W. P. BERGGREN (author's closure to discussion)--Informal discussion has suggested the following supplementary remarks:

(1) The magnitude chosen for L, the volumetric heat of fusion, will be affected by migration of water during freezing and by the presence of unfrozen water below 32°F, in so far as these factors can be evaluated.

(2) It should be emphasized that the curves (Figs. 1 and 2) are sample results of the analysis of idealized systems, in which thermal properties, as well as imposed temperature-conditions (see Table 3), have been arbitrarily assigned.

(3) The applicability of Table 2 is quite general except for the assumption $(a_1/a_2) = 1.82$ (ratio of thermal diffusivity frozen and unfrozen), which is fairly insensitive to moisture-content of the soil. The purpose of this Table is to facilitate evaluation of equations (9), (10), and (12) for specific problems by giving directly the roots of equation (13). These roots (magnitudes of β) are expressed in terms of two dimensionless parameters which are evaluated readily from the conditions of the problem.

SNOW-STUDY PROGRAM AT SODA SPRINGS NEAR DONNER SUMMIT OF CENTRAL SIERRA NEVADA

J. E. Church

This report presents tentative conclusions on cooperative investigations of snow and snow-melting by the Nevada Agricultural Experiment Station and the United States Weather Bureau at Soda Springs, California. The undertaking is expected to lead to an improvement in the measurement of snowfall and to a better understanding of the hydrometeorological factors affecting the runoff from snow.

The observational work during the past season was made difficult by the interruptions normal to war time, although at all times the project had the full cooperation of the military. It is expected that this project will be continued and expanded until abundant data for dependable conclusions have been accumulated.

The study of snow at Donner Summit originated at the sessions of the International Commissions of Snow and Glaciers at Washington in 1939 through the queries of Carroll F. Merriam regarding the possibility of a critical temperature and density at which snow would suddenly and rapidly melt and the writer's interest in seeing the Stevens seasonal rain-and-snow gage put to a prolonged test in heavy and deep snow. Vernon E. Rupp, when hydrologic engineer of the Weather Bureau at San Francisco, joined in the latter desire and obtained permission from the Weather Bureau to install the Stevens type-W recorder at Soda Springs. The Leupold Stevens Instrument Company and the Weather Bureau bore the expenses of installation while the Experiment Station provided supervision during the winter.

In the summer of 1942 Merrill Bernard, Hydrologic Director of the Weather Bureau, with Vernon E. Rupp and Ray K. Linsley, met the writer at Lake Tahoe and proposed a continuation and expansion of the program, which was finally made formal in a cooperative agreement signed by the Weather Bureau and the Experiment Station.

The following studies have now been organized: (1) Efficiency of precipitation-gages and snow-surveying under severe mountain winter conditions; (2) the physics of snow-melting; (3) temperature in the snow; (4) changes in snow-texture. The two latter were suggested particularly by Phillip Light and Roy E. Lundquist.

Equipment--Originally at Soda Springs Station there was one platform provided by the Southern Pacific Company and a tower. On the latter was the Friez reconnaissance precipitation-recorder. On the former were the usual Weather Bureau cooperative instruments and the Stevens type-W recorder. The snow-survey was being conducted in a pasture 1,000 feet to the east. It seemed best to place as many instruments as feasible in the pasture because of the snow-course there but likewise to keep near the hotel the instruments that must be visited daily. Otherwise extreme snow-conditions might make it difficult to visit the instruments without far greater expenditure of time than available funds permitted.

Finally, in consultation with Bertram S. Barnes, Mr. Rupp's successor, two centers were de-

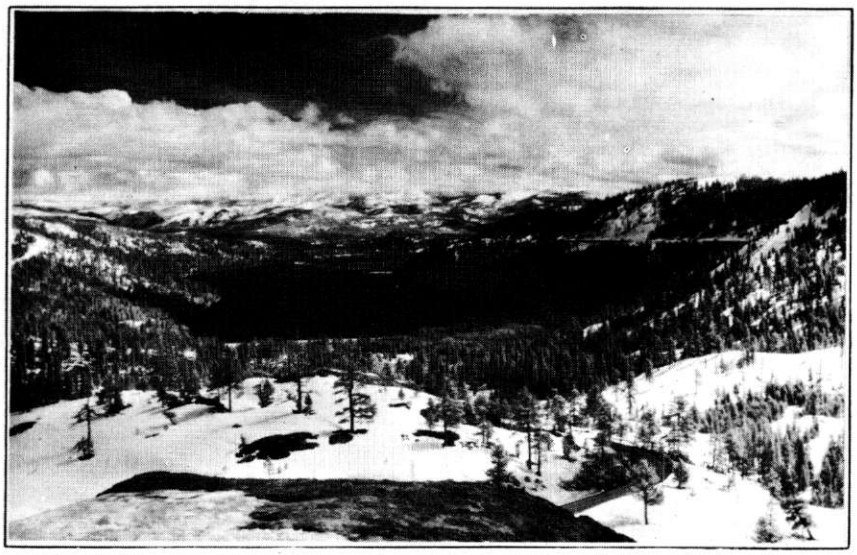


Fig. 1--View east from Donner Summit over Donner Lake and Mount Rose

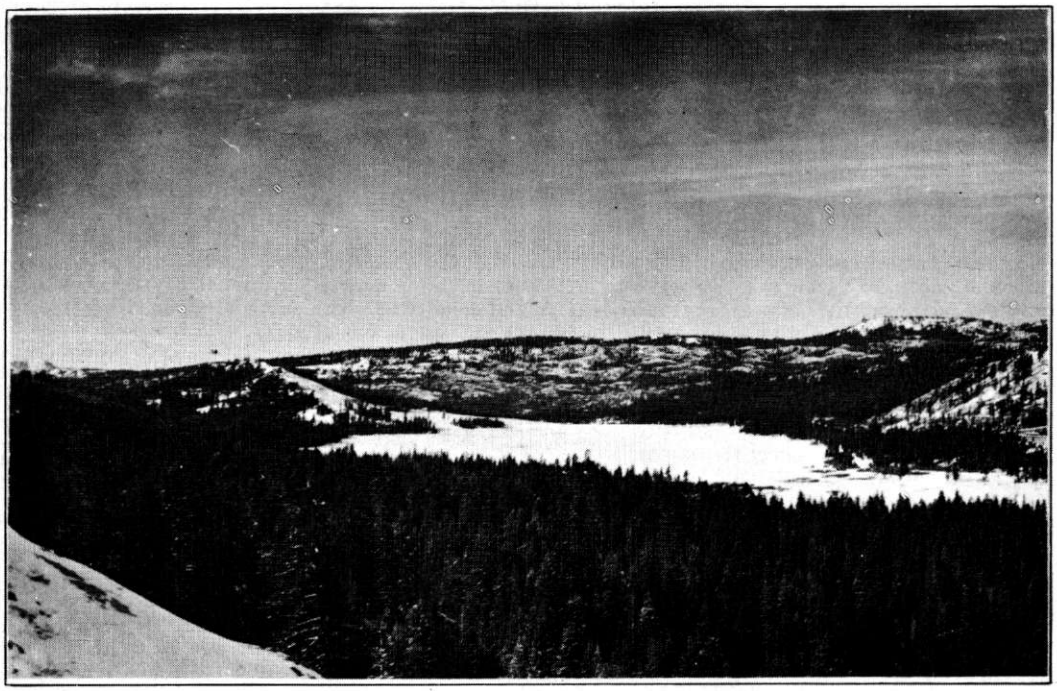


Fig. 2--View west from Donner Summit over Lake Norden and Soda Springs at base of Beacon Hill beyond

veloped, one at the hotel and the other in the pasture. The original platform was extended to carry a series of precipitation-gages, sunshine-recorder, wind-vane and anemometer, and telethermoscope. A hygrothermograph was placed in the shelter with the maximum and minimum thermometers. The sunshine-recorder and wind-apparatus were connected with a triple register in the Post-Office Building by cable and wires furnished generously by other cooperators among whom was the Signal Corps of the Army. The standard rain-gage was retained as the basis of comparison of the catch of the various gages.

