mechanical difficulties of observing these factors reliably and continuously are great. If one of you, through experience in a field however remote could solve even one of these problems in our field, this conference would be a success if we accomplish nothing else.

As an object of observation and research, snow is reclacitrant. It is in a continual state of change. If it is disturbed in any way it ceases to be natural snow and becomes laboratory snow with entirely different properties. We have, therefore, elected to concentrate upon methods of observing snow and related factors in the natural state, so far as possible.

Nature of the Base

It is important to the hazard forecaster to have accurate information concerning the base. If the snowpack is unstable, all or part of it may become involved in an avalanche originating at the surface, thus increasing the severity of the hazard. On the other hand, the collapse of an unstable layer

Ber. Pass
Climax Av.

Stabilization cracks

within the base may trigger the climax type of avalanche which every snow ranger dreads. Such a condition existed at Squaw Valley in 1958-59. Knowing that it existed we broke the unstable layer prematurely in selected areas so that it settled in place. Elsewhere the natural avalanches were of maximum violence.

Our European colleagues have concentrated upon the study of the base and most of our methods are borrowed from them.

Penetrometer

Ram Profile

Slab strata
Depth Hoar

The ram sonde, or penetrometer, is a device which measures the snow's resistance to penetration. This resistance profile can be interpreted in terms of zones of strength and weakness. While not an instrument of precision, the ram sonde is a relatively quick method of investigating the snowpack. It is particularly useful in those areas where depth hoar is a primary factor in avalanches. Whit Borland and Dick Stillman have developed some valuable criteria on the stability of the hard slab-depth hoar combination characteristic of Colorado.

Time Profile

Time
Profile

The time profile is a more elaborate study of the base which requires excavation. It includes resistance to penetration, density, temperature gradient and changes within individual layers such as shrinkage and metamorphism. Its principal value is as a long-range hazard forecasting technique.

Colored Thread Profile

Colored
Thread
Profile

The colored thread profile is simply a method of positive identification for each layer within a snowpack. It may be employed alone or in connection with a time profile. Through this technique we learned that slab layers have an abnormally low rate of shrinkage so long as they retain the slab characteristic.

Settlement Gage

The electrical settlement gage is an adaptation of the Wheatstone Bridge principle. By this means we can telemeter the shrinkage of the snowpack layer by layer, and detect any abnormal developments. Since settlement is one of the better stability indicators, the technique is valuable.

Against the background of such studies as the ram sonde, time, colored thread and settlement profiles, the hazard forecaster in the field can make a fair estimate of the nature of the base at any given moment.

New Snowfall

Snow Stakes

We have learned from experience that at least 80 percent of avalanche activity takes place during or immediately after storms. In this country we have concentrated study upon the contributory avalanche factors which operate at or near the surface.

Operations Recorder

Operations Recorder

The Esterline-Angus Operations Recorder is the heart of any such observation center. I am sure you are familiar with this versatile instrument. We use it to record such data as wind force and direction, snowfall intensity, precipitation intensity, settlement and avalanche occurrence.

Snowfall Intensity

S.I. Gage

There is a close relationship between snowfall intensity and avalanche hazard. An inch an hour is critical and intensities up to six inches per hour have been recorded. We have yet to develop a better method of observation than a man trotting out to the snow study plot at short intervals. We did invent a snowfall intensity gage. It never worked very well, but it worked well enough to focus our attention on another factor of greater importance to hazard forecasting.

Precipitation Intensity

Precipitation intensity is defined as the amount of water being deposited per hour in the form of snow. Our studies are unique in the field and reveal it as one of the better indicators of storm-induced avalanche hazard.

The factor can be observed manually, like snowfall intensity. We have also had considerable success with automatic gages.

P.I. Gage

The most serious problem has been to get a representative catch of snow into these gages during the windy storms which are of most interest. The conventional slat-type collector is entirely unsatisfactory. We invented our own collector for wind-driven snow which consists of a directional intake, an expansion chamber and an exhaust.

Wind Action

Wind

When associated with transport of snow at the surface, wind is a dominant contributory avalanche factor. We have learned that precipitation intensity in the accumulation zone of an avalanche is likely to be three times what it is in a sheltered study plot.

Slab Fracture

Wind also alters the nature of the snow, forming stable windpack in some places and highly unstable slab in others. Our European colleagues, incidentally, do not agree that there is an essential difference between windpack and slab. In our minds we are convinced that there is such a difference even though we can't measure it or reduce it to a formula, on the grounds of behavior.

Wind force and direction we can record by conventional means. At Squaw Valley we operate anemometers and wind vanes connected to a recorder by wire circuits at a range of three miles. There is no reason to think that this is the limit. For accurate observation it is important to record this factor at several different elevations. The main problem is icing which has a habit of knocking out the instruments at the most interesting point in a storm. One of the projects we recommend is development of an anemometer de-icing system. Perhaps an entirely different approach is necessary, such as a device that registers wind by deflection or vibration.

