TECHNICAL REPORT NO. LWL-CR-01C73

SNOW STABILIZATION FOR HELICOPTER LANDINGS

Final Report
Contract No. DAAD05-73-C-0170

By
Franklin Institute Research Laboratories
Benjamin Franklin Parkway
Philadelphia, Pennsylvania 19103

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U. S. ARMY LAND WARFARE LABORATORY
Aberdeen Proving Ground, Maryland 21005

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ABSTRACT

This report describes the procedures for and the results of field tests conducted to stabilize snow by chemical treatment. Sintering of the snow by spraying methanol on its surface suppresses a possible "white out" condition when helicopters perform normal take-off and landings upon the treated areas. The addition of a violet dye to the methanol also provided the aircraft pilot with a definitive form of reference when the ground was covered with snow and no nearby markers were present.

FOREWORD

The work described in this report was performed under Contract DAAD05-73-C-0170. The Franklin Institute Research Laboratories wishes to acknowledge the technical guidance given by the following personnel of the Applied Chemistry Branch, U.S. Army Land Warfare Laboratory:

Mr. Stephen Clancy (former Project Officer)

Mr. Ralph Allen, Project Officer

In addition to the above personnel, The Franklin Institute Research Laboratories wishes to acknowledge the assistance given by Major Richard Webb of the Military Operations Division of USALWL who performed the aircraft flight tests.

The principal engineer on the project at FIRL was Mr. E. R. Evans of the Multi-Disciplinary Laboratory.

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FINAL REPORT

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APRIL 1973

THE FRANKLIN INSTITUTE RESEARCH LABORATORIES
BENJAMIN FRANKLIN PARKWAY • PHILADELPHIA, PENNA. 19103

1. INTRODUCTION

A. Background

Air mobility essential for military operations in snow covered environments is seriously hampered by blowing snow occurring when helicopters take-off and land. The transition period which occurs when helicopters leave snow covered terrain to become airborne, and vice-versa for landing, is highly critical. Safety dictates that the pilot's vision and depth perception must be unimpaired. Mechanical aids and instruments have materially assisted in take-off and landing operations, but greater assurance of visibility is needed. A clear view of the surface in front and below the aircraft is required. Blowing snow, occurring when aircraft take-off and land, is a serious safety hazard, and is verified by aircraft accident statistics. A means for rapid stabilization of snow that will, in a minimum of time, provide and maintain (for moderate time periods) adequate localized near-surface visibility for the operation of aircraft is required by Department of the Army personnel.

Under previous service contract work assignments, The Franklin Institute Research Laboratories investigated the feasibility of surface stabilization of snow. The results of this prior program indicated that light, fresh snow can be stabilized by the application of suitable chemical agents. Snow surfaces treated with methanol in concentrations as low as 1/4 ounce per square foot did not blow away when subjected to simulated helicopter downdrafts of up to 60 miles per hour. In addition, the load bearing strength of the untreated snow (10 lbs/ft^2) was increased. to approximately 135 lb/ft^2 after treatment with suitable stabilization agents.

Of the agents evaluated, methanol was found to be the most effective material in achieving snow stabilization as well as the most effective of the agents in increasing the load bearing strength of the snow.

B. Scope

Although the initial program demonstrated the feasibility of stabilizing fresh snow, the field tests were conducted with maximum test areas of 100 square feet. This size test area was suitable for tests which utilized a "Mitey Mite" blower to simulate helicopter downdrafts; however, tests were required using actual helicopters. A minimum test area for a helicopter landing test would be a 50 foot by 50 foot square.

Data was also needed on helicopter downdraft velocity during take-off and landings. Available data on this matter was either contradictory or non-existent depending on the type helicopter considered.

Under Contract No. DAAD05-73-C-0170, FIRL was directed to secure the anemometer, thermograph, wind set, commercial sprayer and other supplies to support a field test program using helicopters. The field tests were to be conducted during the period of January 29, 1973 through February 16, 1973, at the Municipal Airport in Watertown, New York. This site was previously used during the feasibility study since a review of the climatic conditions expected in the eastern United States indicated that the area around Watertown, N.Y. offered the best chance for appreciable snowfalls. Watertown is located on the northeast tip of Lake Ontario and is considered a "snow belt" region.

2. PRELIMINARY PREPARATIONS

A. Field Equipment

1. Anemometer and Direction Indicator

To monitor helicopter downwash velocities, a modified Type C Wind System was purchased from the Belfort Instrument Company. The Type C System includes a standard three-cup anemometer wind speed transmitter, a single tail direction vane and an eight-light direction.

Wind speed is sensed by a wind-powered permanent magnet, alternating current generator working through a rectifier in the meter movement. The meter is calibrated from 0 to 50 miles per hour with a tripling switch that increases the scale range to 150 miles per hour.

