Plow Clean Without Scraping

C. J. Posey

Snow is most commonly removed from highways by a plow mounted at an angle on the front of a heavy truck. If the truck moves fast enough, the snow is thrown well to the side; otherwise, it is pushed up into a ridge. At night a shower of sparks can often be seen as the blade scrapes the pavement. This wears the blade as well as the concrete and the reflective paint of traffic stripes. Where it does not contact the pavement, the blade may leave a hard-packed slippery skin of snow. Scraping can be avoided and at the same time the snow removed completely by directing a thin sheet of high-velocity air at the pavement from under the blade. The air is intended not to blow the snow off the road but to lift it a few inches off the surface so that the plow can shove it off in the usual manner.

Computations show that a turbocompressor would be required for a full-size installation. None could be obtained for use during the past winter, therefore snow-removal efficiency tests were made with a jet 6 in. long. Wet and dry snow could be completely removed from pavement and grassed areas, but not wet snow that had frozen to the pavement. It is concluded that full-scale designs should be developed and tested.

The method most commonly used in southern New England for removing snow from highways is to mount a plow with heavy steel blade and cylindrical or conical moldboard at an angle on the front of a heavy truck. If the truck is moving fast enough, the snow is thrown well to the side; otherwise, it is pushed up into a ridge. At night a shower of sparks can often be seen as the blade scrapes the pavement. This wears the blade as well as the pavement and the reflective paint of traffic stripes. Where the blade does not contact the pavement, it may leave a hard-packed slippery skin of snow. This scraping can be avoided.

A thin sheet of air directed forward under the bottom edge of the plow with sufficient velocity will lift the snow or compress its bottom layers enough so that the moldboard can push it all aside. Preliminary computations assuming different air pressures and thicknesses indicated that the air jet should issue from a slot 0.02 in. wide, and that the pressure behind the slot might vary from 2 to 5 psi. For a slot 130 in. long, computations yield the results given in Table 1.

On the assumption that 10 percent of the power of the jet is utilized in lifting 50 pounds of snow 0.20 ft. for every foot of forward motion, the theoretical maximum plow speed in clearing a 10-ft lane is 17 mph when the pressure is 2 psi, and 78 mph when the pressure is 5 psi. An evaluation based on momentum may be more realistic. If the air jet is turned from a 45-deg downward-forward angle to, say, a 75-deg upward angle, measured from the backward horizontal, the horizontal component of its momentum will be (sin 45 deg - cos 15 deg) = 0.96 times the values given in Table 1. The bottom layer of snow "approaches" with the velocity of the plow, and is turned through an angle of 180 - 75 = 105 deg. If it weighs 0.5 lb/sq ft, its relative momentum of approach is $(0.5V/32.2)V = 0.0155V^2$, where V is the plow speed in ft/sec. Because it leaves with a slight rearward horizontal component, the horizontal component of the change of momentum is $(1 - \sin 15 \text{ deg})(0.0155V^2) = 0.0115V^2$. If this is equated to 0.96 times the tabulated values, the plow speed turns out to be 21 mph for 2 psi pressure and 32 mph for 5 psi pressure. Although neither of these simple analyses can be expected to represent such a complicated phenomenon very well, the results give some idea of the possibilities. Apparently the compressor will have to supply air in the range of 500 to 1,000 cu ft/min, but the pressures need not be high. With supply lines

TABLE 1

AIR THROUGH A 0.02- BY 130-IN. SLOT

Pressure (psi)	Velocity (mph)	Volume (cu ft/min)	Weight (lb/min)	Horsepower	Momentum (lb to stop)
2	330	520	42	5	10.3
5	520	820	66	21	26.0

of adequate size, 20 psi will do. The type of compressor used for operating jackhammers and air tools supplies a much smaller quantity of air at higher pressures, 80 to 100 psi or more, and is not satisfactory for our purpose. Compressors with the right capacities are available on the market, however. They can be driven by a gas turbine or by the exhaust gases of a diesel or other internal combustion engine. First developed to replace the more expensive gear-driven superchargers, "turbochargers" are coming into common use on the highest powered diesel trucks.

Because no turbine-driven compressors were available for this investigation, which has had no budgetary allocation, experiments to test the effectiveness of the air jet had to be on a small scale (Fig. 1). A slot 0.02 in. wide by 6 in. long was cut in the bottom of a copper pipe 1 in. wide and 8 in. long, to the middle of which a 1-in. by 4-ft pipe fed air brought by a 1-in. diameter pressure hose from a 40 cu ft heavy pressure tank supplied by a large stationary piston-type compressor. A valve permitted bleeding air through the desired range of air pressures desired, as measured by a pressure gage 2 in. below the valve. The are pressure at the slot was thus slightly below the pressure shown on the gage. The range was limited by the length of hose, which permitted operation only a few feet outside the northeast overhead door of the Mechanical Engineering Laboratory at the University of Connecticut, Storrs.

