SR 120

Special Report 120
EFFECTS OF A 20-TON TNT EXPLOSION ON A SNOW COVER

by
Roy E. Bates and James R. Hicks

APRIL 1968

Conducted for
DEFENSE ATOMIC SUPPORT AGENCY
by
U.S. ARMY MATERIEL COMMAND
COLD REGIONS RESEARCH & ENGINEERING LABORATORY
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PREFACE

This study is part of U.S. Army Cold Regions Research and Engineering Laboratory (USA CRREL) requirements for the Operation Distant Plain Project. It was conducted by Mr. Roy E. Bates and Mr. James R. Hicks, Research Division, for the Defense Atomic Support Agency (DASA). The study is DA Task IIIe under DA Project Snow and Frozen Soil Phenomenology.

The authors thank Mr. Michael A. Bilello and Mr. North Smith of USA CRREL for their constructive reviews. Logistic support was furnished by Suffield Experiment Station (SES). Photography was provided by the Photographic Interpretation Research Division (PIRD), USA CRREL.

USA CRREL is an Army Materiel Command laboratory.

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SUMMARY

The effects of a 20-ton surface burst explosion on the physical properties of drifted snow were measured. Density of the snow cover increased an average of 17%. Snow hardness decreased an average of 3%. Topographic surveys showed that snowdrift heights decreased through compaction resulting from ground shock and airblast. The results are for drifted snow accumulated around a drift fence. Different results might occur in a naturally accumulated snow cover.

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Introduction

This study concerns the physical properties of the snow cover before and after a 20-ton TNT surface burst explosion, and airblast surface erosion caused by the explosion (Event 5 of Operation Distant Plain, at Suffield Experiment Station, Alberta, Canada).

Records of the amount of snow on the ground from November through March at Suffield, Alberta, Canada, over the past 10 years* showed that snow accumulation in this area was light (Table I). Therefore, thirteen sections of 5-slat metal snow fence were installed on 1 November 1966 (Fig. 1) to accumulate snowdrifts at the test site. The row of snow fences started 150 ft from ground zero and extended northeast to approximately 330 ft from ground zero. The fences faced the prevailing storm wind direction (southeast) for maximum snow accumulation.

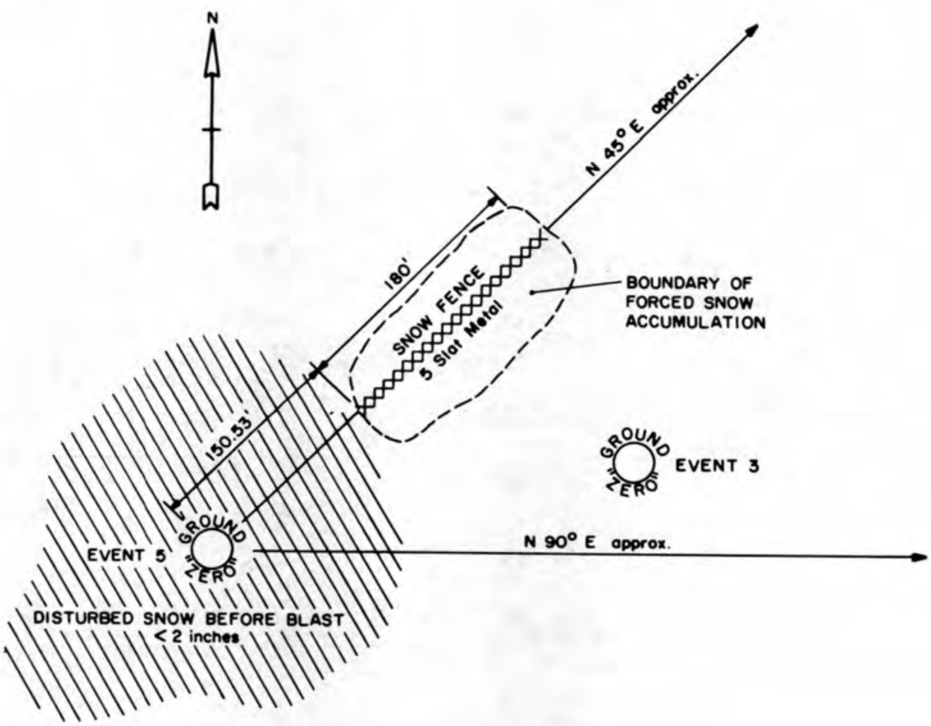

Figure 1. Layout, Event 5, Suffield experimental test site.

* Department of Transport, Canada, Monthly Meteorological Observations.

Table I. Snow on ground at end of month (in.), Suffield, Alberta, 10-year record.

Winter season	November	December	January	February	March
1957-58	Missing	T*	2	2	0
1958-59	7	T	5	4	0
1959-60	0	T	1	4	0
1960-61	2	5	1	T	0
1961-62	2	2	0	2	0
1962-63	0	2	5	T	0
1963-64	0	T	2	0	1
1964-65	4	14	8	1	0
1965-66	9	2	12	9	0
1966-67	1	1	2	4	Missing

* T = trace.