Wind direction is indicated by a rotating commutator, fixed brush type vane which utilizes eight contact points for 360° of rotation. The indicator displays a circle of eight lights, one for each cardinal and intercardinal point of the compass. The contacts are so positioned as to allow adjoining contacts to be energized simultaneously; thus sixteen points of the compass or every 22 1/2 degrees are indicated.

2. Thermograph

This instrument was used to record surface and subsurface snow temperatures simultaneously during snow stabilization procedures.

The sensing elements are liquid-filled bourdon tubes. The recording mechanism is enclosed in a steel and glass case. The clock movement, which revolves the cylinder, is geared for weekly rotation, and temperature fluctuations recorded in degrees centigrade.

3. Spray Unit

A commercial orchard-type sprayer was selected as the means for applying the methanol. The Matador 43415 power sprayer has the following specifications and features:

Figure 2-1. Anemometer Used in Downwash Tests

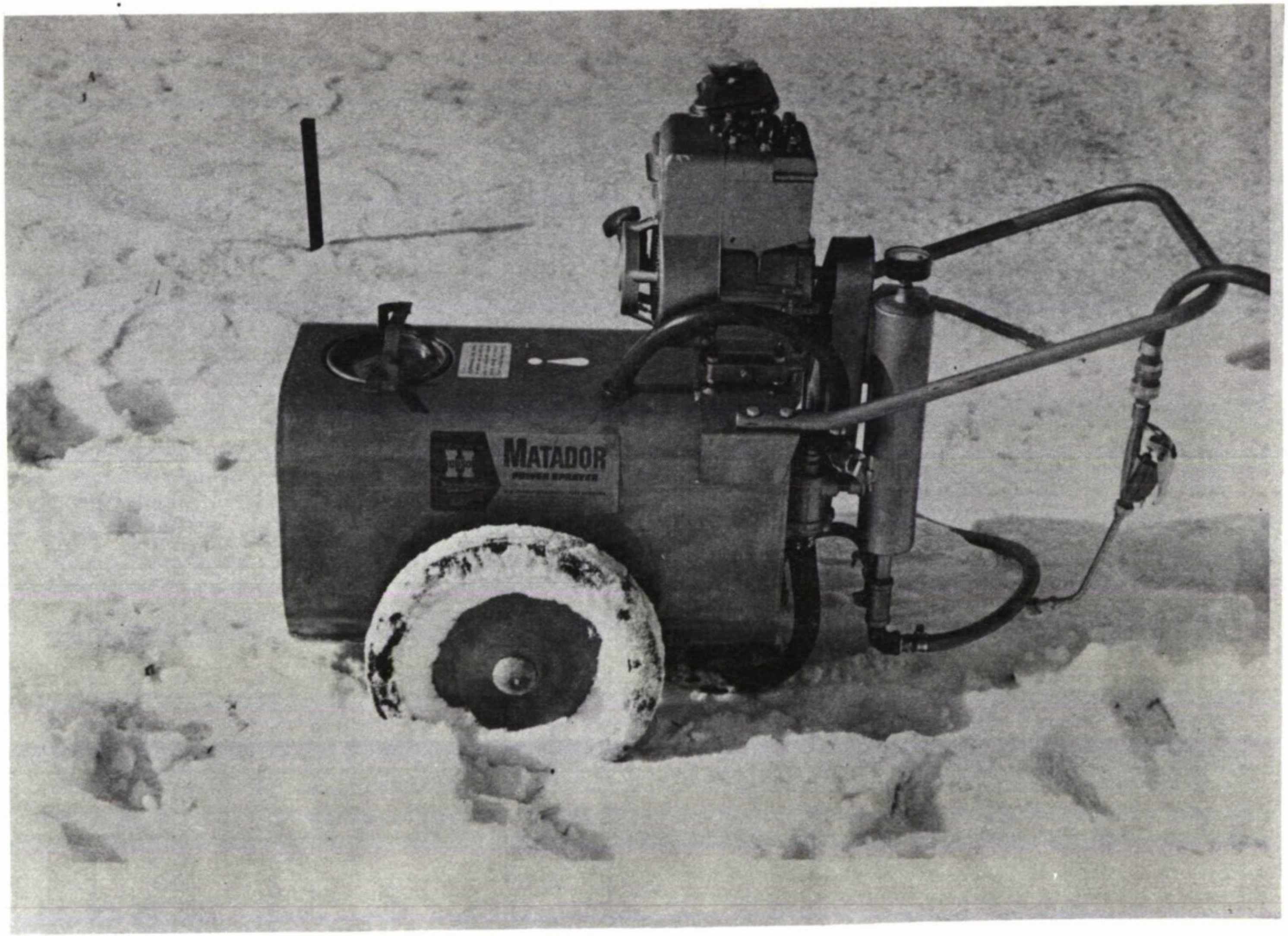


Figure 2-2. Matador Sprayer

Pressure Range	20 - 250 psi
Pump Capacity	3 GPM
Engine	2 h.p.
Tank Capacity	15 gal.
Tires	14 x 2 cushion
Overall Dimensions (LxWxH)	41" x 19.5" x 33"
Weight	108 lbs. (empty)
Spray Range w/Methanol	25 ft. (no wind)
Hose Length	25 ft.
Hose, Type	Kem-Oil #250

4. Load Bearing Equipment

To evaluate the load bearing strength of the treated and untreated snows, a simple device was built consisting of a series of weighted discs which are placed on a 7 inch diameter plywood disc positioned on the selected snow area. When the load bearing strength of the snow is exceeded, a fracture of the snow surface occurs. Generally, untreated snow has load bearing strength of approximately ten pounds per square foot.

In addition to the above tests, other routine data was also recorded. This included snow density, temperature, humidity, wind direction/velocity and related meteorological conditions.