For a long time we have believed that turbulence and rapid fluctuations in wind velocity play an important part in the formation of slab. Recent laboratory studies tend to confirm this belief. The equipment to observe such factors under natural conditions does not exist. The Beckman-Whitley Wind System is the nearest approach known to us. Two installations at Squaw Valley last winter turned out to be unreliable mechanically when operated at long range and much too fragile for the conditions encountered in the Sierras.

Settlement

Settlement Gage 1 & 2

Settlement in new snow is also an indicator of stabilization or the lack of it. Observing this factor during a storm turns out to be unexpectedly difficult. We have developed both automatic and manual devices.

Temperature

Temperature has a dominant influence on snow quality. In hazard forecasting trends and sudden changes in either direction are of particular interest. These can be observed by conventional methods.

There is also a temperature differential with respect to elevation. Where this differential is radical, as in the Sierras, with precipitation ranging all the way from rain in the valley to powder on the peaks, conventional equipment does not serve the hazard forecaster's purpose. One of the research projects we recommend is development of a method of telemetering temperature.

Avalanche Occurrence Timing

Avalanche Sentinel

From the analytical standpoint, the hazard forecaster is interested in the exact time of avalanche occurrence. We have developed two systems of monitoring this item, one based on wire circuits and one based on radio.

Summary

Storm Plot

As result of our observations of contributory avalanche factors over a period of years we have been able to develop case histories of a large number of storms. These case histories do for conditions on the surface what time profiles do for conditions in the base. They are the foundation for our techniques of avalanche hazard forecasting.

Instruments, both automatic and manual, are essential. Conventional instruments will seldom do the job without modification.

In many cases, we must develop our own special purpose instruments. There are basic requirements. It is not enough for such instruments to be sufficiently accurate and sensitive. They must also be rugged enough to operate under extreme conditions, simple enough to require no elaborate maintenance.

In order to improve our instrumentation and hence our hazard forecasting technique, we propose two immediate projects:

1. Develop a de-icing system for anemometers
2. Develop a method of telemetering temperature.

AVALANCHE CONTROL
(Explosives, Projectiles, Use, Structures)

By
M. M. Atwater, USFS

I believe I am entitled to state that we have brought these techniques of avalanche control through positive means to a high level. At Alta the size of the usable skiing area has been multiplied several times, partly by building new lifts, but more importantly by removing one slope after another from the "Permanently Closed" list. At Squaw Valley, during the dress rehearsal for the Olympic Winter Games, we shot it out with a Sierra blizzard that bombarded us with eight feet of snow and six inches of rain. We headed off a climax avalanche cycle which would otherwise have destroyed the main lift and killed a considerable number of people. During the Games themselves we more than once demonstrated that we could subdue thirty avalanche paths on four different mountains in less than two hours.

This is quite a far cry from the days when the only defense we had against avalanches was the "Closed Area" sign. These signs did nothing to deter the avalanches and very little to deter the people. Obviously this was no way to run a ski area, to develop it, invite the public in and then fence off the best slopes with closure signs. We either had to find a positive approach or resign ourselves to mass disaster.

I don't intend to bore you with the long and often frustrating story of how we developed the positive techniques which are so commonplace now and were so frighteningly new even ten years ago. Our purpose here is to determine where we stand now and where we want to go.

The modern snow ranger has a varied arsenal at his command. To begin with he has hazard forecasting. Without the foreknowledge of danger which comes only from accurate observations and skilled interpretation all avalanche control techniques are mere guesswork.

He has his own skis. Their shearing action is an effective field test and avalanche trigger. The technique is limited to hazard of moderate proportions. Snow rangers are not classed as expendable.

He has a variety of explosives, from the very fast charges we use on slope avalanches to the slower-burning powders which have proved to be more effective against the equally dangerous cornices. Explosives are expendable, but this technique also has its limitations, mostly of time and distance.

He has 75 and 105 mm recoilless rifles which in turn are successors to the pack howitzers and French 75s we used earlier. With these very mobile and reliable weapons, the modern snow ranger can shoot up an entire ski area from one or two handy and well-protected positions. Or he can mount his weapon on a vehicle and shoot his way along an avalanche-haunted highway. Besides taking the long, laborious and often dangerous climb out of avalanche-busting, the rifles have another important virtue. They can hit the targets under all conditions of weather and visibility. In this manner we can trigger avalanche cycles prematurely, before they have grown to destructive size. The rifles also have their limitations. In a big area some important targets are always in defilade or so close to structures that we can't fire because of the fragmentation shower.