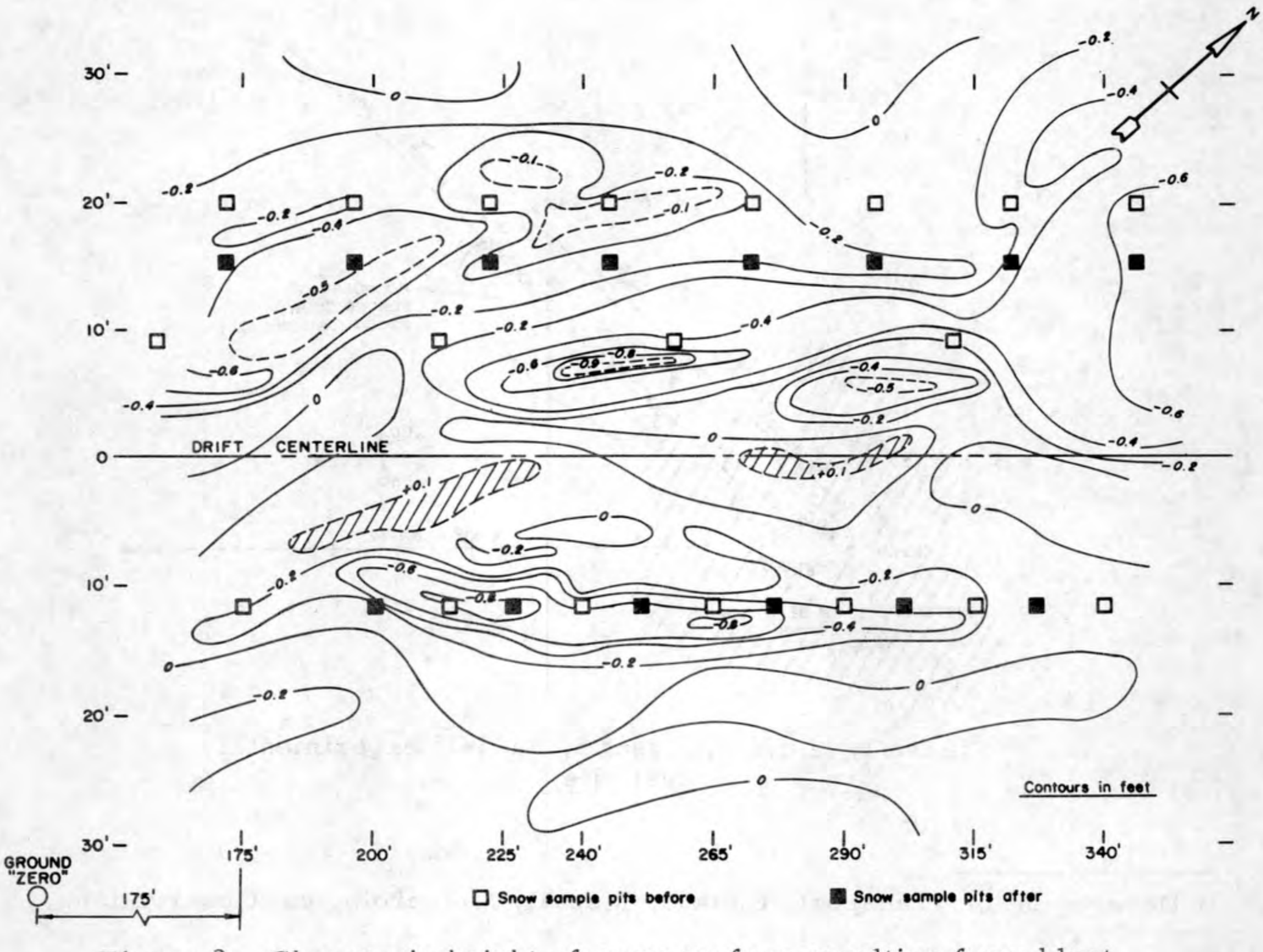

Figure 2. Changes in height of snow surface resulting from blast.

Comparisons were made of snow properties (particularly snow density in g/cm^3 and snow hardness in g/cm^2) measured before and after the event. The measurements were made using the USA CRREL Snow Density Kit in accordance with USA CRREL Instruction Manual 1.* Pre- and post-shot snow topography was surveyed and a contour map (Fig. 2) was drawn showing changes in snow elevations in the accumulated drift after the explosion. Also, snow erosion by airblast and crater debris in the snow were observed.

Climate data

Weather data recorded at Suffield Experimental Station, Ralston, Alberta, approximately 30 miles from the test site are presented in Appendix B. The climatic data recorded prior to Event 5 were studied to determine its influence on the age-hardening process of the snow accumulated in the drift.

These data show that less than 5 in. (13 cm) of snow was on the ground before the snowstorm of 4-5 January 1967. Most of the snowfall that occurred before this storm was either blown away by strong winds or melted and refrozen as an ice layer. The snowstorm of 4-5 January 1967 deposited 7 in. (18 cm) of snow having a water equivalent of 0.85 in. The prevailing wind during this storm was easterly; the mean hourly wind speed was 14.9 mph and the peak gust was 28 mph. The climatic records further indicate that most of the snow in the drift at the time of the blast (9 February) was accumulated from this storm by the high winds which occurred through 12 January 1967. The snow surface thawed and refroze daily between 10 and 13 January and 2 and 9 February 1967. The result was the formation of an upper layer of snow greater than 3 in. (8 cm) deep which was harder and denser than layers deeper in the accumulated drift. Ice lenses within the drift also indicated that some surface melting occurred earlier in the snow season.

Measurements prior to blast

Snow property measurements were made on 7-8 February in the fence-accumulated drifts in accordance with USA CRREL Instruction Manual 1. Twenty-one snow profiles were taken before the explosion on 7-8 February 1967 (see Figure 2 for location of pits). The maximum depth of the drifts was 78 cm.

Each snow profile consisted of the following measurements for each layer: temperature, hardness, and crystal classification and thickness. Air temperature, cloud cover and general surface condition of the snow were also noted.

Twenty-one snow profile studies were made, eight on the lee (northwest) side of the drift fence, seven in the windward drift and four at the crest of the lee drift after the fence was removed. Two snow profile studies were made at undisturbed sites or areas not influenced by the drift fences. The snow varied from 5 to 20 cm deep in the vicinity of these undisturbed sites which had grass stubble protruding above the surface crust layer. A snow topographic survey was made of the drift area before the blast. Figures 3 and 4 are photos taken prior to the blast. Three layers of snow with 1 to 3 cm of hard crust or ice between layers can be distinguished in Figure 3. Also, there was approximately 3 cm of snow over an ice layer in a 7-ft-wide wind-swept area between the leeward and windward drifts (Fig. 4).

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* U.S. Army Cold Regions Research and Engineering Laboratory (1962) Instructions for making and recording snow observations, Instruction Manual 1.