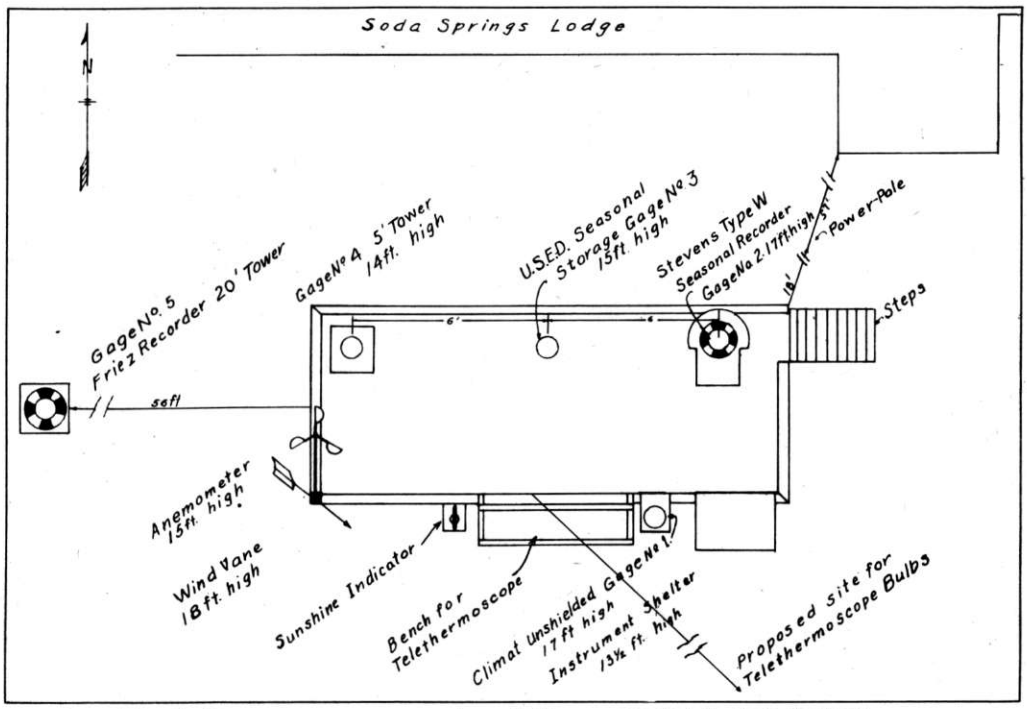


Fig. 3--Snow-gage arrangement on platform near Hotel, Soda Springs, California, December 1942

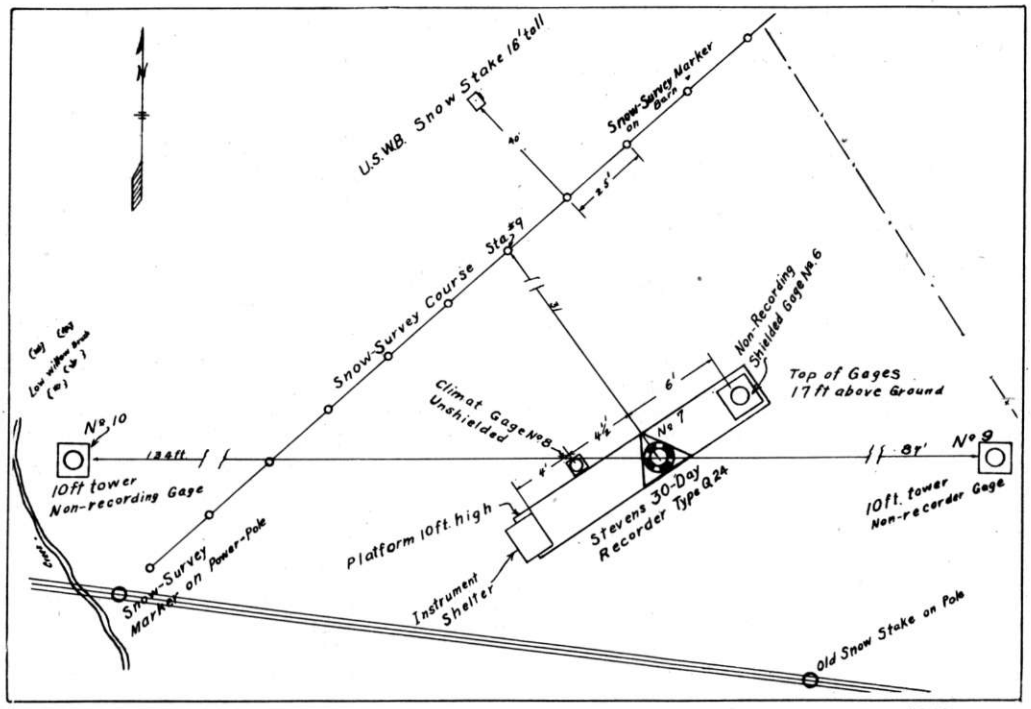


Fig. 4--Snow experimental plot in pasture, Soda Springs, California, December 1942

Table 1--Monthly summary of data for catch, in inches of water, obtained with precipitation-gages, Soda Springs, California, 1942-43

Month	Location										Depth on ground by snow-stake	Snow-survey, av. 10 measurements	
	Hotel					Pasture							
	No. 1, stand. un-shielded	No. 2, type-W Stevens	No. 3, Army Eng. Corps	No. 4, check for No. 3	No. 5, Friez recon-nais-sance	No. 6, stand. shield-ed	No. 7, type-Q Stevens	No. 8, stand. un-shielded	10 feet above ground No. 9	10 feet above ground No. 10		Depth	Water-equiv.
Nov.	12.81	.....	.....	.....	12.98	.....	12.60[b]	.....	.....	.....	18	17.7	8.3
Dec.	8.77	.....	9[b]	9.92[d]	9.57	9.41[d]	9.02	8.37[d]	8.05[d]	9.23[d]	34	32	13.0
Jan.	15.79	.....	17[c]	13.65	17.22	18.96	17.67	14.25	17.80	18.075	93	90.5	28.2
Feb.	3.96	.....	4.0+	5.19	4.85	4.75	4.85	3.89	5.47	5.31	86	77.7	32.5
Mar.	9.70	.....	9.0	9.84	11.63	9.545	9.37	8.695	10.545	10.425	84	78.5	38.4[e]
Nov.-Mar.	51.03[a]	.....	39.0[b]	38.60[b]	56.25	42.66[b]	53.51	35.21[b]	41.86[b]	43.04[b]	...	.....	.....
Apr.	2.60	.....	2.50	4.155	3.83	3.87	3.72	3.55	4.09	4.15	21	24.0	11.8
May	2.23	.....	2.88	2.38	2.34	2.23	2.22	2.05	2.37	2.39	0	0	.....
Dec. 1-June 1 adjusted	43.05	.....	45.96	45.42	48.33	50.62	47.05	42.67	50.18	51.44	...	.....	.....

[a]Equal 141.8 per cent. [b]Incomplete. [c]February 6. [d]Estimated. [e]Equal 98.2 per cent.

Notes: All gages except No. 1 and No. 8 were equipped with wind-shields.

Gages No. 9 and No. 10 were three feet deep for increased storage and lessened evaporation.

Comparison should be made by months rather than by the entire season, for some gages such as Nos. 3, 4, 6, 8, 9, and 10 were not installed until after the heavy precipitation of November. The Stevens type-W (No. 2) early suffered mechanical injury which has only recently been detected and repaired. The Army Engineers gage (No. 3) could be only approximately measured by stick and awaits the close of the season before the contents are drawn off and weighed. (Weight July 26, 1943, 47.38 in.)