This is a good place to mention that our objective is not to start avalanches. True, it makes a satisfying climax to the operation, to watch an avalanche beat its brains out harmlessly and hear the oh's and ah's of the spectator. But if we had our way we'd kill every avalanche before it's born. In a ski area the best place for the snow is on the slope, not in the bottom of the gulch. The fact that we can only partially attain this goal is the best indication that we still have plenty to learn.

Once the stability of a slope has been positively established, the modern snow ranger turns the public loose on it. The skiers are an important part of his arsenal although the skiers might be surprised to learn the fact. This is the next to the last step in an avalanche control program, stabilization by use. The objective is to remove the avalanche potential from each layer so that ideally we are never fighting more than the last layer deposited.

The final weapon in the snow ranger's arsenal is education. A man came into my office the other day and said, "Well, you have a pretty easy year, hardly any avalanches." I said, "Yes, only 137." He wouldn't believe me until I ticked them off for him on the chart. We still have to use "Closed Area" signs if only for short periods and in a few places, and the public has to cooperate. Nothing is more convincing than to conduct an avalanche shoot in full view of a Sunday crowd and let the skiers see for themselves what it's all about. The lesson is not one you teach today and expect to stay taught indefinitely. Each season brings a new crop of skiers, the old hands tend to become complacent. And always there is the problem of the nomadic skier who isn't satisfied with a tamed area. His pioneering spirit needs to be salted with an ounce of respect and fear.

Slides

1. Mt. Superior avalanche (Alta). Hazard forecasting indicated the danger. Avalanche control removed it before people got in the way.
2. Lift terminal destroyed. Hazard forecasting indicated that this would happen in time to keep the avalanche from killing several people as well as the lift.
3. Protective skiing. The Trough at Berthoud Pass.
4. The Headwall (Squaw Valley). Avalanche removed by hand-placed charges. Close to structures.
5. Firing the 75 mm recoilless rifle.
6. Firing the 105 recoilless rifle.
7. Canyon of the Rio Blanco (Chile) soon to be site of a highway. Artillery fire is the only feasible method of avalanche control.
8. Crater and stabilization cracks on the Headwall (Squaw Valley) made by delayed action projectiles.
9. (Squaw Valley) Hand-placed charges.

10. Stabilization by use, close-up.
11. Stabilization by use, Collins Face (Alta).
12. Closure sign. Education.
13. Crosscountry skiers. Education.
14. Windbaffles.
15. Windbaffles after avalanche.
16. Cornice control fence.
17. Effect of fence on cornice formation.

Where do we go from here? During a discussion of this subject recently someone asked, "What's the purpose of any more avalanche control research? The way it is already, an avalanche hardly raises its head before you shoot it off."

We would be egotistical indeed if we believed that there is nothing more to learn. As I pointed out in the previous discussion a great deal of improvement is needed and possible in the techniques of hazard forecasting. In avalanche control we developed three new techniques just in the Olympic Winter Games period: bangalore torpedoes and projectiles against cornices and bombing slope avalanches from lifts. Just recently we have reports of success in releasing avalanches by means of sonic boom from aircraft.

We should continue our experiments with explosives: how much to use and what kind. As to quantity, we still have no better guide than the old powder monkey's maxim: be sure to use plenty. The only way to improvement is through controlled test under conditions where the effects can be measured. As to kind, we have by means explored all the possibilities.

Efficient as they are, we do not believe the recoilless rifles are the final word. Modern rockets would appear to be superior in a number of respects: elimination of the troublesome backblast of the recoilless weapons, more mobility, simpler launching, more shock power and less fragmentation, eventually cheaper.

As limited and practical objectives we propose two projects:

1. Explosives testing: continuation of a project begun once and discontinued.

2. Rocket testing: to determine whether or not these weapons have the stability, accuracy and shock power required for use in avalanche control.

INVESTIGATIONS OF SNOW CONDITIONS CAUSING AVALANCHE

By
Whitney M. Borland, SIPRE

Project CE75, Investigations of Snow Conditions Causing Avalanche, was assigned to me as a member of the 5002nd Research and Development Unit, USAR, on May 20, 1949. In September 1949, a weather station was set up at Berthoud Pass. Instruments were furnished by the Weather Bureau and the Bureau of Reclamation, and daily observations were made throughout the season.

In the fall of 1950, the Forest Service began observing weather and snow conditions at the pass. Richard Stillman was assigned to the station as Snow Ranger. The Forest Service took over the station installation and part of my instruments, and since that time I have been cooperating with the Forest Service at this station in making observations and analyzing data.