B. Helicopter Downwash Tests

To provide data regarding helicopter downdraft velocities, several tests were conducted at Phillips Airfield, APG and on a commercial helicopter in Syracuse, New York.

Monitoring of downwash velocities was recorded using the modified anemometer described in Section 2, A. The anemometer cups were positioned at a height of 18 to 20 inches above ground in all helicopter tests. Maximum wind velocities have been estimated by the U.S. Army Aeromedical Unit at Fort Rucker to be between 5 and 20 inches above ground for most operational helicopters.

Figure 2-3. Load Bearing Test

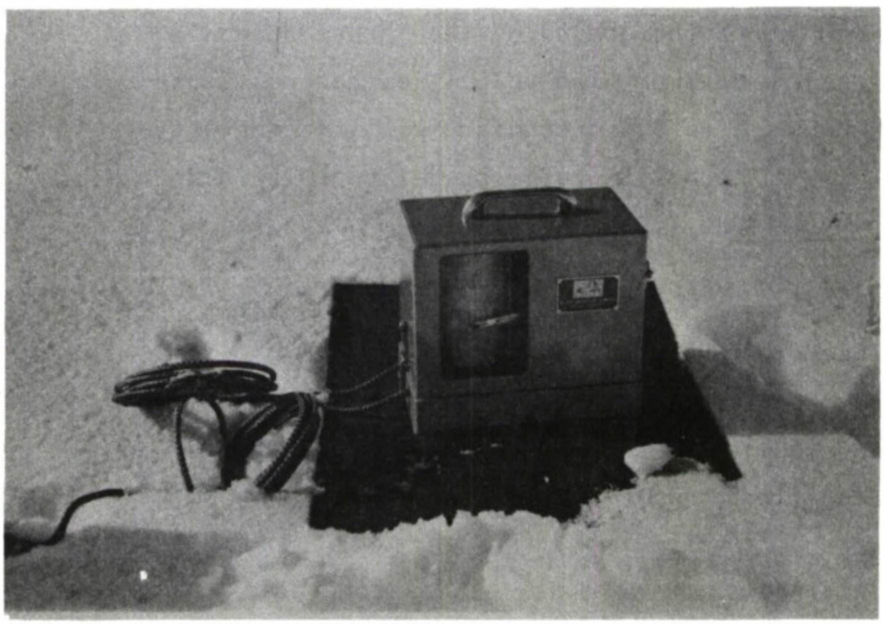


Figure 2-4. Recording Thermograph

General characteristics of downwash[2]:

The following comments are generally applicable to downwash when the helicopter is at a hover:

1. "Downwash" does not produce significant vertical components to the resultant wind when a helicopter is within ground effect. The resultant winds are horizontal at all levels to which a standing man is exposed.

2. The magnitude of resultant wind is directly related to the gross weight of the aircraft, and to some extent to disc loading. Initial downwash velocity is directly proportional to the square of disc loading.

3. The magnitude of resultant winds at ground level is inversely proportional to the height above the ground of the thrust generator when the thrust generator is within ground effect.

4. The magnitude of resultant wind is not uniform vertically above a point on the ground.

5. The height above the ground of maximum winds is directly proportional to the effective disc diameter of the thrust generator, and to the height above the ground of the thrust generator.

6. Maximum wind velocities generally are recorded in a circle of radius 1 to 1.5 disc diameters from the center of impingement.

7. In helicopters, operation "within ground effect" occurs when the rotor is at 1.0 disc diameter or less above the deflecting surface.