All gages except No. 9 and No. 10 are fully 15 feet above the ground; No. 5 on the tower is somewhat higher.

In the pasture a Stevens type-Q recorder with tower was erected with a trestle containing two precipitation-gages, one unshielded and the other protected, together with a maximum and minimum thermometer, hygrothermograph, and an anemometer with dial but no triple register. Flanking the trestle were two towers containing rain-gages of three-foot depth but erected only ten feet above the ground because of lack of material. This in fact turned out fortunately.

The barograph owned by the Experiment Station was placed in the Post-Office to supplement other weather data. Other equipment has been accumulated as plans progressed. These are four metric anemometers, two standard anemometers provided by the Weather Bureau, and one standard anemometer loaned temporarily by Blue Hill Meteorological Observatory. Two telethermoscopes were provided by the Weather Bureau with supplementary housing by the Experiment Station that has provided also a dozen thermometers sealed in glass tubes for determining temperatures in snow. A drift-snow catcher and calorimeter have been designed and eight dyes, a pound each in quantity, have been procured. All instruments have now been tested and are ready for continuous use with the return of snow.

Every week since November through May the writer has visited Soda Springs and has usually remained two days each time and on occasion several days. The only regret is that he could not have been there continuously. Observers during the period were W. H. Sanders, until the Military Police of the Army took over the hotel, and, since that time, Arthur Couillard of Donner Summit Lodge, a quarter-mile west.

Ten precipitation-gages were placed under test during the winter and have been found to agree so closely with each other that admiration rather than criticism of their performance must be expressed. Table 1 shows in detail the closeness of the individual gages month by month.

Three conclusions from this list have been formed. (1) The precipitation at the two stations was practically identical, showing that the precipitation in this area is uniform. (2) The unshielded gages show a considerable catch-deficiency with respect to the shielded type and therefore the latter type should be considered the standard, but also that the gages nearer the ground catch more precipitation than those higher above. At first it was believed that the lower gages were being affected by drift-snow and for this reason the drift-snow catcher was designed. The uniform excess, even in spring when drift-snow was scant and rain was heavy, indicates, however, that the slowing

Table 2--Wind-velocity, Soda Springs, California

Date	Wind-movement				State of weather
	General direction	Miles for 24 hours preceding 5 p.m.		Difference (hotel-pasture)	
		Near hotel	In pasture		
1943					
Apr. 28	NW	88	82	- 6	Stormy
29	W	95	88	- 7	Clear
30	NW	90	100	+ 10	Part cloudy
May 1	NW	114	123	+ 9	Clear
2	NW	72	59	- 13	Part cloudy, clear
3	W	77	...	.....	Clear
4	NW	73	79	+ 6	Clear
5	W	102	102	0	Part cloudy
6	S	37	73	+ 36	Clear
7	NW	65	167	+102	Clear
8	E	284	380	+ 96	Clear
9	W	151	123	- 28	Clear
10	NW	100	125	+ 25	Clear
11	W	174	107	- 67	Clear
12	W	122	101	- 21	Clear
13	NW	4[a]	132[a]	(+128)[a]	Clear
14	NW	104	120	+ 16	Clear
15	NW	151	169	+ 18	Cloudy
16	SE	121	175	+ 54	Part cloudy
17	SE	169	255	+ 86	Clear
18	SE	139	226	+ 87	Clear
19	SE	72	173	+101	Cloudy
20	SE	86	63	- 23	Clear
21	W	88	121	+ 33	Clear
22	S	172	243	+ 71	Clear
23	SE	120	171	+ 51	Clear
24	SE	102	123	+ 21	Clear
25	W	124	111	- 13	Clear
26	W	54	121	+ 67	Clear
27	SE	89	169	+ 80	Clear
28	W	80	35	- 45	Clear
29	W	105	168	+ 63	Clear
30	NW	103	72	- 31	Cloudy
31	NW	174	166	- 8	Rain
Maximum[b]		284	380	+102	.....
				- 67	.....
Minimum[b]		37	35	0	.....
Average[b]		113	137	+ 24	.....
		Velocity in miles per hour			
Average daily					
Maximum[b]		11.8	15.8	+ 4.3	.....
				- 2.8	.....
Minimum[b]		1.54	1.46	0	.....
Average[b]		4.7	5.7	+ 1.0	.....

[a]Something wrong. [b]Omitting May 3 and 13.

of the wind nearer the ground permits more precipitation to enter. (3) The use of oil in the cans has apparently reduced the evaporation from them almost to nought. At one time an evaporation of 0.01 to 0.10 was noticed in the pasture with no evaporation whatever at the hotel. This slowing of the evaporation makes it feasible to use the ordinary open can in locations that can be visited only occasionally. The plan is being put in use immediately in Lamoille Canyon of the Ruby Mountains in determining the variation in precipitation with altitude up the slope of the canyon. The Tahoe National Forest also favors the plan in its desire to provide information to the public regarding precipitation in remote places in its forest that can be visited only occasionally.

The calcium chloride, except in cold weather and extremely heavy precipitation, serves well in keeping the contents sufficiently slushy to melt the accumulating snow. If stirred, its efficiency is much greater. In some of the cans this was not practiced, for a test of cans for long periods unattended was desired.

The wind-shields of the open type have shown their efficiency provided they are sturdily constructed. The open slats evidently atomized the wind as do trees in the forest and neutralized the air-currents. It is planned to attach streamers to the shields another winter to determine the direction of the wind as affected by the slant of the shields.

The shields, as constructed by Leupold-Stevens with chains of interlaced links, withstood a heavy gale January 21, 1943, that turned most of the other shields of open links inside out or tore them apart. Ashton Codd, who has rendered major service in establishing the project at Soda Springs during both years, installed sliding guide-wires on one of the gages (No. 10) to prevent the slats from being blown upward onto the can. This has had complete success in steadying the shield and holding it in position.

The question of the velocity of wind at which wind-shields are wrecked is a bit confused by the great divergence found between the velocity of the wind at Donner Summit and at Soda Springs Hotel during the above storm. The maximum velocity of the wind at Donner Summit was in excess of 100 miles hourly but at Soda Springs was as low as ten miles per hour. The observer, however, at the latter place estimated the wind at 60 miles per hour on the Friez tower, at which time he was hurriedly resetting the instrument. At the points somewhat more exposed than the anemometer, as on the Friez tower and in the pasture, the wind was undoubtedly much stronger. Table 2 affords comparison of the diurnal wind-movement at the two stations. The gale was blowing from the west and the pasture was in the axis of the wind.

Despite the freezing of the contents during January and the smothering of some gages under their own wreckage of shields and the leaving of some unprotected from the wind, the total precipitation was still reasonably uniform, probably because of the heavy precipitation already fallen when the wrecking occurred. Gages Nos. 1 and 6 had no shields and the shields of Nos. 2, 7, and 10 were unaffected. The last group was more sturdily built.

One pleasant surprise that came later was the realization that at least in intermittent storm and sunshine the orifices of the precipitation-gages can clear themselves. During the spring a most unusual phenomenon occurred at Soda Springs of snow so cohesive that it formed caps four to six inches high on all the gages. In fear lest this snow would be lost, the observer carefully trimmed these so that the cores fell into the tank. In the Friez recorder (No. 5) the resultant splash was 0.5-inch water on the record. Fortunately no effort was made to clear the gages in the pasture. On inspection it was found that the Stevens gage (No. 7) at the same time recorded a splash of similar amount. If the weather had been cold and the contents of the can had been frozen, the snow would probably have been wasted.

Recording-gages--Unfortunately recording-gages must be made sensitive in order to record the falling moisture and for this very reason they are subject to oscillation.