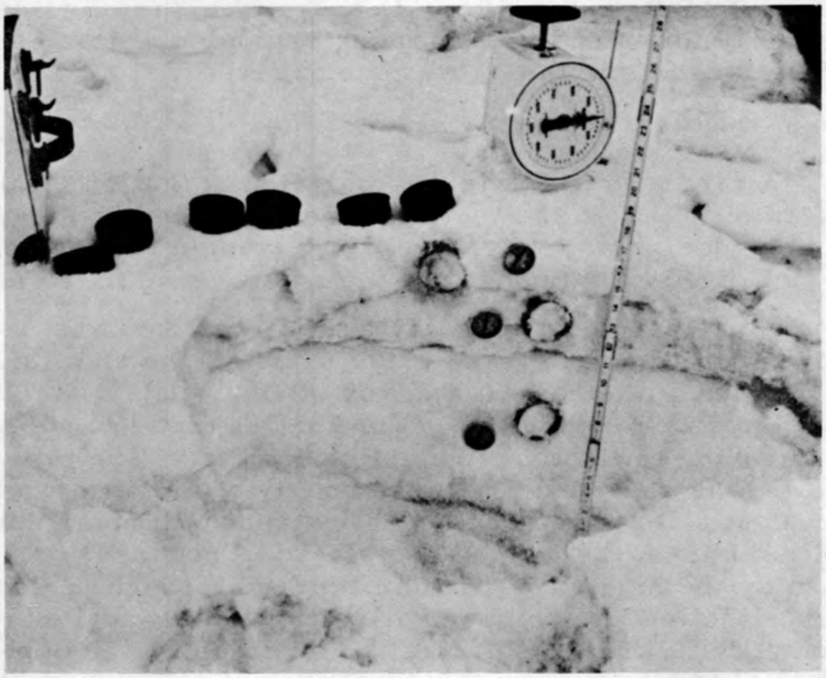

Figure 3. Snow observation before explosion.

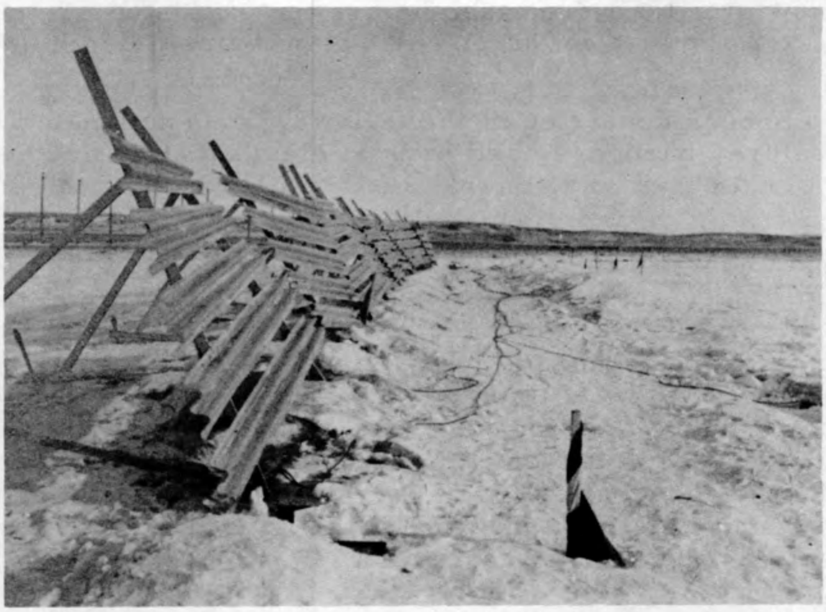

Figure 4. Drift fence and snow accumulation before explosion.

Measurements after blast

Immediately after the blast, 16 new snow profile studies were made as near as possible to the same locations studied before the explosion (see Fig. 2 for location of pits). The snow in the windward drift, in the portion nearest to ground zero, was partly blown or melted away by the blast. The little snow remaining at this site was full of mud and water and no representative observation was possible. A post-shot snow topographic survey was made of the drift area and the changes in surface elevation due to the explosion are compared in Figure 2. Figures 5 - 9 show surface conditions and debris in the snow after the explosion.

Figure 5. Drift fence area after explosion.

Figure 6. Drift fence area after explosion.

Figure 7. Snow surface after explosion.

Figure 8. Snow surface after explosion.

Figure 9. Snow surface after explosion.

Analysis

Density and hardness were the only snow properties with measurable changes throughout the layers (Appendix A). Weighted mean density values for the entire layer of snow and the geometric mean of the hardness measurements were used in this study. These values gave the best correlation with age-hardening of seasonal snow cover. *

The weighted mean density for each observation was computed as shown in Table II.

Table II. Example of weighted mean density computation (for snow shown in Figure 3).

	Thickness of layer (cm)	% of total depth	Observed snow density (g/cm^3)	Weighted snow density (g/cm^3)
Layer 1 bottom	20	50	.260	.130
Layer 2	8	20	.364	.073
Layer 3	12	30	.294	.088
Total	40	100%		0.291(g/cm^3) Weighted mean

* Bilello, M.A. (1957) A survey of Arctic snow cover properties as related to climatic conditions, U.S. Army Snow, Ice and Permafrost Research Establishment Research Report 39.

The geometric mean of snow cover hardness for each observation was computed to reduce the effect of extreme values:

$$\sqrt{(\text{Maximum hardness})(\text{Minimum hardness})} = \text{Geometric mean.}$$

Weighted mean density and geometric mean hardness were plotted for the windward and leeward drifts against distance from ground zero (Fig. 10, 11). Before the explosion, the leeward drift densities averaged lower than those of the windward drift (Fig. 10). Probably the drifting snow filtering through the fence was not compacted by wind action as much as the snow deposited on the windward side of the fence. This would explain the larger increase in the weighted densities in the leeward drift from airblast compaction (Fig. 10). Larger increases in density persisted to a greater distance from the blast crater in the leeward drift than in the windward drift.

When all weighted density measurements (Appendix A) for both drifts are considered, results show an average weighted density increase of 17% due to the explosion.

The geometric mean snow hardness values for the entire layer show no definite trends when plotted against distance (Fig. 11). This inconsistency can be attributed to the difficulty of accurately measuring the hardness value and poor statistical sampling. The percentage increase or decrease of hardness at each site after the explosion was computed and results (Appendix A) show a decrease of 3%.