In 1951, the Colorado State Highway Department hired a man to make snow observations and to advise them when the avalanche hazard was high so that the avalanches might be controlled by placed charges or by cannon fire. At first, the cannon firing was done by the Colorado National Guard, but later the Highway Department obtained two 75-mm pack Howitzers. In 1950, an informal organization was set up to facilitate the collection of data and the dissemination of information on avalanches. The active members of this organization were: the Forest Service, Colorado State Highway Department, and the National Ski Patrol. This organization functioned for 3 or 4 years, but finally died out for want of support. In the spring of 1951, a state highway avalanche man was assigned to me for training during weekends. During that spring, penetrometer tests were taken at the fracture line of several avalanches affecting Federal highways and with the help of the National Ski Patrol, we were able to release artificially two avalanches by backpacking surface charges to the upper part of the slide paths. In the fall of 1952, the Colorado Highway Department set up a weather station at the top of Loveland Pass and I have assisted them during weekends in analysis of their data since that date.

In September 1953, Dr. Henri Bader of Snow, Ice and Permafrost Research Establishment (SIPRE) visited the Denver area and looked over Project CE75. As a result of this visit, snow surveying instruments were made available to the Forest Service, Colorado State Highway Department, and myself. Also, Project CE75 was given financial support by SIPRE. This support has been continued since that date and has made the continuation of the project to the present time possible. In February 1955, Alfred Fuchs visited the project and conferred with both the Forest Service and the Colorado State Highway Department officials. In April 1959, James A. Bender, Chief, Snow and Ice Basic Research Branch, SIPRE, visited the project and in March 1960, Rene Ramseier, SIPRE, spent 10 days visiting the project and discussing conditions with the Colorado State Highway and Forest Service.

Seven interim reports have been issued for Project CE75 which contain weather data, various measurements taken in the snow cover, and the occurrence of avalanches in both the ski areas and along the highways. These reports contain all the data collected by both the Forest Service and the Colorado State Highway. Copies of the reports are sent to both these agencies as well as to the Army through channels. The following table lists the reports, seasons covered by each, and the number of observation stations in operation:

Report No.	Season	Station
1	1949-50 1950-51	1 1
2	1951-52 1952-53	1 2
3	1953-54	3
4	1954-55	3
5	1955-56	3
6	1956-57	3
7	1957-58	4
8	1958-59 will cover data from 4 stations and is nearly complete.	
9	1959-60 covering the past seasons will report on 4 stations.	

For the past 5 years, reports have also contained weather data from the High Altitude Observatory near Climax, Colorado.

At the present time all four stations are equipped with hydrothermographs, recording rain gages, three of them have anemometers, snow stakes, and the standard Weather Bureau 8-inch can. Since 1950, colored-thread profiles have been obtained and pits have been dug every 2 weeks to obtain the physical characteristics of the snowpack. Numerous special studies are reported on concerning temperature within the snowpack, wind baffles, wind fences, formation of cornices and snow creep.

For the past 2 seasons, the project has analyzed weather information and snow conditions for the State Highway and predicted avalanche hazards, since they have not had an avalanche man since 1958.

AVALANCHE PROGRAM OF THE NATIONAL SKI PATROL SYSTEM, INC.

By
Wm. R. Judd, National Director, NSPS

The N.S.P.S. initiated an avalanche-training program for its ski patrolmen about 1946 in Colorado. The following year, sufficient funds were raised by the NSPS to invite Andre Roch of Davos (Switzerland) Technological Institute to this country to instruct our future instructors. This program was completed early in 1948. In 1951, the program was put on a national basis with our development of an intensive course that qualified the participant for an "Avalanche Shoulder Patch" to wear on his official parka. Since that time when we graduated 15 in the course, we have awarded an additional 314 patches. It is of interest that in these first 15 were 6 U.S.F.S. Rangers and Patches No. 1, 3, 4, 6, 7, and 14 being given to Rangers M. Atwater, W. F. Davis, J. Herbert, F. Koziol, H. Lee, and W. Parke, respectively. This training program showed a gradual increase annually until 1956 when a considerably more difficult course was instituted to qualify for the patch (See Appendix A for typical examination given at completion of course.) Since 1956, the graduates have gradually increased annually.

This "patch" course is given in a condensed version to those ski patrolmen not wishing to qualify for the "patch" or not having the ability to do so. We estimate that over 1,200 patrolmen have received this condensed course within the past 3 years. (For details on contents of each course, refer to Appendix B.) This past season alone, it is estimated that 860 patrolmen are taking such a course.

Our avalanche training is organized on a divisional basis. Each of our nine divisions have a man assigned as chairman of avalanche activities. His duty is the development and prosecution of training programs for patrolmen and the skiing public. He generally has assistance from other patrolmen in his division. As part of this program, and at the request of the Safety Services Division of the U. S. Army Command in Southern Europe, we are making arrangements to send an instructor to Garmisch-partenkirchen, Germany, to instruct our two ski patrols in that area. These latter patrols are U. S. Army personnel on TDY at ski areas used by our G.I.'s.