In the case of the Stevens type-W gage, the weigh-beam was so delicate that the instrument acted like a seismograph, responding when one ascended the platform or opened the iron door and retracing when the door was closed or one descended. For this reason a heavier oil in the damping-cup was used but further tests in the laboratory will be made in the summer of 1943 toward reducing the sensitiveness. If the record of precipitation hourly instead of at 15-minute intervals is satisfactory, as in the case of mountain precipitation and particularly snow, the contact-points might possibly be drawn farther apart. This gage has a capacity for double the 40 inches of precipitation that normally falls at Donner Summit. Through the use of a storage-battery sufficient heat was delivered to the collar to prevent any snow-accumulation beyond a fleck or two of frost throughout the winter. Its accuracy of catch, therefore, was extremely high. The batteries also did not freeze, indicating that primary cells if sufficiently strong and insulated may maintain themselves without serious deterioration from cold. If the sensitiveness of the instrument can be overcome, its length of period could easily be a year. To make the period this long, however, in case the precipitation is excessively heavy as it was the past winter, it will be necessary to develop a counterpoise on the weigh-beam to record the additional weight. At present the capacity of the weigh-beam is only 40 inches.

The Stevens type-Q recorder planned originally for only a month with a maximum catch of 24 inches of water is remarkably sturdy and steady though the pen is affected by climbing the tower.

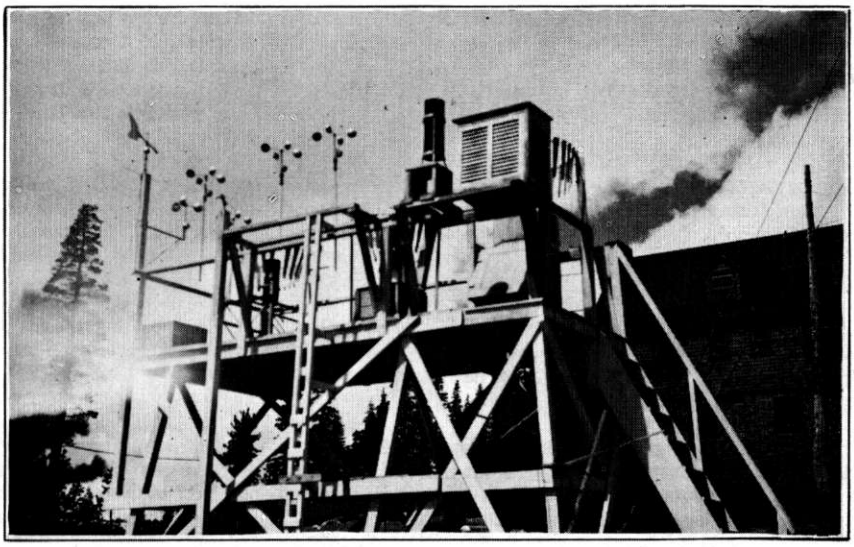


Fig. 5--Platform at Hotel, metric anemometers under test
(Trellis for cables telethermoscope)

Fig. 6--Buried in snow

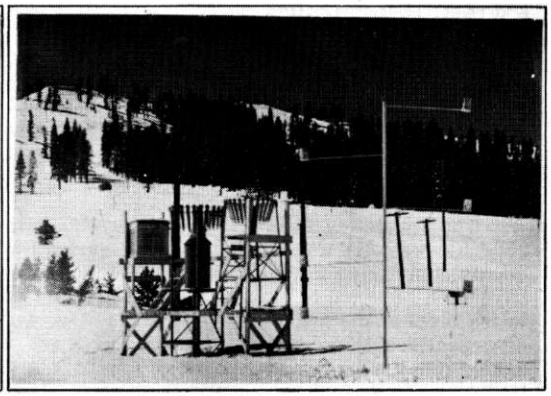


Fig. 7--Drift-snow catcher

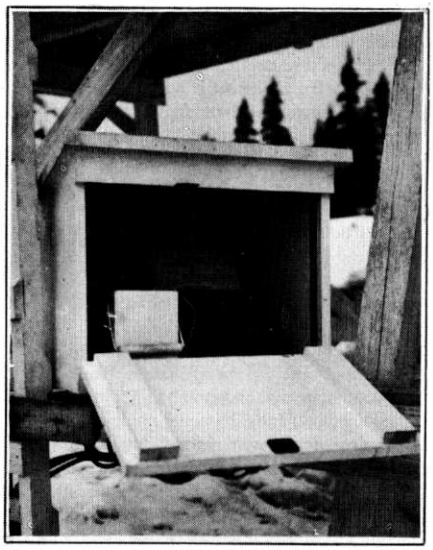
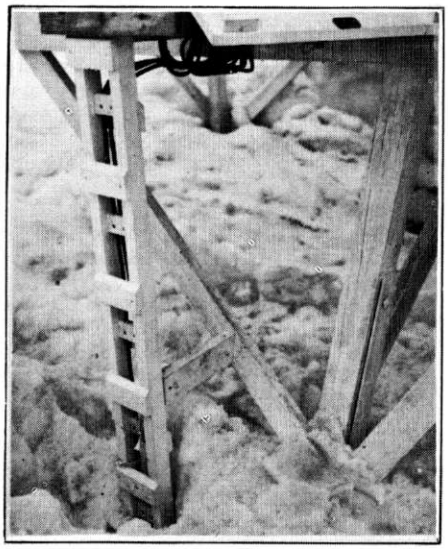


Fig. 8--Telether-moscope-case

Fig. 9--Telether-moscope-trellis for holding cables and thermal units in position



The pen--a barrel siphon--has not been filled since November 1942 and even now after seven months, when expanded by moisture in the air, is half full. The test will be continued to determine its maximum duration. With some increase in its capacity this instrument, driven by weight, should be capable of recording for six months except where the precipitation is extremely heavy. Even under the unusual conditions of this past winter it recorded for a month at a time without attention.

The Friez gage, which was built for the special purpose of recording detailed precipitation for short periods of time, naturally suffers under the severe conditions of the mountains and the height of its tower. However, its recording is accurate, except when the pen oscillates greatly in the wind or is thrown beneath the flange.

It now appears that the oscillation of the pens in all of the recorders is due to the suction of the wind passing over the orifice even more than to the vibration caused by the impact of the wind on the instruments themselves. The heavy gale of January 1943 evidently sucked the air upward in the Friez gage so greatly that the pen that had recently been set only an inch above the flange was caused to drop and catch below it.

Record-sheets in mountain areas or when not punctually removed should preferably overlap so that the pen can continue its trace without being caught either by the clip or the crease where the clip is inside the drum. It was found in the hygrothermographs that the pen would easily slip into the crack and be torn loose. The tendency of the sheets in the moist air to expand and wrinkle would likewise be reduced if the sheets overlapped. In this case a metal elastic band above and below would hold the sheet in position. In the case of the Stevens type-Q recorder, perforations in the record-sheet make it possible to hold the sheet in place by pins and so distribute the expansion and restrict it to limited areas.

Snow-surveying has been maintained at frequent intervals throughout the entire winter but no opportunity for the comparison of the accuracy of snow-surveying as compared with the catch of precipitation has been afforded because of the open winter, which has produced 141.8 per cent of normal precipitation and only 98.2 per cent of snow-residue. The value of both types of measurement is obvious, the former to show the gross assets and the latter the snow-residue on the eve of major runoff. Both types of measurements must be continued and should supplement each other.

The physics of snow-melting--The observation made last year that the snow-crust formed at 35°F as recorded a few feet above the surface was repeatedly confirmed the present year with crusts sometimes forming when the temperature was even at 40°F. Two additional thermographs have been obtained to make a series of traces of the temperature from the level of the snow upward to the level of the hygrothermographs at the two stations. Unfortunately these thermographs have divergent scales so that the comparison is not so easy. Several thermometers insulated in sealed tubes have been procured to determine the temperature at varying depths in the snow-cover itself from the surface to the ground.