1. Commercial Helicopter Tests

The general intent in the proposed field tests for Watertown was to use a commercially available helicopter if possible so that if weather conditions would change rapidly, the aircraft would be readily available.

A preliminary test series was conducted at Syracuse, New York (30 min. flying from Watertown) on the largest helicopter available, a Bell Model 260.

The aircraft was flown through a series of take-offs, landings and hovers similar to those shown in Figure 2-6 for military aircraft. The maximum downwash velocity generated at any time during these flight maneuvers was 24 mph and was considered inadequate for the proposed field tests.

2. Military Helicopter Tests

To supplement the available data on helicopter downdraft velocities, several tests were conducted using military aircraft at Phillips Air Field, APG.

The three aircraft tested consisted of a UH-1H, OH-58 and a UH-1M. These aircraft were maneuvered through a series of altitudes within downwash effects of the recording anemometer. The results of these tests are shown in Figure 2-6.

It was anticipated at this point in the program that a UH series helicopter (UH-1H, UH-1M or UH-1C) would be flown from APG to Watertown to be used in the test program.

Figure 2-5. Preliminary Downwash Tests

ALTITUDE	DOWNWASH VELOCITIES (MPH)		
	UH-1H	OH-58	UH-1M
At 50 ft. alt. executing tight circle around anemometer (approx. 50 ft. diameter).	35	24	29
Making normal landing within 12-15 ft. of anemometer. Max. velocity recorded when copters were 2-3 ft. above ground.	52	31	48
Normal take-off and hover 15 ft. directly over anemometer.	46	28	38
Hovering over anemometer at 25 ft. for 1 min. then setting down for landing; then take-off with right turn.			
Hover	42	24	39
Landing	48	33	44
Take-off	43	27	41

Notes:

- Ground wind speed - 3 to 5 mph from N.E.
- Air temperature - 23°F
- Anemometer height - 20 in. above ground
- Anemometer cup position - horizontal

Figure 2-6. Preliminary Helicopter Test Results

3. WATERTOWN FIELD TESTS

A. Site Preparation

The test team arrived at Watertown, New York on the evening of 29 January 1973. During the period of 30 January 1973 through 2 February 1973 in which there was no accumulation of snow, the test personnel established the site which included: staking out four fifty-foot by fifty-foot helicopter landing pads, setting up the rental truck cargo area as a laboratory and shelter, and installing the meteorological instruments adjacent to the land areas.

The weather remained unsuitable (no snow, high temperatures) for the next six days. While the moderate weather conditions prevailed, the test team personnel engaged in practicing with the Matador spray equipment and maintaining the daily meteorological log. Figure 3-1 is a record of the daily weather conditions at Watertown.

Practice spraying was conducted near the main test area on a few small pockets of coarse residual snow and the barren ground. During these practice sessions when the wind speed was above 3 mph, the sprayer personnel experienced great difficulty in applying the prescribed coverage rates of one ounce and one-half ounce per square foot. Attempts at correcting this situation by decreasing the operating pressure from 220 PSI to 140 PSI and changing the nozzle orifice opening from 1/16 inch to 1/8 inch provided only minimal improvement. To overcome this aerosoling behavior effect of the methanol, it was necessary to increase the application rate to concentrations of approx. 4 ounces and 2 ounces per square foot of area when ground wind speeds were above 3 mph.