As the number of qualified personnel increases, the NSPS has gradually increased its ski public education program on avalanche hazards. In the past 3 years, well over 4,000 recreational skiers have received lectures of from one to 3 hours in this regard. Some patrols have carried the training to television shows, radio programs (including warnings of critical conditions when a ski area weather forecast is presented), public gatherings at movies, and at Alta, the public is invited to attend demonstrations of avalanche control work by the U.S.F.S. The coming season, the patrols in Colorado, Wyoming, and New Mexico have planned a public education program that will reach over 2,000 persons. All of this educational work is financed by local patrol funds and personal contributions of time and money.

U.S.F.S. Cooperation

All patrols were requested to provide information on the amount of cooperation they received from local USFS personnel. The result of this questionnaire provided the following information:

Wash., Ore., Idaho	-- Five rangers assisted in instruction.
Mont., No. Wyoming	-- USFS assisted in first school this year.
Alaska	-- Two rangers (not in winter sports administration) assisted in the training. In Anchorage area, the primary aid came from U.S. Bureau of Public Roads personnel.
Calif., Nev., Ariz.	-- Considerable USFS cooperation, particularly from Rangers Atwater and Stillman. Also National Park Service Ranger L. Bodine.
Eastern Seaboard & New England	-- Received aid from one snow ranger.
Great Lakes states	-- No local USFS rangers qualified to assist, but local USFS offices loaned visual aides for training. Also, the patrolmen from this area were permitted to attend western U.S. Forest Service courses.
Utah, So. Idaho	-- Program under chairmanship of USFS scientist E. La Chapelle.
Colo.,So.Wyo.,N.M.	-- Four USFS rangers currently assisting in both field and classroom programs.

All of the above patrols indicated they were receiving excellent cooperation from local USFS personnel. For example, in the northwest, the USFS maintains rescue caches containing avalanche rescue supplies.

Avalanche Rescues

Complete records of ski patrol work in rescuing victims of avalanches were impossible to obtain. Fragmentary records indicate that in the 1959-60 season, the patrols have participated in 7 avalanche searches and rescues. These involved 2 fatalities. In addition, in the past three seasons, the patrols have participated in 8 avalanche searches and rescues. Since 1951, the patrols have records of a total of 18 fatalities caused by avalanches. These were not all recreational skiers, but included highway workers, snow surveyors, etc. It is interesting that at the only avalanche area in New England - Mt. Washington - the greatest danger is from falling ice, not avalanches. The local USFS there has been trying to shoot it down without success; this season they are to try 50-caliber machine guns. It seems that these shooting methods cannot result in duds and therefore the methods that can be used are very limited. This falling ice killed one person on May 23, 1936 and one on May 17, 1958.

In most of the above search operations, the patrol is assisted by USFS personnel. If the avalanche scene is some distance from a ski area, it generally involves a joint effort of the local sheriff, the local mountain rescue squads (if any), the state highway patrols, and occasionally, military assistance from USAF or USA personnel. Very often local chapters of the American Red Cross will provide food and temporary shelter for the search personnel if the search extends overnight.

Instruction Materials

For use of patrol classes, the NSPS provides a set of some 75 35mm slides that cover types of avalanches, route selection, probing and hasty search procedures, control of avalanches by skiing and explosives, avalanche forecasting through instrument measurements, etc. In addition, many of the patrols have developed "popular" 35mm slides to use in lecturing to the skiing public. We also make available a copy of "Avalanches To Order" which was supplied to our national office without cost by the U.S. Forest Service office in Washington. For text material, we currently are using: "Instructor's Outline-Advanced Avalanche Course." This 35-page mimeographed booklet is available at our national office at 50¢ a copy. It is based on and refers to the USFS Avalanche Handbook. The latter document is still used by some of our patrols who are fortunate enough to have a few copies. In addition, a condensed description of avalanche dangers and recognition is provided in one chapter in the National Ski Patrol Manual ($1.00 per copy).

The National office maintains a permanent file of detailed accounts of avalanche fatalities and rescues. Also filed are the comprehensive annual reports on avalanche research compiled by our National Avalanche Chairman, W. Borland. (Mr. Borland performs this latter research under the direction of and financed by the Snow, Ice and Permafrost Establishment of the U.S. Army.)

We investigate avalanche rescue devices. (See Appendix C for a recently developed search device.) These investigations have resulted in our importing the following items which are available for sale at our national office (1130 16th St., Denver 2, Colorado).