Dyes--An old plan of using dyes has now been brought to fruition through the assistance of Dr. Phil E. Church of the University of Chicago. Several dyes were procured for a test. Most of them are satisfactory but one, the Fuchsine, was found to meet every requirement. It does not cause the snow to melt but lies dormant and green until it comes in contact with moisture when it immediately turns red. It is possible thus by sampling or cutting pits in the snow to determine the movement of moisture in the snow. It does not, however, penetrate soils or at least muck, but our present interest does not yet extend that far. Other visible detectors of water-movement in soils may be known or discovered.

Non-water-soluble powders have been found that can be placed on the snow to mark the various strata as they form at the surface or even later by aid of the snow-sampler.

The following case history will reveal the delicacy of this powder and its value in studying water-movement in the snow, thus assuring the qualitative study of this subject.

May 2, 1943, 8 a.m.

Planted dye (minimum temperature during night 28°F, present temperature 34°F); crust solid with frost.

Though pin-points of moisture attach themselves to the warm hand from frost, No. 6 (Fuchsine) is dormant except on three tiny crystals--even where scattered over frost-spicules. But slowly, after several minutes, occasional flecks of crimson dye appear like stars in the evening sky. Now the flush as of dawn in color as the Sun comes from thin clouds. The color travels up the individual

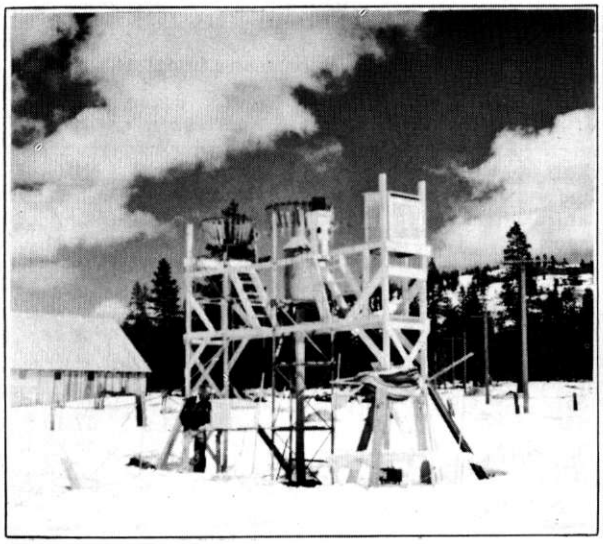


Fig. 10--Trestle in pasture with telethermoscope and thermographs on snow and midway upward to hygrothermograph in shelter

Fig. 12--Snow on branch of pine susceptible to insolation

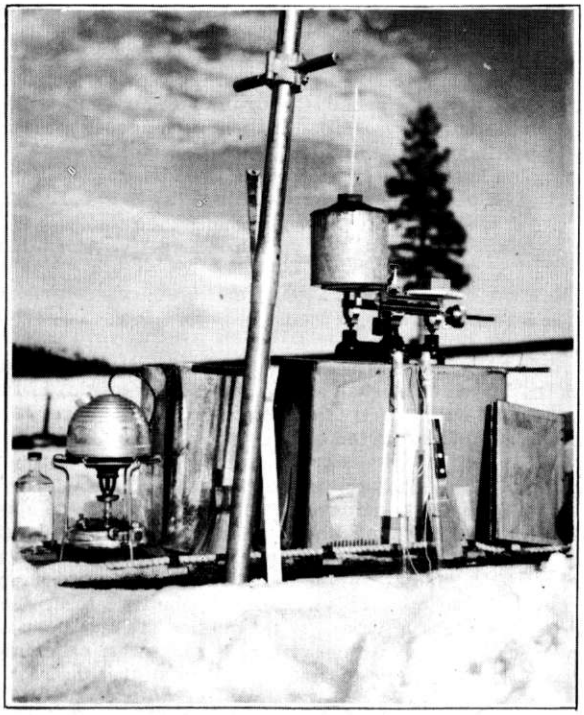


Fig. 11--Calorimeter-equipment

needles or spikes of the frost-stars and does not jump across. The frost is a tangle of rods, but only the topmost rods are colored, evidently where moistened by the Sun. The grains of dye deeper in the frost are still dormant. Now tiny flashes of color where a frost-rod has melted. Now they quicken and the red becomes more continuous as the water spreads.

A core of snow representing a cross-section of the snow-cover is cut and laid on the surface of the snow to test its moistness by sprinkling dye upon it. The core is only 12-1/2 inches long for the snow-cover is in its last stages. First 5-1/2 inches frozen dry and firm. The dye there is

Table 3--Summary of calorimetric data, Soda Springs, California, 1943

Equation: C in calories = [(2.45 in oz + hot water in oz)/snow in oz] [(temperature hot water in °C - final temperature in °C) - final temperature in °C]

No.	Date, weather[a]	Length core	Density snow	Grain-size	Temperature snow	Moisture[b]	Mass hot water	Temperature hot water	Mass snow	Final temperature	Calories per gram	Thermal quality
	1943	in	pct	mm	°F		oz	°C	oz	°C		pct
1	Apr. 25	3.5	?	2	32(?)	W	10.71	49	3.43	30.1	42.48	53
2	Apr. 26	15	53.3	1-2, ice 4	33	Mf	9.921	50.2	8.0	6.4	61.31	77
3	Apr. 27, sr	.....	.....	2	...	FW	9.921	20.9	1.5+[c]	16.0+[c]	16.39[c]	20[c]
4	May 2	17.3	68.0	2-4	35	W,CP	10.248	61	10.04	5.8	63.75	80
5	May 3, c, pc	6.5[d]	69.4	2-3	33[e]	MC	9.880	58.6	4.51	24.9	67.1	84
6	May 3	8.5[f]	51.5	3-4	33[g]	MP	10.71	63.4	4.38	30	70.2	88
5+6	.....	15.0	59.3	....	...	.....	.....	.....	8.89	.....	.....	...
7	May 3	17.5[h]	48.7	....	...	Sd	10.285	62(?)[i]	8.52	5.4	78.9(?)[i]	99[i]
8	May 3	[j]	.....	4-10[k]	...	W	10.58	35.4	7.822	0.05[l]	58.7	73
8a	May 3	4[m]	31.2	4 est.	...	W	10.37	62.6	1.262[c]	49.5	84.1[c]	105[c]
9	May 7	3-5, total 15	47.9	1-2, max. 4 congealed	32.5[n] 32.7[o]	MW, CP	10.342	54.0	7.181	10.4	67.25	84
10	May 7, ss	10.7	53.9	1-2	32.7	MC[p]	10.059	51.0	5.77	13.0	69.38	87

[a]Symbols for weather: s = snow; r = rain; b = calm; pc = partly cloudy; sr = sunrise. [b]Symbols: W = wet; M = moist; D = dry; P = packs; C = crumbles; Mf = moist freezing, that is, MC; FW = firm wet slush; Sd = soil dripping. [c]Use with caution account small quantities; should try larger amount. [d]Upper 6.5 inches. [e]Eight inches down. [f]Lower 8.5 inches. [g]Twelve inches down. [h]Including ice button. [i]Probably 52°C on basis 52°C value for calories per gram is 64.03 and thermal quality 80 per cent; probably error delay in recording. [j]Scooped up at trestle--most nearly "latent heat." [k]Corn-snow, chunk of ice also. [l]A few crystals still unmelted. [m]At trestle, upper part of snow. [n]At 2.5 inches. [o]At 4.5 inches. [p]Though slightly WP.