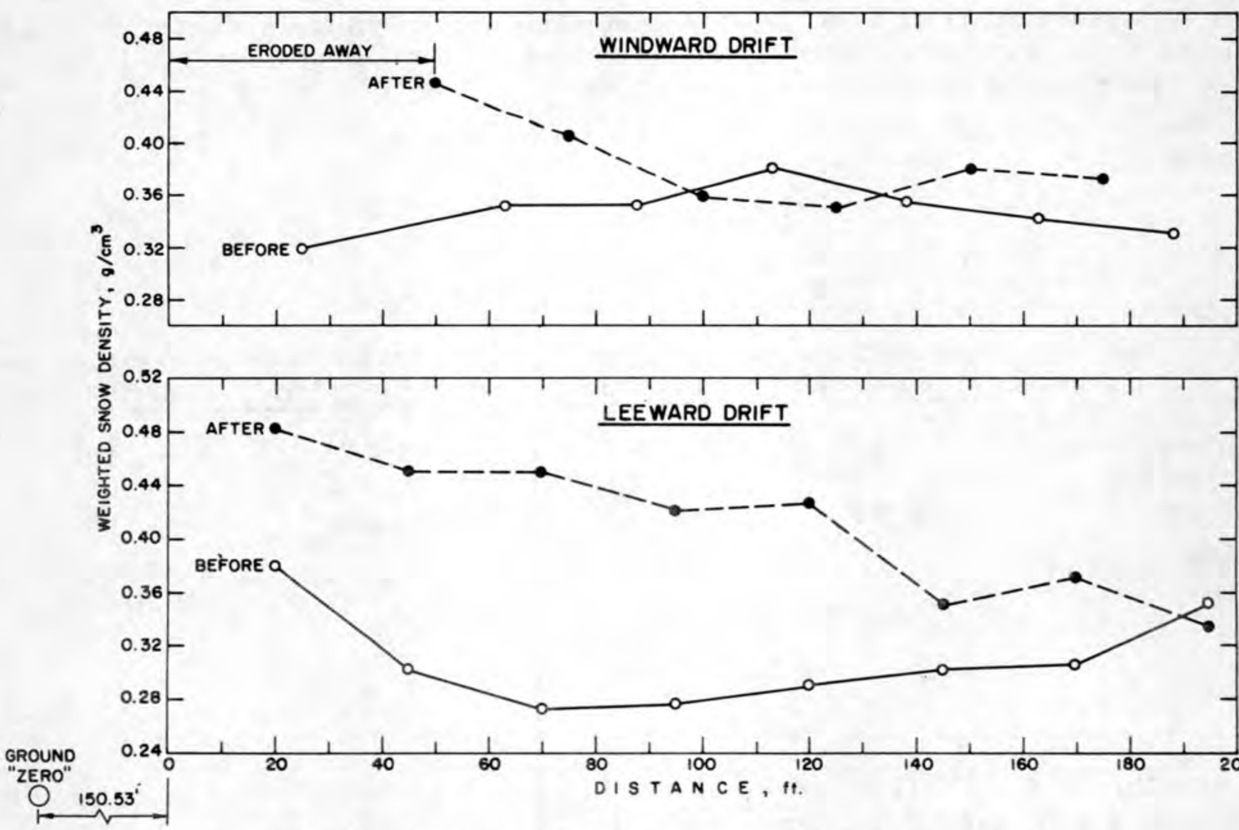

Figure 10. Changes in density resulting from blast.

The top and bottom snow layers in the drifts were separately analyzed for changes in density and hardness due to the explosion (see Tables AII, AII, Appendix A for data). The results show the average hardness value decreased in the top snow layer and increased in the bottom layer. Both layers had hardness changes which reached a magnitude of 55%.

Data (Tables AII, AIII) show that the upper layer had the higher average hardness value before the shot. This harder layer is identified as the middle layer in Figure 3, but was generally the top layer throughout both drifts. The explosion and the resultant ground shock apparently lifted, fractured, and vibrated the snow into a denser but unbonded snow mass (Fig. 5 - 9). After the explosion, the Canadian hardness gage was inserted into this disaggregated snow with much less resistance.

The average snow density of the entire snow pack increased due to the blast effects with greater increases occurring with depth in the pack due to less dense snow in the bottom layer.