1.	Lightweight sectional probe (Austria)	$ 4.00*
2.	Lightweight oxygenating probe (Austria) This device is a hollow, sectionalized probe that has a valve attachment at the top to connect to an oxygen tank for supplying air to a deeply buried victim before he is dug out.	10.70
3.	Akia (Austria) This is a very lightweight (25 lbs.) aluminum rescue sled that can be broken into two parts for easy backpacking. It is highly maneuverable in most types of snow. The price depends upon the various accessories ordered.	132.00+*
4.	The Halper Sledge (Norway) These are components to make a rescue sled from a pair of skis and poles. The resulting sled is capable of transporting up to 400-lb loads and a toboggan-type front end is available for deep	22.00

* All prices are f.o.b. Denver.

snow work. The entire device including the canvas stretcher weighs about 6 lbs.

5. The Isolaterra Rescue Bag (Germany) — 22.50
This lightweight bag was developed especially for mountain rescues. It has the peculiar property of reflecting body heat (placing your hand within the bag soon gives a sensation of warmth to the hand.) It has sufficient zippers and size so that the entire body can be completely enclosed, even if splinted.

Recommendations

Our divisional avalanche chairmen were requested to submit their proposals for obtaining more efficient avalanche training and rescue operations. Their replies can be summarized as follows:

1. The most urgent and basic need is the new edition of the U.S. Forest Service Avalanche Handbook. This is needed prior to the start of our 1960-61 training in September 1960.

2. We should develop considerably more visual aids for training and particularly for educating the skiing public.

3. Avalanche training should be provided all students of mountaineering.

4. A short movie, 16mm-sound, that depicts field procedures for search and rescue including probing methods is badly needed.

5. Every attempt should be made to have the U.S. Forest Service and National Park Service install avalanche rescue caches in the more remote areas (those that are some distance from ski area caches). The thought was expressed that perhaps these could be combined with major fire control caches.

6. It was recommended that all avalanche-alert procedures developed by the U.S. Forest Service or National Park Service provide for alternate leadership if the local ranger is temporarily absent. This alternate leader could be the local patrol leader or other available National Ski Patrolman having an avalanche patch.

7. To assist in the public education program, it was strongly recommended that avalanche warning signs be standardized throughout the U.S. There should be two basic signs: One for warning of uncontrolled intermittent danger; the other for areas where a temporary hazard exists.

8. It was recommended that uniform and frequent location markers and signs be placed for giving directions to avalanche caches.

9. It was strongly urged that every ranger selected for duty in mountainous snow terrain complete the U.S.F.S. avalanche course prior to the end of his first season of such duty.

10. It was suggested that every ranger having duty in mountain country be required to take a brief course in technical summer and winter mountaineering. This often can be obtained from local mountaineering clubs.

11. The patrol asks that the U.S.F.S. define the question of who has the responsibility for off-ski area avalanche and winter rescues. If an accident occurs on public land, but not near a snow ranger headquarters, shall that ranger have an official responsibility of assisting, leading or organizing the rescue operation?

APPENDIX "A"

AVALANCHE EXAMINATION - NATIONAL SKI PATROL SYSTEM - NRM DIVISION

(1959-60)

DO NOT WRITE ON THIS EXAMINATION FORM. BE SURE TO PLACE YOUR NAME, ADDRESS AND NAME OF YOUR PATROL AT THE TOP OF YOUR TEST PAPER. THERE IS NO TIME LIMIT FOR THIS TEST. WHEN YOU ARE DONE TURN IN YOUR TEST AND THIS FORM AT THE FRONT DESK.

1. Discuss thoroughly the effect of all factors of terrain on avalanche development.

2. What are the three basic criteria and their subdivisions (with definitions) for classifying an avalanche.

3. Name the four avalanche "triggers." - Give an example of each.

4. List the Ten Contributory Avalanche Factors and the critical points for each, discussing the effect of each in connection with avalanche prediction.

5. The most important duty of the hasty search party is: 1. Question the eyewitness, 2. Locate scene of accident and mark the best train, 3. To identify the last seen point and make the hasty search.

6. List the five sections of a Snow Safety Plan.

7. What is the specific time limit we hope to beat in rescue operations, and what is the significance of this limit.

8. Describe a complete avalanche rescue operation from the time the report is originally received until the entire operation is closed, including first aid measures.

9. Why is "PI" considered to be an exceptionally significant factor in evaluating avalanche hazard.

10. Discuss thoroughly the process of stratification and its effect on avalanche hazard development.

11. There are a number of factors (not necessarily restricted to, but including at least some of the formal 10 Contributory Avalanche Factors) that can be checked without the use of instruments. You are a touring skier. List as many of these factors as you can and tell how you can check them. e.g. Wind -- can be felt, can observe snow banners on the ridges and peaks.

12. Name the three alpine zones as classified for avalanche study, and list the criteria for each, including its principal avalanche type.

13. Which two of the Ten Contributory Avalanche Factors, if they reach their danger point, always result in highly destructive slides.