Notes: Tests Nos. 9 and 10 made from residual snow; elsewhere ground bare. Snow had melted suddenly; depth May 4, 8 inches, May 5, 0 inch.

dormant (night temperature 28°F), except under the pressure of my hand, but then only on the outer crystals. Farther down the snow crushes and the moistness gradually increases (test the calories). The dye assumes a red color, well distributed through the core. The grain-size is one mm, increasing to clump-sizes of five to ten mm.

Calorimeter--The quantitative study of the heat of melting, already far developed by Walter T. Wilson, has now been initiated through the development of a home-made apparatus with the assistance of Dr. Samuel B. Batdorf of the Department of Physics of the University and John T. Ryan of the Engineering Laboratory. It comprises a coffee jar set in a tin-can and surrounded by rock-wool with a top covering of storage-battery plastic. The orifice is two inches wide, thus making it possible to drop snow-cores as cut by the snow-sampler readily into it. The thermos character of this jar is sufficient to cut out the influence of the outside air and leave the observer abundant time to determine the maximum and minimum temperatures in the experiment. By rolling the can to and fro in one's arms the water can be thoroughly mixed so that the readings are exact.

A weighing-scale graduated in grams, loaned by the Department of Chemistry, was recalibrated to record ounces (or inches) of water as measured by the snow-sampler with the Utah cutter. The capacity of the balance was increased from 11 ounces total to three times by employing a counterbalance that could bring the instrument into balance after the weighing of the jug, and the jug with hot water, thus leaving the last measurement to represent the weight of the snow.

A sheet of cross-section metric paper was used to determine the size of the snow grains, while the length of the core cut by the sampler, when weighed in the jug, gave its exact density. The temperature of the snow was determined by thermometers insulated in glass tubes. The snow

was classified as wet, moist, or dry, with a supplemental quotation as to whether it packed or crushed.

With this apparatus several measurements of the calories required to melt the snow were made. Those measurements about which no question of accuracy arose appear quite reliable in their mutual agreement. It is planned to continue the calorimetry of the snow throughout next season from new snow to weathered snow, and snow in the final stages of melting. Only careful operation seems necessary to acquire a large fund of reliable data. The data so far obtained with description are given in Table 3.

Melting and freezing--The effect of insolation in melting the snow is everywhere apparent, yet the duration of diurnal melting is relatively brief and apparently depends upon the combination of maximum and minimum temperatures, particularly upon the latter. Not so much the temperature of 32°F but the actual temperature of the snow below freezing determines the hour of the beginning of active melting in the morning while the temperature of freezing in the evening determines its immediate cessation. The day is, therefore, uneven in its divisions, for active melting may occur as late as 11 a.m. but always ends promptly when the Sun approaches the horizon.

Actually, as already mentioned, snow may freeze at an air-temperature of 35° or even 40°, depending upon the character of the snow and its lack of saturation. The snow-crystals are extremely porous and air-filled, which apparently accelerates loss of heat by radiation and hastens freezing. The coldness of the snow acquired during the night requires a considerable period to be brought to the point of melting, while little loss of heat is necessary to permit the melting snow to fall below the freezing-point. Therefore, instead of a 24- or even 12-hour day of melting, six hours in early spring at altitude of 7,000 feet represents the usual melting-period. This should have considerable bearing on the so-called daily rate of melting, based sometimes on experiments in the laboratory.

This theory should be checked out carefully this coming year. One or two quotations from field-notes will indicate the general trend.

December 9, 1942

Temperature last night 27°F; snow therefore not very cold.

New snow three inches deep, crystals one mm or smaller, cohere. Barometer rising.

On pine trees, snow concave or retracted from needles. Some drip and cohesion of trailing snow. By evening snow has largely disappeared from trees exposed to the Sun.

At 4^h 30^m p.m. temperature 35°F, sky thinly overcast (cirrus) or clouds broken, snow freezing. Crust 0.35 inch, the amount of melting during the day. Snow below crust is dry. Temperature 0.3 inch above snow 31°F.

At 5^h p.m. fog forming over valley. Relative humidity 98 per cent (?). Radiation despite humidity.

Place thermometer among pine needles under their snow-canopy and in free air (shaded) close by.

December 18, 1942

Temperature at 10^h 45^m a.m., 41°F. Frost-feathers still on snow at 11^h a.m., melting only on wood. Feathers only slightly moist to the touch. Melting-day therefore short, but snow where dirty already melting.

December 23, 1942

Dusk (5^h p.m. or later); current temperature, 36°.5 F; raining (no crust); temperature one-third inch above snow in rain 35°F.

[Note: Temperature of rain probably that of wet bulb or 35°F; melting of snow therefore slight.]

9^h p.m., temperature 33°-36°F, oscillating. Wind blew hat off. Thin layer of new snow on old; all soft. Rain must be turning to snow.

In front of hotel, snow-banks moist but congealing. There only 36°F at 9^h 45^m p.m.

10^h 30^m p.m. On hotel porch 36°F. Incipient crust in front of hotel but snow still made a well-packed snowball. Therefore, snow congeals, though more slowly, at 35°F (head height) even when air is moist and sky is clouded, and radiation slowed down. The potency of radiation on congealing is therefore strong.

Notes: Humidity therefore seems to have no effect on the temperature of freezing but merely retards its coming. Then, for example, the temperature of freezing in damp New England is the same as in the arid West. However, the human discomfort in the former is greater. Test this in laboratory and in the Appalachians. In the lower mountains of the East, humidity may delay the fall of the temperature so greatly that freezing may even not occur during the night. Thus the hours of active melting per day may far exceed the eight or fewer per day usual to the Sierra Nevada.

Fig. 13--Formation of ice window-panes over pits following a windy day

Temperatures in the snow: Telethermoscope--Supplementing the use of the portable thermometers sealed in tubes is the telethermoscope, suggested by Phillip Light. The telethermoscope consists of a series of resistance-thermometers arranged at fixed levels in the snow and soil. The purpose of this instrumental set-up is to obtain simultaneous temperature-readings at frequent intervals throughout the snow and soil-column. This was installed at the hotel in order to make it easier for the observer to take readings once or twice daily. In soft snow the pasture seems too remote. However, at the hotel the saturation of the soil with drainage-water made it impossible to obtain soil-temperatures of any value.

Since the instrument as received was not built to withstand weather, a shelter-case was made for it with permanent switch and installation except that the battery was provided with a separate plug like a flat-iron so that it could be kept in warmth except when taken out for the individual observations.

To prevent the thermal units from being dragged down by the snow as it settled and thus distorting their location, a trellis was provided for holding the cables and the units firmly in position at fixed distances above the ground. The only difficulty with the present apparatus is that the length of the cables is insufficient to reach more than half-way up the platform whereas the instrument was planned for installation on the platform by the side of the sunshine-recorder.

When the snow had finally shrunk to a depth of less than three feet, the telethermoscope was moved to the pasture to obtain a longer series of test-readings. One thermal unit, the one used in the soil, seems to be defective. The others, though irregular in their readings, have been sufficiently uniform to merit the continuation of the experiment during the coming year. The instrument should afford a daily picture of the variation of the temperature at fixed elevations in the snow-cover. It is recommended that the instrument returned to Washington for readjustment be returned so that an installation can be made both at the hotel and in the pasture for the value of comparative measurements and more points of measurement. The extension of the trestle in the pasture by a cat-walk will make it possible to place the units where the soil-moisture is satisfactory and the snow unblown. Longer cables, however, should be provided to keep the instrument at all times above the snow.