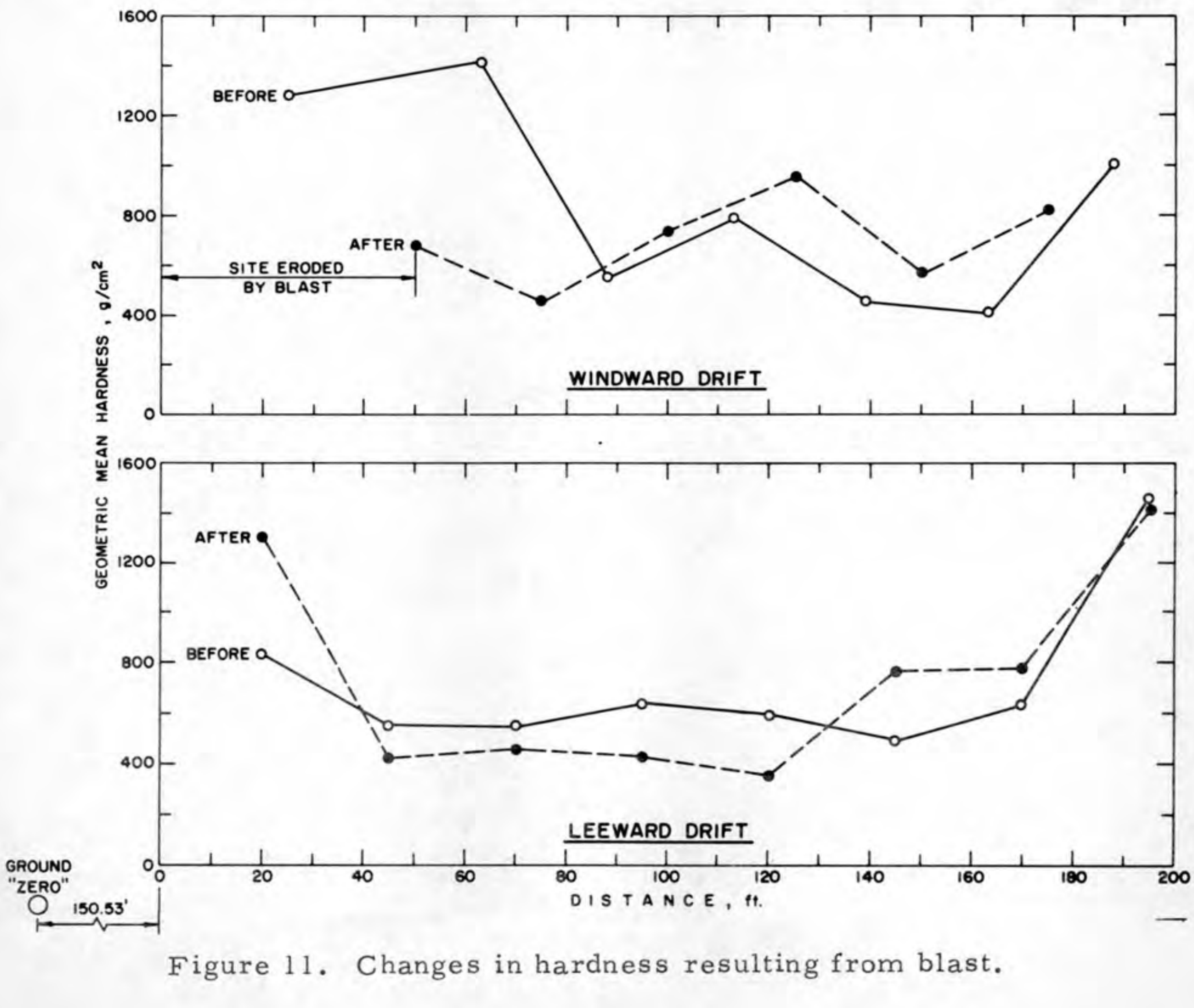

Figure 11. Changes in hardness resulting from blast.

Crater debris penetrated the surface of the snow drifts (8 to 20 cm) in obviously greater amounts at locations nearer ground zero (Fig. 4 - 6). The camera position for these photographs was approximately 150 ft northeast of ground zero facing northeast along the length of the accumulated snow drifts.

Two observation pits were dug in undisturbed snow approximately 400 and 600 ft from ground zero (Appendix A). Slight changes in density and hardness were noted in these pits after the explosion. The snow depth at these two sites was approximately 20 cm with a crusty-ice surface layer 3 cm thick. After the explosion this crusty-ice layer was cracked but intact and lightly covered with ejecta. Similar conditions were noted over most of the non-drift areas surrounding the explosion.

Snow topography

The elevations of the snow surface before and after the blast were surveyed by personnel of the Suffield Experiment Station. The changes in elevation after the blast are presented in contour form in Figure 2. Generally, the elevation decreased due to compaction of the snow from ground shock and air-blast effects. However, two areas near the centerline, where only thin layers of ice were present, showed increases in height. This probably resulted from rearrangement of the soil mass by ground shock.

APPENDIX A: SNOW PROPERTY MEASUREMENTS

Table AI. Entire layer analyses.

Data	0' + 20 ft*		0' + 45 ft		0' + 70 ft	
Date	Pre-shot 7 Feb 67	Post-shot 9 Feb 67	Pre-shot 7 Feb 67	Post-shot 9 Feb 67	Pre-shot 7 Feb 67	Post-shot 9 Feb 67
Measurements at rear of drift fence (leeward)						
Air Temperature	+0.5°C	+3.5°C	-0.5°C	+1.0°C	+1.0°C	+2.0°C
Snow Depth	38 cm	39 cm	56 cm	55 cm	42 cm	38 cm
Crystal Classification	Dd-Wa	Db-Wa-Wc†	Dd-Wa	Db-Wa-Wc	Dd-Wa	Db-Wa-Wc
Weighted Density	.338 g/cm^3	.484 g/cm^3	.303 g/cm^3	.451 g/cm^3	.273 g/cm^3	.452 g/cm^3
Weighted Temperature	-3.5°C	-1.2°C	-4.7°C	-1.5°C	-3.2°C	-1.2°C
Geometric Mean Hardness	837 g/cm^2	1300 g/cm^2	548 g/cm^2	418 g/cm^2	548 g/cm^2	458 g/cm^2
Temperature Gradient Through Snow	.02°C/cm	.14°C/cm	.03°C/cm	.09°C/cm	.04°C/cm	.10°C/cm
Density Change**	0.146 g/cm^3 or 30%		0.148 g/cm^3 or 33%		0.179 g/cm^3 or 40%	
Hardness Change**	463 g/cm^2 or 36%		-130 g/cm^2 or -24%		-90 g/cm^2 or -16%	
	0' + 95 ft		**0' + 120 ft**		**0' + 145 ft**	
Air Temperature	+1.0°C	+1.5°C	+1.5°C	+1.0°C	0°C	0°C
Snow Depth	43 cm	37 cm	40 cm	42 cm	48 cm	42 cm
Crystal Classification	Dd-Wa	Db-Wa-Wc	Dd-Wa	Db-Wa-Wd	Db-Wa	Db-Wa-Wc
Weighted Density	.276 g/cm^3	.420 g/cm^3	.291 g/cm^3	.426 g/cm^3	.301 g/cm^3	.352 g/cm^3
Weighted Temperature	-4.1°C	-2.0°C	-4.4°C	-2.3°C	-5.2°C	-1.9°C
Geometric Mean Hardness	633 g/cm^2	424 g/cm^2	592 g/cm^2	346 g/cm^2	490 g/cm^2	775 g/cm^2
Temperature Gradient Through Snow	.12°C/cm	.06°C/cm	.02°C/cm	.08°C/cm	.06°C/cm	.12°C/cm
Density Change	0.144 g/cm^3 or 34%		0.135 g/cm^3 or 32%		0.051 g/cm^3 or 14%	
Hardness Change	-209 g/cm^2 or -33%		-246 g/cm^2 or -42%		285 g/cm^2 or 37%	
	0' + 170 ft		**0' + 195 ft**			
Air Temperature	0°C	+1.0°C	0°C	+1.0°C		
Snow Depth	41 cm	32 cm	28 cm	26 cm		
Crystal Classification	Db-Wa	Db-Wa-Wc	Db-Wa	Db-Wa-Wc		
Weighted Density	.307 g/cm^3	.372 g/cm^3	.357 g/cm^3	.335 g/cm^3		
Weighted Temperature	-4.5°C	-2.0°C	-4.1°C	-2.3°C		
Geometric Mean Hardness	633 g/cm^2	775 g/cm^2	1449 g/cm^2	1414 g/cm^2		
Temperature Gradient Through Snow	.11°C/cm	.27°C/cm	.13°C/cm	.13°C/cm		
Density Change	0.065 g/cm^3 or 17%		-0.022 g/cm^3 or -6%			
Hardness Change	142 g/cm^2 or 18%		-35 g/cm^2 or -2%			