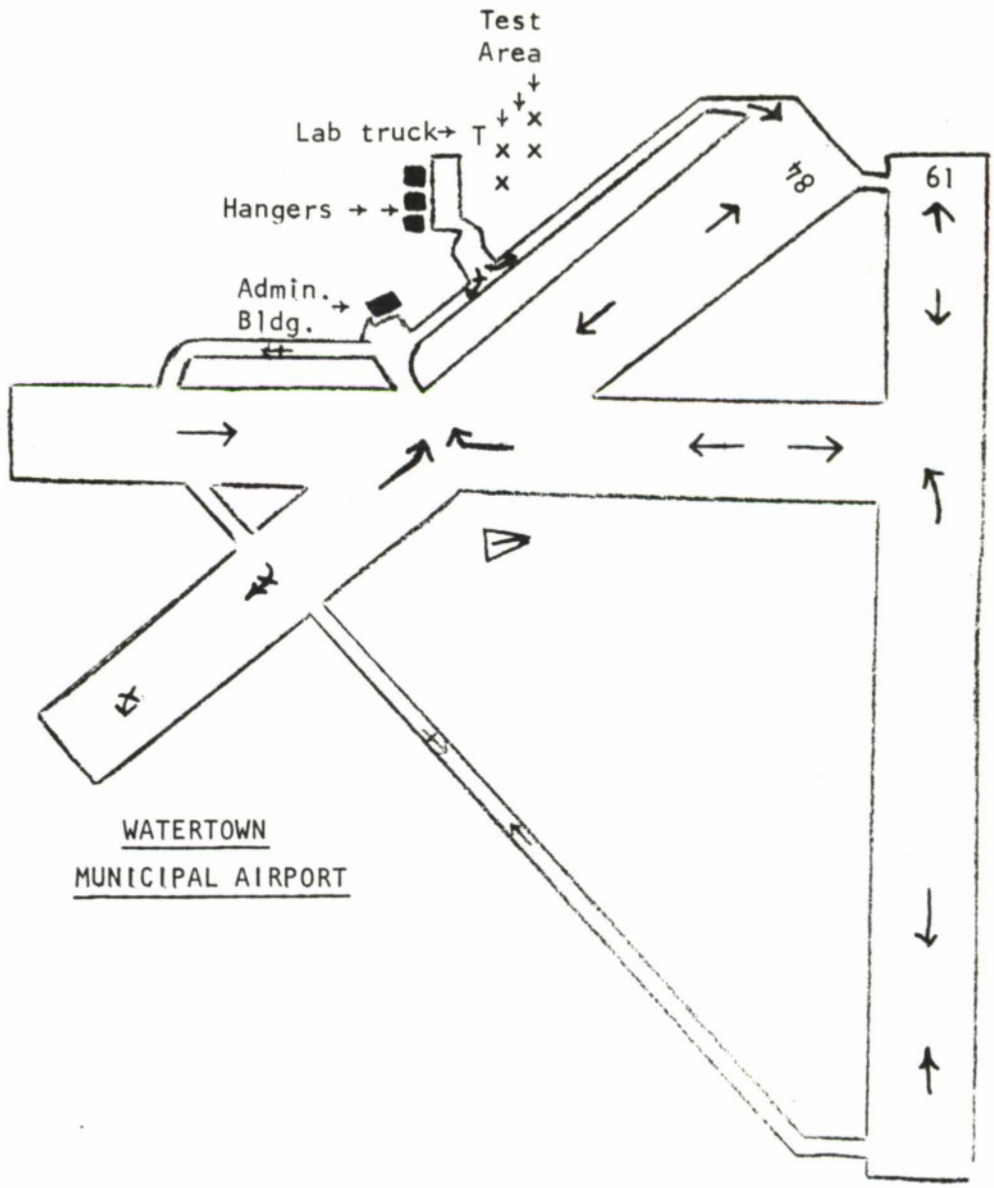
Although spraying distances of 25 feet were obtained when the spray system was received and checked out (at FIRL), this distance was severely reduced at Watertown when the wind was greater than 3 mph. Distances of 16 to 18 feet were the maximum attainable. As a result of this second inadequacy, it became necessary for the spray gun operator to walk upon

DATE	TEMPERATURE (°F) High	TEMPERATURE (°F) Low	RELATIVE HUMIDITY	BAROMETER*	WIND (mph) Speed	WIND (mph) Dir.	PRECIPITATION
1/29/73	-	-	-	-	15	-	Light snow flurries
1/30/73	27	- 1	88%	30.10 -	20	S.W.	Light snow flurries
1/31/73	5	-17	39%	30.64 -	5	N.E.	-
2/1/73	41	8	63%	30.47 ↓	10	S.W.	-
2/2/73	54	33	45%	29.78 ↓	25	S.W.	Rain
2/3/73	38	24	86%	29.38 ↑	20	S.W.	Mixed rain & snow
2/4/73	36	21	88%	29.87 ↓	10	S.W.	-
2/5/73	35	11	59%	30.34 ↑	12	N.E.	-
2/6/73	41	31	58%	30.40 -	8	N.E.	-
2/7/73	38	31	75%	30.23 ↓	8	S.	-
2/8/73	34	11	75%	29.84 ↓	5	N.	6-inch snowfall
2/9/73	12	-5	52%	30.22 -	5	N.	1-inch snowfall
2/10/73	28	-	65%	30.29 ↑	8	N.W.	Snow showers

Notes: Temperature - 24 hour period
Humidity - Taken at 0900 hours
Barometer - " " " "
Wind - " " " "
Precipitation - 24 hour period

* - = steady
↑ = rising
↓ = falling

Figure 3-1. Watertown Meteorological Log



Sketch of entire landing area and taxi patterns for each wind direction including direction of last turn before takeoff and first turn after landing.

Figure 3-2. Watertown Test Site Location the test area during the actual stabilization tests and then spray coat his tracks when egressing.