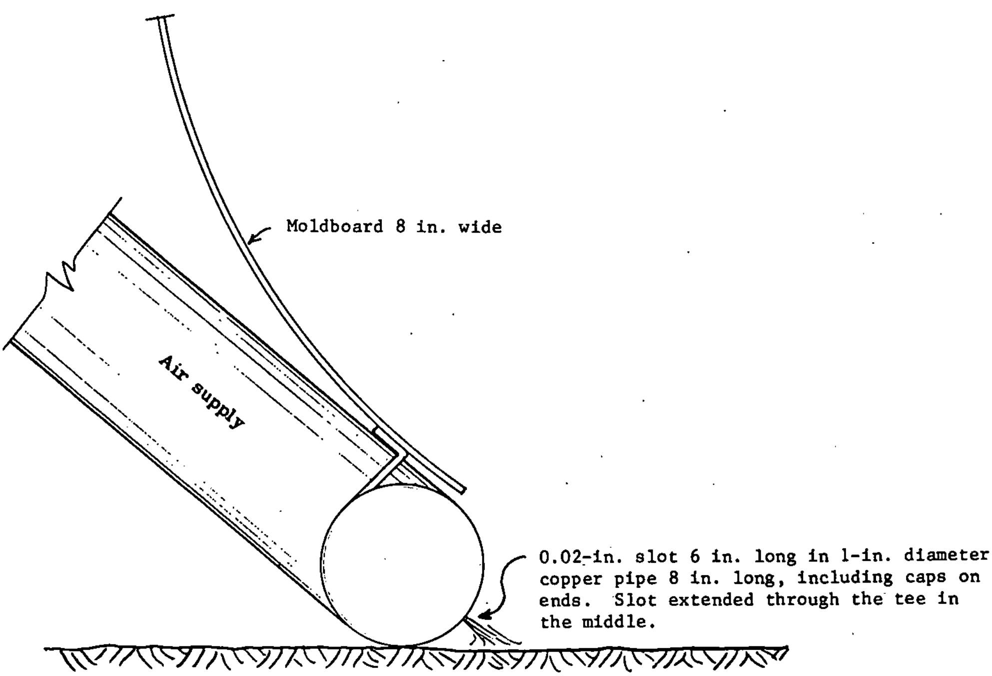

Figure 1. Model apparatus used in the tests. For full-scale installation on a plow, the pipe with the jet should be behind the moldboard and slightly farther from the ground. It seems most likely that it should be in sections about 2 ft long, each with ample-sized air supply connections.

TEST RESULTS

In addition to the limitations of the apparatus described, the tests had to wait for snows, which were not frequent in Storrs this winter. The first snow was about 6 in. deep and was followed by rain so that the bottom inch of snow was saturated. When this snow came, the apparatus was not complete, for the initial attempt at building it had produced a rough slot about 0.06 in. wide. With 2 psi pressure through this wide slot, not only was the snow lifted off the pavement, but the pavement was actually dried, and where it was cracked, pieces were blown away. The weather turned cold shortly and the saturated snow froze. The jet was then unable to clear the pavement, but it would lift the crust that had formed on the top of the snow and clean the loose snow down to that which was frozen hard.

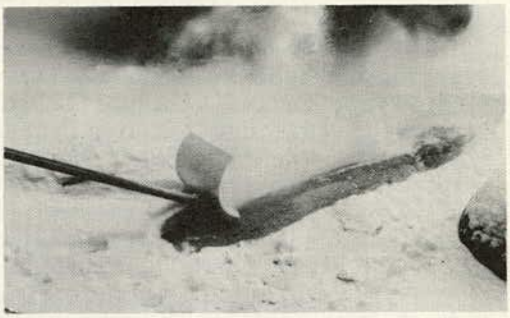

Figure 2. Operation of model apparatus in dry snow.

By the time the ice had melted off and a dry 4-in. snow had fallen on bare ground, a new pipe with 0.02-in. slot had been made. Its operation is shown in Figure 2. It also cleared snow from the grass at the edge of the pavement (Fig. 3). Finally, a wet snowfall, again about 4 in. deep, was cleared as shown in Figure 4.

On Easter Sunday, Storrs had a snowfall of 7 to 9 in. Snowplows used on the local roads scrape with the blade sliding on the pavement, without support from shoes or casters, so that ordinarily much of the surface is scraped clean. The roads had been plowed before 7:00 Monday morning, but for some reason the snow had formed a crust in contact with the pavement. This crust had not been removed anywhere along the roads leading to the campus. The air jet, however, was able to remove the full depth of snow and the crust in one pass, with the pressure of 5 psi. The sun shining on the roads soon melted the frost left by the plows.

Figure 3. Snow removed from grass at edge of pavement.