Data	0' + 25 ft		0' + 63 ft	0' + 50 ft††	0' + 88 ft	0' + 75 ft
Date	Pre-shot 8 Feb 67	Post-shot 9 Feb 67	Pre-shot 8 Feb 67	Post-shot 9 Feb 67	Pre-shot 8 Feb 67	Post-shot 9 Feb 67
Measurements made at crest of front drift (windward)						
Air Temperature	-1.5°C	Site too eroded by blast for any suitable measurement	-1.0°C	0°C	-0.5°C	-0.5°C
Snow Depth	42 cm		50 cm	39 cm	62 cm	44 cm
Crystal Classification	Db-Wa		Db-Wa	Db-Wa-Wc	Db-Wa	Db-Wa Bottom Dd-Wc Top
Weighted Density	.319 g/cm^3		.352 g/cm^3	.445 g/cm^3	.352 g/cm^3	.409 g/cm^3
Weighted Temperature	-5.8°C		-5.4°C	-1.8°C	-6.2°C	-3.0°C
Geometric Mean Hardness	1283 g/cm^2		1449 g/cm^2	671 g/cm^2	548 g/cm^2	458 g/cm^2
Temperature Gradient Through Snow	-.07°C/cm		-.11°C/cm	.10°C/cm	-.01°C/cm	.09°C/cm
Density Change	N/A		0.093 g/cm^3 or 21%		0.057 g/cm^3 or 14%	
Hardness Change	N/A		-778 g/cm^2 or -54%		-90 g/cm^2 or -16%	
	0' + 113 ft	**0' + 100 ft**	**0' + 138 ft**	**0' + 125 ft**	**0' + 163 ft**	**0' + 150 ft**
Air Temperature	+1.0°C	+0.5°C	+0.5°C	-0.5°C	+1.0°C	0°C
Snow Depth	78 cm	47 cm	67 cm	52 cm	69 cm	43 cm
Crystal Classification	Db-Wa	Db-Wa-Wc	Db-Wa-We	Db-Wa	Db-Wa-Wc	Db-Wa-Wc
Weighted Density	.380 g/cm^3	.358 g/cm^3	.355 g/cm^3	.351 g/cm^3	.342 g/cm^3	.379 g/cm^3
Weighted Temperature	-5.7°C	-1.7°C	-5.9°C	-2.8°C	-6.4°C	-2.5°C
Geometric Mean Hardness	775 g/cm^2	725 g/cm^2	447 g/cm^2	949 g/cm^2	400 g/cm^2	566 g/cm^2
Temperature Gradient Through Snow	.01°C/cm	.03°C/cm	.04°C/cm	.05°C/cm	.03°C/cm	.09°C/cm
Density Change	-0.022 g/cm^3 or -6%		-0.004 g/cm^3 or -1%		0.037 g/cm^3 or 10%	
Hardness Change	-50 g/cm^2 or -6%		502 g/cm^2 or 53%		166 g/cm^2 or 29%	

* 0' is 150.53 ft from ground 0, N 45° E.

† Under Crystal Classification when Wc, Wd or We appear they define moisture in top layer, see USA CRREL Instruction Manual I.

** Positive increase unless noted by minus sign.

†† Post-shot data taken within 13 ft of pre-shot data.

Table AI (Cont'd). Entire layer analyses.

Data Date	0' + 188 ft Pre-shot 8 Feb 67	0' + 175 ft Post-shot 9 Feb 67	0' + 200 ft then 65 ft NW* Pre-shot 7 Feb 67	 Post-shot 9 Feb 67	0' + 500 ft then 100 ft SE* Pre-shot 7 Feb 67	 Post-shot 9 Feb 67
Measurements made at crest of front drift (windward) (Cont'd)						
Air Temperature	+0.5°C	0°C	0°C	0°C	-1.0°C	-0.5°C
Snow Depth	41 cm	36 cm	19 cm	20 cm	22 cm	23 cm
Crystal Classification	Db-Wa	Db-Wa-Wc	Db-Wa	Dd-Wa	Db-Wa	Dd-Wa
Weighted Density	.331 g/cm³	.370 g/cm³	.296 g/cm³	.292 g/cm³	.292 g/cm³	.336 g/cm³
Weighted Temperature	-6.4°C	-3.0°C	-2.5°C	-1.5°C	-2.5°C	-1.0°C
Geometric Mean Hardness	1000 g/cm²	821 g/cm²	80 g/cm²	150 g/cm²	120 g/cm²	150 g/cm²
Temperature Gradient Through Snow	.09°C/cm	.11°C/cm	N/A 1 layer	N/A 1 layer	N/A 1 layer	N/A 1 layer
Density Change	0.039 g/cm³ or 11%		-0.004 g/cm³ or -1%		0.044 g/cm³ or 13%	
Hardness Change	-179 g/cm² or -18%		70 g/cm² or 47%		30 g/cm² or 20%	

Data Date	0' + 9½ ft Pre-shot 8 Feb 67	0' + 59½ ft Pre-shot 8 Feb 67	0' + 109½ ft Pre-shot 8 Feb 67	0' + 159½ ft Pre-shot 8 Feb 67
Measurements made at crest of rear drift (leeward) after snow fences were removed				
Air Temperature	3.0°C	3.0°C	3.0°C	3.0°C
Snow Depth	50 cm	46 cm	55 cm	52 cm
Crystal Classification	Db-Wa	Db-Wa	Db-Wa	Db-Wa
Weighted Density	.344 g/cm³	.339 g/cm³	.336 g/cm³	.363 g/cm³
Weighted Temperature	-3.5°C	-4.2°C	-3.7°C	-4.9°C
Geometric Mean Hardness	866 g/cm²	548 g/cm²	561 g/cm²	1024 g/cm²
Temperature Gradient Through Snow	.13°C/cm	.03°C/cm	.07°C/cm	.09°C/cm