A mild snowstorm hit test area during the night of 8 February 1973. A total snowfall of 6 inches accumulated, consisting of 3.0 inches of heavy wet snow as a base and 2.5 to 3.0 inches of fine powder. The snowfall was accompanied by winds of 5 to 10 mph resulting in very little mechanical working of the snow. The average density was calculated to be 0.18 gm/cc.

Two of the test areas were sprayed, one at the rate of 4 oz/ft^2 containing a violet dye; the other sprayed at 2 oz/ft^2 and containing a red dye. The application rates (4 oz. and 2 oz.) were based on the total amount of alcohol used since each site had a 4 to 5 foot work border and a large amount of methanol was lost to aerosoling and spillage. It was estimated by the sprayer operators and after an examination of the treated snow surface that the actual coverage rate was approximately 2 to 3 oz/ft^2 and 1/2 to 1 oz/ft^2. The aircraft flight test results for these two pads is discussed in Section 3-B.

The other two pads were prepared the following day after an additional 1 inch snowfall. The same methanol application rates were applied; however, the dye colors were changed. The 4 oz/ft^2 site was colored orange and the 2 oz/ft^2 pad colored with bright green dye. Figure 3-3 lists the statistical results of the snow stabilization; both test date results were the same.

Type:	3 inch base of heavy wet snow, 2.5 to 3 inch cover of fine granular, plus 1 in. of fine powder on 3/9/73.
Depth:	6 to 7 inches
Density:	0.18 gm/cc (untreated)

Load Bearing Strength:	18.3 lb/ft^2 (untreated)
Load Bearing Strength:	10.13 lb/ft^2 (after treatment)
Snow Surface Temperature:	28°F (treated)
Snow Sub-Surface Temp:	25°F (untreated)

Figure 3-3. Stabilization Test Results

The reduction in load bearing strength in both test series was the result of several factors: (1) the relatively mild air temperature; (2) heavy wet sub-surface snow and (3) only 6 to 7 inches of total snow. All of these factors combined to prevent total sintering. Although the snow was very heavy after treatment, it did not effect the final results with the aircraft.

B. Aircraft Flight Tests

On 9 February 1973 and 10 February 1973, Major R. Webb, USALWL, performed a series of normal landings and take-offs from the treated areas. The aircraft used in these tests was a UH-1C. This model generated downwash velocities of 65-72 mph over the test areas. These wind speeds are somewhat greater than those achieved during the preliminary velocity tests and are due to the increase in main rotor blade width of the C model Huey.

The aircraft personnel reported that the two areas treated with the higher concentrations ($\approx$ 4 oz.) of methanol gave superior suppression to a possible "white-out" condition with ground visibility always present. For comparison purposes, a landing was attempted in an untreated area near the test pads. The pilot experienced great difficulty in making the landing due to the "white-out" which destroyed orientation with the ground.

The addition of a dye to the methanol gave the pilot a definitive form of reference when the ground is snow covered and no nearby markers are present. Of the four colors used (green, red, orange and violet) in these tests, the violet colored pad was visible at a slant range of approximately 8 miles from 2500 feet altitude.

The following series of photographs present a pictorial reference of the snow stabilization tests conducted at Watertown, New York.

NOTE:

On 5 March 1973, the subject contract was modified so that FIRL could supply USALWL with the following items to conduct additional snow stabilization tests at Fort Wainwright, Alaska.

1. Sufficient methanol to treat five test areas

   3 ea. of 2,500 ft^2

   1 ea. of 10,000 ft^2

   1 ea. of 40,000 ft^2

   Plus 100 gal. for practice spraying
2. Sufficient violet dye to color the alcohol
3. The Matador sprayer system
4. Spare parts for the sprayer including: hoses, spraying nozzles, spray guns, tools, engine oil, etc.
5. Crating and packaging of the above items and air shipping to Fort Wainwright.

Figure 3-4. Typical Test Areas (2500 sq. ft. each)

Figure 3-5. Spraying Methanol on Test Pad

Figure 3-6. Landing in Untreated Area Leading to White-Out Condition (1 of 3)

Figure 3-7. Landing in Untreated Area Leading to White-Out Condition (2 of 3)