Snow- and ice-types--Lundquist's classification of snow and ice has been developed and made practical by retyping it in the form of a book with pages protected against the snow and moisture by cellophane. To it has been attached a metric cross-section sheet for determining the sizes of snow-crystals. A scalpel for cutting snow, a large needle in a cork-handle, and a magnifying glass, complete the outfit for disengaging and magnifying the snow-crystals for study. Supple-

REPORT ON SNOW-TYPES

MONTH OF _____, 19____

(Place check in appropriate square for classification and date)

Type	Day of month																													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
(I) TYPE OF SNOW- OR ICE-DEPOSIT																															
(A) Fresh accumulations																															
(1) Snowflakes																															
(2) Snow-grains																															
(3) Snow-pellets																															
(4) Sleet																															
(5) Hail																															
(6) Rime																															
(7) Glaze																															
(8) Frost																															
(B) Old deposits (or weathered)																															
(1) Fine powder-snow																															
(2) Coarse powder-snow																															
(3) Fine granular snow																															
(4) Medium granular snow																															
(5) Coarse granular snow																															
(6) Corn-snow																															
(7) Soft crust																															
(8) Hard crust																															
(9) Consolidated ice																															
(II) DEGREE COHESION OR COMPACTNESS																															
(A) Loose snow																															
(1) Fluffy																															
(2) Loose																															
(3) Initially cohesive																															
(B) Firm snow																															
(1) Firm																															
(2) Very firm																															
(C) Compact snow																															
(1) Compact																															
(2) Very compact																															
(D) Hard snow and ice																															
(1) Unusually compact snow																															
(2) Granulated crusts or																															
honeycombed ice																															
(3) Solid ice																															
(E) Slush																															
(1) Firm slush																															
(2) Amorphous slush (fluid)																															
(III) QUALITY																															
(A) Dry snow																															
(1) Fresh snow																															
(2) Old snow																															
(B) Moist snow																															
(C) Wet snow																															
(D) Dripping wet snow																															

Notes: _____

Fig. 14--Specimen monthly form for report on snow-types

menting this is a report-book with a space for each day of the month and all of the months of the winter in which by means of a cross it is possible for the observer quickly to indicate the daily features of the snow. Ray K. Linsley has suggested that the measurements be made beneath the snow as well as on the surface.

Only two or three changes are recommended in the classification. (1) The term "old deposit" should be changed to "weathered snow" for snow-weathering can take place almost within a single day and change the character of snow completely from that it had when newly fallen. (2) The term "amorphous slush" should be changed to "fluid slush" as being more readily understood. (3) The grain-size could be more simply expressed in terms of mm than in any available divisions of the inch or the thickness of wire or sheet metal. While the inch is understood by all, 0.04 inch could scarcely be visualized and cannot be so readily expressed as one mm. Offsetting the unfamiliarity of the length of a millimeter is the scale in millimeters attached to the outlines on which the snow-crystals can be strewn and measured at a glance. Lundquist's chart should be in the hands of every observer of snow. A copy of the report-chart for field-use but without the millimeter-sheet is shown in Figure 14.

Supplemental reports--The subject of perennial snow and its ultimate glaciers, and snow-perils and avalanches have been quite fully treated and published in the Scientific Monthly for March and April 1943, and in the March 1942 issue a report was made on snow-sport and transport. These are all parts of the study at Soda Springs, including also 1942, when the investigations were initiated; the articles are copiously illustrated.

Nevada Agricultural Experiment Station,
Reno, Nevada

WESTERN SNOW-CONFERENCE

MINUTES OF BUSINESS MEETING

The annual business meeting of the Western Snow-Conference was called to order by J. C. STEVENS on June 16, 1943, at Corvallis, Oregon, following luncheon at the Benton Hotel. The meeting was then turned over to R. A. WORK, who presided.

A report [see Appendix A] from the chairman of the Executive Committee, FRED PAGET, was read to the group by Mr. WORK, who recommended that it be accepted as read and that FRED PAGET be given a unanimous vote of thanks by all members for his very strenuous work in holding the organization together during these trying times. It was so moved by Mr. CANFIELD, and the motion was seconded and carried.

With reference to discussion of drop in membership from 600 to 176, J. C. STEVENS asked: "With no dues, the question is whether those 600 members were bona fide members. Before dues were assessed, probably only 50 per cent were actual members." Dr. J. E. CHURCH, in answer to this comment, stated it had been the policy of the organization that anyone attending a meeting was automatically a member. Many, perhaps, had no permanent interest in the work; the 176 current members, however, are interested in the future of snow work. (Note: Members on November 1, 1943, numbered 190.)

WALTER E. JOHNSON, Acting Treasurer, submitted a report of the financial standing [see Appendix B]. The last examination of the books, January 15, 1942, which were audited and found correct, revealed a deficit of $370.22. The financial condition today, however, is better, showing a bank balance of $427.66 and an unencumbered balance of $77.66. Motion by ASHTON R. CODD that the Treasurer's report be accepted was seconded and carried.

No old business other than matters mentioned in Mr. PAGET'S report was brought up.

Election of officers--Mr. WORK referred to the policy expressed by vote of the membership of having all officers and members of the Executive Committee continue in office for the duration of the war, and following a short discussion said "It clearly is the sentiment of the group at this annual meeting today that the present officers be continued in accordance with former action."

In answer to G. H. CANFIELD'S question as to what area was involved--West Coast or Oregon--he was assured that the group represented the entire Western United States.

ASHTON R. CODD recommended allowing the appointment of other members to the offices of those who are taken into the armed service to keep the Executive Committee to its full membership. It was brought out that this provision is now in the By-Laws.

Name--In accord with a suggestion in Mr. PAGET'S report, J. C. STEVENS moved that the name of the organization be changed from Western Interstate Snow-Survey Conference to the shorter form of Western Snow-Conference. The motion was seconded and carried without further discussion.

Membership and dues--Mr. STEVENS brought up the fact that it had come to his attention that some members were not paying American Geophysical Union dues of $3.00 because they paid dues of $1.00 for Western Snow-Conference and received the Proceedings of both the Union's Section of Hydrology and Snow-Conference. He questioned how many would be willing to join the American Geophysical Union, with its dues of $3.00, and continue membership in the Snow-Conference as an affiliated branch. Perhaps some members might be lost to the Snow-Conference; however, even from a considerably smaller group the $3.00 instead of $1.00 per year would result in increased income. He asked if the Proceedings were available for purchase through any other channels.

Dr. CHURCH replied that the Proceedings were offered for sale at about $2.00 per volume, of which Western Snow-Conference provides only one part. A member of the Snow-Conference in this way gets only a part--probably material from one meeting--of what he would get were he to pay the full American Geophysical Union membership dues of $3.00. The Weather Bureau previously purchased a number of copies for distribution; however, this income is now reduced because of the number of their men who are becoming members and receiving individual copies through this channel.

Perhaps members who join the American Geophysical Union need not be required to pay the fee of $1.00 but the group could still remain as a sub-section of the American Geophysical Union, publishing with the Union in its Transactions under their supervision, and having the responsibility and privilege of voting for at least a part of the direction of things.

"I believe we should keep this group because of the concentration of interest," Dr. CHURCH said. "Let those who do not want to join the American Geophysical Union still pay only the dues of $1.00 to the Snow-Conference. Dr. FLEMING has published our Proceedings free and given us copies at $0.35 to be sold to interested organizations at $0.50, and so helping us financially. Though we appreciate his generosity, we should nevertheless reserve a place for those interested only in the snow."

W. W McLAUGHLIN, like Dr. CHURCH, did not want to see those interested only in the viewpoint of snow forced out of the present organization by an increase in dues. Many would get value received and more if they became members of the American Geophysical Union. He sympathizes with Dr. FLEMING'S ideals and generosity and likes to see records in a printed form, but still he prefers the idea of keeping members in the Snow-Conference and then encouraging the members to join the American Geophysical Union, even at the cost of $4.00 instead of $1.00.

Mr. WORK said "We want to keep 176 members and also encourage more to join and pay their dues. It seems necessary to continue solicitations from power-companies, experimental stations, and other interested organizations which have supported the work. Along with that we will work with the Committee on Membership of the American Geophysical Union under WILLIAM LANG in an effort to sometime reach the goal of 500 new American Geophysical Union members."