14. Describe thoroughly the method of test skiing a suspected slide area.

15. Where is an explosive charge placed for maximum effect in an artificial release mission.

16. Total snow depth yesterday was 100" as measured on the totalizer stake. Today the storm stake (when read immediately at the end of the storm) read 12". Six hours later the totalizer stake reads 110". How much settlement have you had? What is the settlement ratio?

17. Describe depth hoar in terms of its physical properties.

18. Discuss regelation and its various effects on slide development. Compare it with the effect of "interlocking."

19. Describe an electrical blasting cap, tell how it is used and discuss the precautions that must be observed with respect to it.

20. What effect does the temperature gradient of the snow pack have on the metamorphosis of the individual snow crystal in the stratification and fernification of the total snow pack.

21. Compare "Wind Slab" and "Wind Crust" with respect to physical properties, location, method of formation and general effect on avalanche hazard development.

22. List eight physical properties of snow and their various effects tending to encourage or discourage slides.

23. Why is it so necessary that the survivor return to the scene of the slide.

24. Seven main types of avalanches are listed in your text. List the three most usual types and describe them as respects, appearances and general pattern, where and when found, potential for property damage and injury.

25. You are a touring skier. What precautions will you take in respect to route selection, timing and party conduct to reduce the danger of being involved in a slide.

26. True course to the scene of an accident in the back country is 360°. Mean Declination Constant in that area is 17°. What is the magnetic heading (course) to the scene of the accident.

27. Compare the terms, "hangfire" and "delayed action" as applied to avalanches.

28. At what point in an avalanche rescue operation does voluntary labor normally cease to function, i.e. when is its responsibility completed.

29. Diagram the development of a cornice, labeling various parts.

30. You propose to take a ski tour. You are advised by the local snow ranger that the current avalanche hazard is rated at 2 Plus. What does this mean, and what is its effect on your plans, if any.

AVALANCHE TRAINING REQUIREMENTS FOR NATIONAL SKI PATROLMEN

Avalanche training is required for all national ski patrolmen regardless of where they live or ski. While many may ski in avalanche-free areas, a majority visit areas where the hazard always is present. In view of these circumstances, the following requirements must be met by all NSP nominees:

A. For appointment as national ski patrolman in areas where avalanche hazards exist:

   1. Where probe poles are available and avalanches do occur, training shall be —

      a. Participation in one simulated rescue operation and a written report of this operation. In this operation, dummies are buried beneath at least 6 ft. of snow and an "eyewitness" comes in and gives the alarm. Both hasty search party and main party are organized and dispatched to the "accident" scene. Probe lines are formed and the search continued until the dummies are found. (The USFS Avalanche Handbook outlines the written report required); and

      b. One day shall be spent in the field with the USFS or other qualified persons familiar with the habits of avalanches and the forecasting of avalanche hazard; and

      c. A minimum of 3 hours in the classroom. The lessons should cover: (1) recognition of avalanches and avalanche hazard in the patrolman's ski area; (2) an explanation of how local weather build up avalanches and the factors responsible for their release; and (3) winter survival, safety and route selection to avoid avalanches.

B. For appointment as national ski patrolman and award of avalanche patch:

   1. Completion of requirements when in A above; and

   2. Completion of an additional 8 hours of classroom work given over a period of not less than 3 days. This course is to be based on the NSPS instructor's outline for avalanche courses, and each applicant must pass a written test at the end of the course; and

   3. Completion of an additional 4 hours of field work in avalanche recognition and selection of safe routes for travel and skiing.

C. For appointment as national ski patrolman in avalanche-free areas:

   1. Where probe poles are not available and there is insufficient snow to conduct the simulated rescue problem. The candidate has to complete a minimum of 7 hours of classroom work based on the USFS Avalanche Handbook and the Ski Patrol Manual. Four of these hours

shall be spent on the subject of avalanche rescue, two on route selection, and one on winter survival.

D. Training aids:

Films: USFS has available without charge: "Avalanches to Order" (narrated by Lowell Thomas); "Snow Ranger" (sound with much avalanche data); "Avalanche Rescue" (no sound but a prepared script to be read)

Guides: USFS Avalanche Handbook
Avalanche Instructors Handbook Outline (available from NSPS office)
Avalanche Requirements (available from Divisional Patrol Officers)

<u>Qualifications for Instructors of Avalanche Courses for NSP Nominees</u>

1. Attend a Forest Service avalanche school, or been awarded an avalanche patch, or had equivalent training consisting of the following:

   a. Minimum of 10 hours classroom work, and 8 hours field work with a competent instructor; and

   b. Taken part in at least one simulated rescue problem and written up a report on it. (Natural or actual avalanche rescue can be substituted for requirement B.)