Summary of changes pre-shot vs post-shot

Rear of drift fence (leeward)

Site	Density % ±	Hardness % ±
0' + 20 ft	30	36
0' + 45	33	-24
0' + 70	40	-16
0' + 95	34	-33
0' + 120	32	-42
0' + 145	14	37
0' + 170	17	18
0' + 195	- 6	- 2
AVG =	24.2%	- 3.3%

Front of drift fence (windward)†

Site	Density % ±	Hardness % ±
0' + 25 ft	Eroded by blast	
0' + 63	21	-54
0' + 88	14	-16
0' + 113	- 6	- 6
0' + 138	- 1	53
0' + 163	10	29
0' + 188	11	-18
	8.1%	- 2.0%

1. Average density increase for entire drift area = 17.4%
2. Average hardness decrease for entire drift area = -2.7%

* Undisturbed snow not under influence of drift fence.
† Post-shot measurement made 13 ft less than pre-shot measurements in windward drift.

Table AII. Top snow layer analyses.

Pre-shot			Post-shot			Percentage change	
Site	Density g/cm³	Hardness g/cm²	Site	Density g/cm³	Hardness g/cm²	Density % ±	Hardness % ±
Drift rear of fence leeward			Drift rear of fence leeward				
0' + 20 ft	.410	7000	0' + 20 ft	.488	2000	16	-71
0' + 45	.312	3000	0' + 45	.448	700	30	-77
0' + 70	.322	3000	0' + 70	.432	700	25	-77
0' + 95	.356	2000	0' + 95	.444	600	20	-70
0' + 120	.294	3500	0' + 120	.476	400	38	-89
0' + 145	.402	3000	0' + 145	.392	2000	- 2	-33
0' + 170	.344	4000	0' + 170	.404	1500	15	-62
0' + 195	.357	6000	0' + 195	.356	5000	0	-17
Snow depth varied (8-13 cm)			Snow depth varied (11-20 cm)		AVG	17.8%	-62.0%
Drift front of fence windward			Drift front of fence windward				
0' + 25 ft	.388	5500	0' + 25 ft		---Eroded---		
0' + 63	.372	3000	0' + 50	.464	1500	20	-50
0' + 88	.392	3000	0' + 75	.396	700	1	-77
0' + 113	.342	2000	0' + 100	.364	1500	6	-25
0' + 138	.344	2000	0' + 125	.328	2000	- 5	0
0' + 163	.320	2000	0' + 150	.368	800	13	-60
0' + 188	.372	2500	0' + 175	.364	900	-2	-64
Snow depth varied (6-8 cm)			Snow depth varied (8-23 cm)		AVG =	5.5%	-46.0%

1. Average density increase for top layer = 12.5%
2. Average hardness decrease for top layer = -55.1%

Table AIII. Bottom snow layer analyses.

Pre-shot			Post-shot			Percentage change	
Site	Density g/cm³	Hardness g/cm²	Site	Density g/cm³	Hardness g/cm²	Density % ±	Hardness % ±
Drift rear of fence leeward			Drift rear of fence leeward				
0' + 20 ft	.278	200	0' + 20 ft	.480	600	42	67
0' + 45	.262	100	0' + 45	.452	250	42	60
0' + 70	.254	100	0' + 70	.440	600	42	83
0' + 95	.264	100	0' + 95	.396	300	33	67
0' + 120	.260	100	0' + 120	.376	300	31	67
0' + 145	.260	80	0' + 145	.352	300	26	73
0' + 170	.264	100	0' + 170	.340	400	22	75
0' + 195	.288	350	0' + 195	.316	400	9	12
Snow depth varied (10-27 cm)			Snow depth varied (13-20 cm)		AVG =	30.8%	63.0%
Drift front of fence windward			Drift front of fence windward				
0' + 25 ft	.296	300	0' + 25 ft		---Eroded---		
0' + 63	.340	700	0' + 50	.428	600	21	-14
0' + 88	.316	100	0' + 75	.424	300	25	67
0' + 113	.392	300	0' + 100	.364	350	- 7	14
0' + 138	.376	100	0' + 125	.360	450	- 4	78
0' + 163	.284	80	0' + 150	.436	400	35	80
0' + 188	.304	400	0' + 175	.376	750	19	47
Snow depth varied (6-28 cm)			Snow depth varied (8-20 cm)		AVG =	14.9%	45.3%