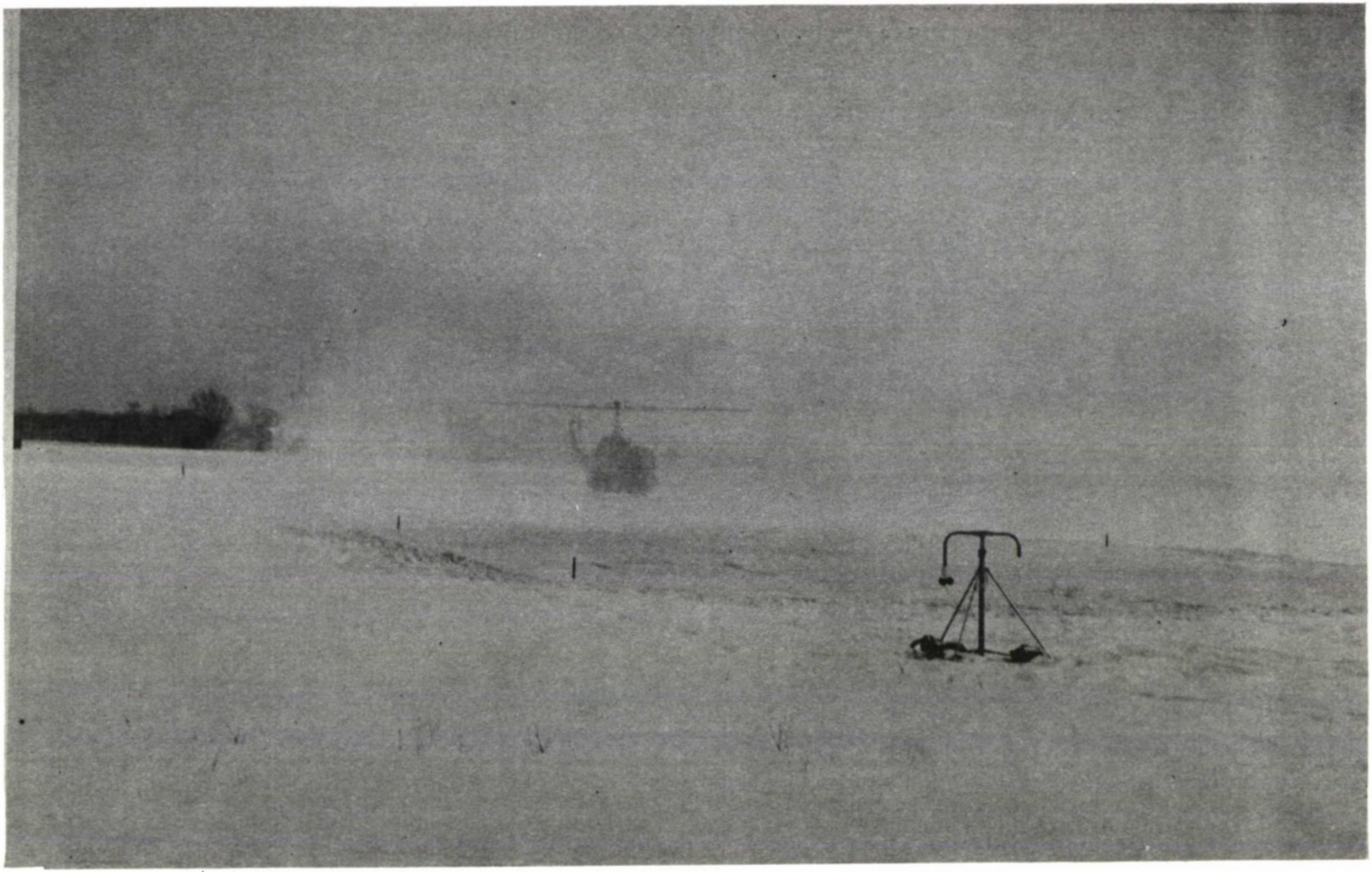


Figure 3-8. Landing in Untreated Area Leading to White-Out Condition (3 of 3)

Figure 3-9. Hovering Over Stabilized Snow (Front View)