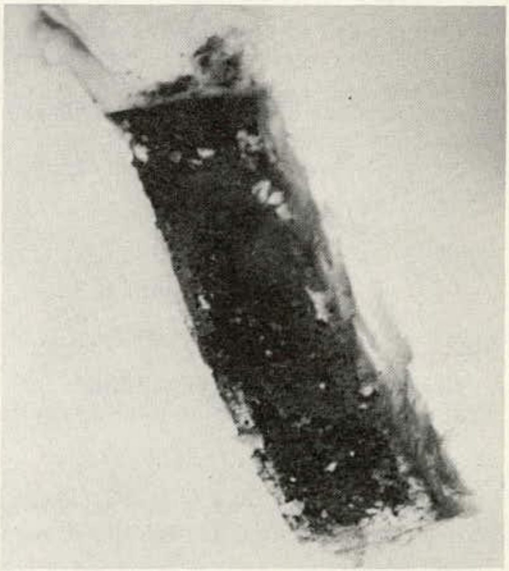

Figure 4. Four inches of wet snow cleared.

POSSIBLE FUTURE DEVELOPMENTS

It is believed that these tests, modest as they may be, provide justification for developing and testing the method at full scale. The present design of the road plow will need to be changed. Perhaps the heavy carbide bar can be eliminated. It may be necessary to add wheels with tires to hold the moldboard the desired distance above the pavement. The suggestion has been made that diesel trucks equipped with turbochargers could have the compressed air fed to the jet instead of to their intake manifolds. (Use of the turbochargers is not essential for the diesel engine, but it is questionable whether the turbocharger would produce enough air with the diesel not developing full power, because this is the running condition for which the turbochargers were developed.) More likely, the gas turbine compressor will operate separately, mounted on the truck.

Many variables need to be investigated. It seems that the method should be most useful in removing snowfalls in the range of a few inches to a foot or more. With all snow removed from the pavement and shoulders, so that thawing and subsequent freezing of sheet runoff on the pavement become a rarity, it should seldom be necessary to use sand and salt.

Informal Discussion

D. L. Richardson

When you run the model at 20 psi do you achieve sonic flow through the slot?

C. J. Posey

We never went past 5 psi; I guess I did not mention it in the paper, but in the first model the slot was 0.06 in. wide, which is wider than desirable. When we applied 5 psi pressure, we not only cleared the snow, but where the asphalt pavement was a little cracked we began tearing out pieces of the pavement. So we could see that a 0.06-in. slot was too wide.

M. E. Volz

I do not see why you have a problem with compressed air because there are many available sources for the volume and pressure you need that are very simple, lightweight, and easy to operate. Have you thought about the small auxiliary power units used on airplanes? They are capable of developing up to 40 lb of air with a volumetric capacity in the thousands of cu ft/min. Do you have any idea of how many cubic feet of air at the pressures you are talking about that you would need for a full-width plow, say 16 ft?

Posey

Up to 800 to 1,000 cu ft/min at 5 psi.

Volz

How far from the pavement would you be able to discharge this air? In other words, what is the elevation of the plow above the concrete?

Posey

We used a little over ½ in., but this needs to be looked into. I would like to have your comments on the availability of these units.

Volz

Would you anticipate that the slot would be self-cleaning?

Posey

I think it would be.

Volz

What is the angle of discharge with respect to the surface?

Posey

About 45 deg forward.

Volz

Then we run into the problem of how the forward speed would affect the data you have so far, because you indicated that you pushed it by hand in your tests.

Posey

It seemed to me that, with a velocity of 330 mph, a relative velocity of 20 to 30 mph on a pavement would not make much difference.

Volz

I will be glad to talk to you about finding a source of air for your gadget. This bears looking into further. I think you have at least pointed the way to a solution to a problem that more and more people are going to have. We have it in the airline business today, but highway departments are going to have it very shortly. The problem is in-runway or in-highway lighting. Conventional plowing methods cause considerable damage to these lights. If something like this were available and could be run on rubber tires far enough above the pavement to avoid the lights, one of the very severe problems we have today would be solved.

Posey

For 10 percent efficiency, I estimate it will take 21 hp for a 10-ft blade. It could not be run off the main engine of the truck because of the rpm from the truck engine. The truck's engine would have to be geared up tremendously to run the thing. I think it would have to be a turbocharger. We could not see how far in front of the blade the air removed the snow. We had no wheels on it to hold it up, so we held it above the ground by hand.

David Minsk

I think there is little doubt that compressed air will be very effective with dry, low-density snow; really you are just blowing feathers. But the question arises, how effective will it be with wet, high-density snow or traffic-compacted snow? Did you make any comparison tests with wet snow with the air and without it?

Posey

With the air, it took care of the slush. I am sure the air can lift this up; but I do not know about hard-packed snow or ice.

A. G. Clary

The FAA has done a study with air for aircraft wheels to eliminate the hydroplaning phenomenon. Of course, this has tremendous potential if we can raise it enough to get it over the raised reflector buttons on highways. Many highway organizations are using caster wheels and shoes to hold the blade above the pavement, so this is no problem.

Posey

I am told that the caster wheels and shoes wear very badly.

Clary

There are heavy-duty casters on the market that are effective.