1. Average density increase for bottom layer = 24.0%
2. Average hardness increase for bottom layer = 55.4%

APPENDIX B: WEATHER DATA FOR SUFFIELD EXPERIMENTAL STATION, RALSTON, ALBERTA

Date	Temp Max (F)	Temp Min (F)	40' Wind Mean Hr speed (mph)	40' Wind Max Hr vel (mph)	Rain (in.)	Precipitation Snow (in.)	Precipitation Total (in.)	Snow on ground (in.)
			November 1 - 15, 1966					
1	42.7	13.4	14.5	S 25				
2	47.7	30.6	9.2	N 24				
3	43.2	23.3	9.5	NW 17				
4	39.9	15.3	9.2	S 15				
5	41.3	25.5	13.9	N 24		.18	.18	
6	36.2	4.4	8.1	N 15		.20	.20	
7	12.9	- 5.3	5.6	NE 9		T	T	
8	16.2	- 4.1	10.7	S 23		T	T	
9	36.7	5.3	13.3	S 20				
10	33.4	6.1	12.3	N 19				
11	21.3	4.6	8.7	W 14				
12	41.3	5.9	17.9	W 35				
13	37.8	7.1	9.0	E 17				
14	33.1	21.0	7.3	E/NW 10				
15	31.1	16.7	7.0	NE 12				
			November 16 - 30, 1966					
16	16.4	12.5	10.5	NE 16		5.1	.58	5
17	8.0	- 7.0	6.3	SE 10		1.5	.19	6
18	41.9	- 7.8	14.5	S 24				3
19	37.3	9.7	12.9	S 23				3
20	44.8	13.6	14.3	N 20				2
21	23.9	20.3	9.4	N 16	T	1.7	.20	3
22	13.3	2.8	8.5	N/NW 15		T	T	3
23	37.1	- 0.3	9.9	S 13				3
24	40.0	17.1	15.0	N 32				2
25	37.4	32.1	17.5	SW 35				1
26	35.1	20.0	11.1	W 17	.01	.1	.02	1
27	37.4	20.8	14.1	SW 27				1
28	41.3	9.8	16.9	NW 25				1
29	- 0.8	- 2.0	12.7	NW 26		T	T	1
30	5.0	- 1.7	6.5	NW/W 9		T	T	1
			December 1 - 15, 1966					
1	9.5	- 8.2	6.7	E 12	0	0	0	1
2	23.1	- 5.5	12.8	S 21	0	0	0	1
3	22.0	5.3	13.2	NW 23	0	2.5	.27	1
4	5.6	- 3.3	7.8	E 14	0	0	0	2
5	34.6	- 3.3	17.3	N/NW 27	0	T	T	2
6	2.0	-11.0	8.6	E 15	0	0	0	2
7	- 2.6	-13.7	9.8	NW 14	0	.1	.01	2
8	- 4.0	-17.1	7.3	NW 11	0	.1	.01	2
9	- 4.3	-17.0	9.0	E 13	0	0	0	2
10	32.1	-16.1	12.3	S 16	0	0	0	2
11	37.5	- 7.0	10.0	S/SW 18	0	0	0	2
12	41.8	32.1	15.5	SW 26	0	0	0	1
13	43.0	27.5	14.8	SW 23	0	0	0	1
14	41.2	31.1	11.5	SW 18	.03	0	.03	1
15	44.4	26.2	14.4	SW 25	0	0	0	1
			December 16 - 31, 1966					
16	45.1	37.4	17.0	W 26				T
17	41.2	29.1	9.1	SW 12				T
18	49.9	30.0	15.5	SW/W 30				T
19	42.3	28.2	10.4	SW/W 16				T
20	42.1	32.6	8.2	W 21				T
21	34.0	24.9	6.5	E 10		T	T	T
22	30.7	21.2	11.0	S 18		.6	.06	1
23	27.8	8.0	9.0	E/SE 13				1
24	32.2	9.8	11.2	SW 18				1
25	20.9	5.9	4.7	E 8				1
26	20.9	5.0	4.2	NW 8				1
27	27.9	17.4	7.3	S 13				1
28	29.8	7.2	10.0	W 15		T	T	1
29	32.6	14.7	12.9	NW 20		.4	.04	1
30	29.7	9.4	8.8	NW 20		T	T	1
31	34.0	14.3	15.6	NW 28				1

APPENDIX B

Date	Temp Max (F)	Temp Min (F)	40' Wind Mean Hr speed (mph)	40' Wind Max Hr vel (mph)	Precipitation Rain (in.)	Precipitation Snow (in.)	Precipitation Total (in.)	Snow on ground (in.)
			January 1 - 15, 1967					
1	37.4	13.6	12.9	W 18				1
2	27.1	11.8	10.0	W/SW 14				1
3	37.3	12.1	13.0	W 32				1
4	27.3	8.1	12.8	E 29		T	T	1
5	17.7	- 4.8	14.9	E 28		7.0	.85	7
6	- 4.1	-22.9	4.7	SE 10		.5	.06	7
7	18.6	-21.6	13.4	W 24				7
8	35.4	19.1	19.5	W 36				6
9	24.4	5.1	9.3	W/SE/E 12				5
10	44.1	11.5	17.5	W 38				5
11	42.5	33.1	15.1	W 35	T	.3	.03	2
12	34.9	26.8	16.0	SW 29				1
13	32.3	16.4	9.3	NW 19		.3	.03	1
14	17.0	2.1	8.4	E 12				1
15	40.8	6.3	16.5	N 31				1
			January 16 - 31, 1967					
16	9.0	- 9.2	10.5	NW 19		1.4	.14	2
17	0.4	-26.4	11.4	S 21		.4	.04	2
18	8.1	- 3.7	11.5	E 18		T	T	2
19	27.3	- 2.3	19.0	SW 44		.2	.02	2
20	40.1	2.6	14.6	SW 41		T	T	2
21	28.6	- 7.0	5.6	NW 9		T	T	2
22	0.9	- 9.0	7.7	NW 12		.1	.01	2
23	- 4.5	-20.2	8.3	E 12				2
24	- 6.6	-18.1	7.6	NW 12				2
25	- 6.7	-21.6	6.7	SE 14				2
26	19.0	-14.2	12.0	S 22				2
27	5.2	-10.2	4.9	E 8				2
28	10.3	- 2.8	6.3	NW 13	T	.2	.02	2
29	21.2	- 2.9	11.3	SW 22	T		T	2
30	36.4	7.1	14.7	NW 25	T	.3	.03	2
31	16.1	0.1	8.1	E 12				2
			February 1 - 15, 1967					
1	25.4	- 8.0	13.7	W 24				2
2	40.1	20.1	23.3	W 39				2
3	41.2	32.6	16.2	W 43	.06	.5	.11	2
4	39.3	8.7	11.0	N 30				2
5	39.3	6.9	8.0	W 11		.5	.04	2
6	34.2	15.2	16.0	N 29	.01	.1	.02	2
7	35.8	12.2	11.0	SW 19		T	T	2
8	42.9	22.9	13.8	W 29				2
9	41.0	19.2	8.2	W 13				2
10	33.8	18.8	9.4	N 17		T	T	2
11	37.5	- 1.0	10.3	SE 16		.5	.05	2
12	42.3	9.5	20.1	W 30				2
13	38.3	11.0	13.8	NE 26		3.2	.17	3
14	11.4	- 6.0	9.1	NE 14		2.5	.23	4
15	- 0.8	-17.1	10.7	E 17				4

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13. ABSTRACT
The effects of a 20-ton surface burst explosion on the physical properties of drifted snow were measured. Density of the snow cover increased an average of 17%. Snow hardness decreased an average of 8%. Topographic surveys showed that snowdrift heights decreased through compaction resulting from ground shock and airblast. The results are for drifted snow accumulated around a drift fence. Different results might occur in a naturally accumulated snow cover.

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