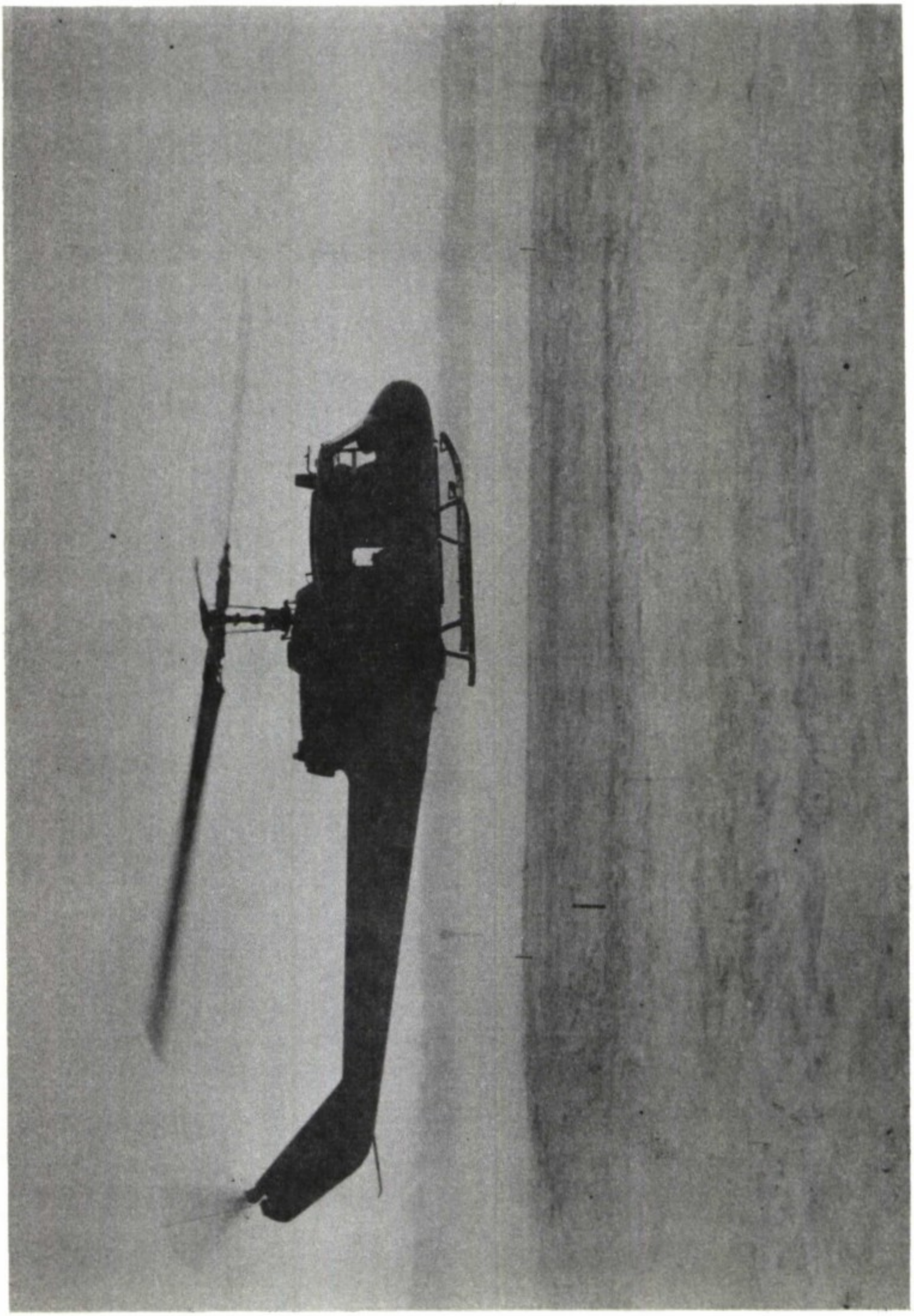


Figure 3-10. Hovering Over Stabilized Snow (Side View)

Figure 3-11. Landing in Treated Area (Vortex Snow Carried in from Flight Path Approach to Area)

4. CONCLUSIONS

A. Snow stabilization was successfully achieved during this limited test program.

B. Areas treated at a rate of approximately 4 fl. oz/ft^2 were more stabilized than the approximate 2 fl. oz/ft^2 rate areas.

C. Although sintering of the treated areas was prevented and the load bearing strength decreased after treatment, no snow or slush was lifted into the helicopter vortex when subjected to 72 mph downwash velocities.

D. The addition of a dye to the methanol will provide the aircraft pilot with a good, visible point of reference.

5. RECOMMENDATIONS

A. That additional tests be conducted to determine:

1. the quantity of treatment required for larger helicopters (CH-47, etc.)
2. lasting (repeat landings) capabilities of treated areas.

B. That USALWL consider the design of or modification to existing airborne equipment for the aerial dissemination of the snow stabilization agent.

C. That any further tests be conducted in areas of end item application.

6. REFERENCES

1. *Snow Stabilization Techniques*, Final Report Contract No. DAAD05-68-C-0283, Franklin Institute Research Laboratories, September 1971.

2. *Effects of Downwash Upon Man*, USAARU Report No. 68-3 by W. P. Schane, LTC, MC U.S. Army Aeromedical Research Unit, Fort Rucker, Alabama, November 1967.

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13. ABSTRACT

This report describes the procedures for and the results of field tests conducted to stabilize snow by chemical treatment. Sintering of the snow by spraying methanol on its surface suppresses a possible "white out" condition when helicopters perform normal take-off and landings upon the treated areas. The addition of a violet dye to the methanol also provided the aircraft pilot with a definitive form of reference when the ground was covered with snow and no nearby markers were present.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
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Sintering						
White Out						
Visibility						
Stabilization						
Load Bearing						
Density						
Downwash						
Spraying						