2. Be able to prepare lesson outlines, conduct a class in a manner providing the patrolmen with adequate training, and supervise and referee a simulated avalanche rescue problem; and

3. Have a lively interest in avalanches, prediction of avalanche hazard, weather and climate, and be recognized as a ski mountaineer; and

4. The instructor's qualifications will be reviewed and passed by a member of the NSPS Avalanche Committee.

<u>Qualifications for Instructors in Avalanche Courses Leading to Award of Avalanche Patch</u>

1. Attended a USFS avalanche school or its equivalent; minimum requirements are:

   a. 20 hours of classroom work; and 40 hours of field work, part of which should be with a competent avalanche instructor and part may be avalanche control work; and

   b. Taken an active part in a real or simulated avalanche rescue and prepared report on same; and

   c. Have led ski or mountain groups cross-country over difficult terrain and be able to instruct in route selection and survival in winter weather in the mountains; and

2. Have had experience in teaching or public speaking and be able to conduct a class in a manner that patrolmen receive adequate training; and

3. Have been active in avalanche and snow studies for at least 3 years (within the past 5 years) and spent at least 15 days during this period in study of avalanches, snow cover, weather conditions, and prediction of avalanche hazard.

4. The instructor's qualifications will be reviewed and passed upon by a member of the NSPS Avalanche Committee with the approval of the NSPS Avalanche Committee Chairman.

Signed Whitney M. Borland
NSPS Avalanche Committee, Chairman

Approved: NSPS Divisional Chairmen and
National Director at
Timberline, May 24, 1957.

SENSOR-PROBE

Immediately prior to the meeting, the NSPS received a report on a new device for detecting bodies buried in avalanches. The purpose of the device is to determine whether the object contacted by a conventional avalanche probe is a human body or a rock, log, or other inanimate object; successful determination would eliminate the present necessity of carefully digging out every object contacted by the probe. This device operates on electronic principles as described below. It has been field-tested with moderate success and reportedly can detect body temperature that radiates through a shirt, sweater, AND padded parka. In the latter test, the meter read about 1/10th full scale after 4 to 8 seconds. The person's arm was inserted into a snow bank and the probe inserted from the top or the other side of the bank. Clear and strong indications also were obtained within 5 seconds when the probe touched a ski boot. The resistance of the element changes greatly with temperature and this change is amplified to provide indication on a milliammeter.

The basic device is a temperature-sensing element on the end of a sectional aluminum tube. The latter is available in 3-foot sections up to 9 feet long. There is no restriction, however, on the length of the probe, and the sections are completely interchangeable.

The sensor is connected by an insulated cable to an amplifier, power supply and indicating meter. These latter elements are contained in a 4" x 6" x 2" box. The power supply is 2 flashlight batteries and a hearing aid battery. Because the current in the sensor is very small, it is amplified in a 2-stage DC transistorized amplifier. A temperature range switch decreases the amplifier gain at higher temperatures and prevents damage to the indicating meter. Five ranges provide adjustment for air and snow temperatures between +75° and -20°F. This switch also operates a pilot light to illuminate the meter for night operation. Because only relative indications are important (since the victims are warmer than snow) the meter is provided with an adjustable, transistorized shunt that removes most of the steady state current but passes any change into the meter.

To use the device, the operator inserts the probe into the snow and allows 20 or 30 seconds for initial temperature stabilization, and then sets the range switch to the appropriate temperature which does not have to be accurately known. The shunt control then is adjusted for a convenient meter deflection; the device then is ready for use. Neither adjustment is critical since the only requirement for operation is that the meter be on scale.

A victim-contact will cause a steadily increasing deflection on the meter after a few seconds contact. Temperature gradients in undisturbed snow and melting temperatures at ground level will give false readings and thus must be taken into account. Usually, however, an avalanche will mix the snow to a homogeneous temperature at all depths above the undisturbed snow.

If the avalanche had buried rocks or stumps recently exposed to the warming of the sun, the sensor-probe could give a reading of warmth similar to a human body. Generally, such occasions would be sufficiently infrequent, that the amount of digging still would not be materially increased.

Initial tests were made in a frozen food locker at -10° to 20°F. No troubles were experienced from water condensation or decreased battery voltage. The response on contact is faster at temperatures between 25° and 35° than at zero temperatures.

The unit is currently being manufactured by Puget Sound Development Laboratories. Since only small quantities have been made, an accurate price is not available; the manufacturers believe, however, that the units can be purchased for between $150 and $175. They also stated they would be very willing to make a unit available for test purposes.

NSPS COMMENTARY: Although we have had no experience with the sensor-probe in actual search, it appears to have utility in avalanche search operations. Since it will not detect temperature changes unless the probe actually contacts the victim's clothing, it is hoped that the device can be further developed to react when it is a few or more feet from the victim. In the latter case, it might be possible to use it as a "mine-detector" type device for scanning the slide surface. Since the device is battery-operated it appears advisable that the meter box be kept inside of the parka until ready for use; this would avoid the possibility of battery freeze in extremely low temperatures.