A count of hands revealed that, of the 25 present at this Western Snow-Conference meeting, 12 were members of the Union.

ELMER FISHER of the Weather Bureau office at Portland, raised a question concerning the membership of organization representatives. Mr. WORK replied that voting membership has nothing to do with individual membership--a man may be a voting member for an organization such as the Weather Bureau and still not be a member himself. Were he to pay his dues, he would be permitted to cast two votes--one for the organization and one personal vote. Mr. WORK urged that interested men join the Western Snow-Conference (six new members came in).

Mr. McLAUGHLIN pointed out that the subscriptions made by the Weather Bureau and others are for copies of the printed report, at a certain amount per copy--getting one vote for perhaps a subscription of $75.00, the same as an individual member gets for $1.00. However, of course, they receive the desired copies of Transactions for distribution.

ASHTON R. CODD asked how many members who belonged to Western Snow-Conference also belonged to the American Geophysical Union. Exact figures were not at hand, but Dr. CHURCH

Election of officers--Soon after the Pasadena Meeting, steps were taken in accordance with the By-Laws of the Conference toward holding the bi-annual election of a new Executive Committee. This had proceeded to the stage of appointing a Nominating Committee when a suggestion was made that the Executive Committee be asked their opinion as to whether or not a new election should be held, or whether it would be best to retain the present officers for the duration of the war. The voting in response to this question was: Retain present Committee, 14; elect new Committee, 4; not voting, 2. The membership was later asked to confirm this decision of the Executive Committee to allow the present Committee to remain in office. Confirmation was given with a vote of yes, 264, and no, 11.

Dues--At the Business Meeting of the Pasadena Conference, it was decided to poll the membership to determine the sentiment as to whether the Conference should go on a dues-paying basis of $1.00 per year, or whether it should affiliate with the American Geophysical Union with dues per member of $3.00 per year. The Chairman appointed a Committee to prepare a circular for submission to the membership. The Committee was composed of: J. E. Jones, Chairman; W. A. Lang; H. P. Boardman; and Merrill Bernard. This proposition was finally submitted to vote and the returns were:

Item	Yes	No	No vote
$1.00 membership	197	45	49
Affiliate with American Geophysical Union	129	87	75

As a result of this vote, a ballot was mailed March 2, 1942, submitting to the membership a proposal for changing the By-Laws to permit the collecting of dues from each member. This amendment was approved with a final vote of 175 to 5.

Membership--In accordance with the amended By-Laws, a circular was sent January 4, 1943, to some 600 individuals, then being carried on our Conference membership-rolls, advising them that dues of $1.00 for 1943 were due and payable. To date 28 per cent have replied and paid their dues. Our paid-up membership now totals 176.

Cooperation with American Geophysical Union--The long history of cooperation and aid given this Conference by the Section of Hydrology, American Geophysical Union, is well known to all of us. Dr. FLEMING, General Secretary of the Union, has extended to the Conference many favors. With the formation of the Great Lakes Snow-Conference and the Eastern Snow-Conference, Dr. FLEMING has made a proposal that if, through the three Conferences, 500 new names can be added to the American Geophysical Union, he will, without cost to the Conferences, undertake to publish all of their Transactions. The 500-goal is a far one, and not very much progress in its direction will probably be made during the war, but in order to make a start in the right direction, a Committee has been appointed to secure as many members as possible for the American Geophysical Union. This Committee is composed of WILLIAM LANG and JAMES E. JONES, both of Los Angeles. A recent communication from Mr. LANG carries the names of seven new members for the American Geophysical Union who have been secured through the Snow-Survey Conferences, and have been forwarded to his Committee for processing.

Treasurer--At the time of the Pasadena Meeting, the Chairman of the Executive Committee was also acting temporarily as Treasurer, substituting for CARL ELGES, our former Treasurer, now a Lieutenant-Colonel in the Coast Artillery.

After it had been decided to continue the Executive Committee in office for the duration, the Chairman tried to find someone else to take over the duties as Treasurer. No willing hand was held out, so your Chairman perforce has continued to pack the load.

Our financial condition is now at the highest peak since the Conference was initiated. This is due to a combination of circumstances: The low cost of the brief Transactions of the Pasadena Meeting; the generosity of the interested organizations who continued their usual annual subscriptions in spite of the abbreviated size of the Transactions; and to the considerable dues collected from the membership. At the time of the Pasadena Meeting, we were in debt $370.22. We now show a balance of $77.66 to the good.

Today there is in the bank account of the Conference a total of $427.66. Of this, however, $350.00 is ear-marked for Dr. CHURCH, to repay a loan made by him to the Conference a few years ago. Dr. CHURCH, in his usual magnanimous manner, has requested that the Conference temporarily retain this money, delaying payment to him until we are sure that we have surmounted our financial difficulties. It is hoped that by restricting the amount of matter to be published in the 1943 Transactions, and a diplomatic appeal to our annual subscribers, we may make our 1943

operations stand on their own feet, and when we do, we can probably then persuade Dr. CHURCH to receive back the money he so generously loaned the Conference.

Change of name--It has been proposed to change the name of this organization from the Western Interstate Snow-Survey Conference to the shorter, more convenient form of Western Snow-Conference. Fourteen members of the Executive Committee have replied to a poll recently submitted to them on this question. The fourteen were unanimously in favor of having the name changed to the shorter form. Although reference to our organization by the longer term is contained in the By-Laws, no statement appears that the Conference definitely shall be known by this name. Curb-stone legal talent is of the opinion that, because of this, it will not be necessary to go to the membership to obtain formal permission from them to change the name. It would be appreciated, however, if this desire for the short name expressed by the Committee could be approved by the members at the Corvallis Meeting, and if so approved, the name Western Snow-Conference will automatically be adopted as the current name for our organization.

Corvallis Meeting--When the holding of the Corvallis Meeting was suggested, a poll was made of the members of the Executive Committee to determine how they felt about it. The vote of the Executive Committee showed a majority favoring the meeting. Mr. WORK, Chairman of the Executive Committee of the North Pacific Area, was thereupon notified to work along with Mr. STEVENS of the American Geophysical Union and MURRAY LUCK of the American Association for the Advancement of Science to arrange the meeting at Corvallis. Early in June, Mr. LUCK advised us that, due to reasons beyond his control, the American Association for the Advancement of Science could not participate in the meeting. Plans for the meeting had by that time progressed to such a stage that the Section of Hydrology of the American Geophysical Union and the Snow-Conference felt that it was best to proceed with the meeting despite the unexpected withdrawal of the American Association for the Advancement of Science.

Comments by the Chairman--Your Chairman regrets that he has not found it possible to attend the Corvallis Meeting, and that he can not be with you tonight. However, he shares with you your continuing interest in the problems of snow.

FRED PAGET, Chairman
Executive Committee

APPENDIX B--REPORT OF TREASURER OF WESTERN SNOW-CONFERENCE

June 10, 1943

The last examination of the Treasurer's accounts was made on January 15, 1942. Audited and found correct by VERNON GIVAN and JERRY CHRISTIANSEN, the status of the finances at that time was:

Assets			
Bank balance		$155.87	
Accounts receivable			
Utah Experiment Station	$25.00		
United States Weather Bureau	75.00	100.00	$255.87
Liabilities			
Owing to Dr. J. E. Church		$422.46	
Owing to American Geophysical Union		203.63	626.09
Amount in debt			$370.22

Today our financial condition is better. The Balance Sheet shows:

Assets		
Bank balance as of June 10, 1943	$427.66	
Liabilities		
Owing to Dr. J. E. Church	350.00	
Unencumbered balance		$ 77.66

Receipts and disbursements since January 15, 1942, have been as follows: