

Improving Snow Plow Design: Highway Maintenance Concept Vehicle Phase V

Meeting Minutes from the Design Charrette
Held in Des Moines Iowa April 26 & 27, 2006

Prepared for the
Clear Roads Program

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INTRODUCTION

The challenges facing states' departments of transportation (DOT) winter operations are numerous. These challenges include rising fuel costs, material costs, flat budgets, and public expectations for clear roadways. The operators face the perils of winter as they strive to provide uninterrupted mobility to the road user. Snow and ice control during winter storms includes highly complex tasks and long, stress-filled hours for equipment operators and their supervisors.

This concept highway maintenance vehicle project undertaken by the Clear Roads consortium is designed to develop highway maintenance vehicles so that they may improve snow and ice control performance, and better suit the needs of the traveling public, the operators, and the highway agencies. This report summarizes the activities of the Design Charrette, which involved determining the desired capabilities for a concept highway maintenance vehicle and predicting the feasibility of assembling prototype vehicles.

On April 26 and 27, 2006 the Clear Roads Project Team convened in Des Moines Iowa to the latest version of the Concept Vehicle Project. The charrette brought together operators and researchers from the seven Clear Roads states to discuss these issues.

Those in attendance were:

Name	Organization
Dennis Burkheimer	Iowa DOT
Jim Dowd	Iowa DOT
Brad Osborne	Iowa DOT
Will Zitterich	Iowa DOT
Jim Bane	Iowa DOT
Bill Schuler	Iowa DOT
Rex Evans	Iowa DOT
Lee Wilkinson	Iowa DOT
Milo Nelson	Iowa DOT
Leland Smithson	AASHTO
Jeffrey Tjaden	Iowa DOT
Dave Budd	Michigan DOT
John Scharfbillig	Minnesota DOT
Mike Sproul	Wisconsin DOT
Greg Shell	Indiana DOT
Bob Lannert	Missouri DOT
Doug Burke	Ohio DOT
Steve Andrie	CTRE-Iowa State University
Dennis Kroeger	CTRE-Iowa State University
Dr. Greg Luecke	Iowa State University

The participants met to define the desired capabilities of a new snow removal device that will meet the goals of the Clear Roads research project. The stated goals of the project are:

- Clear roadway in one pass
- Reduce snow residue behind the plow
- Develop a contour-following blade or alternative to a blade
- Plow speed that is within ten mph of traffic speed—about 40-45 mph

The meeting was conducted in a design charrette style discussion. The participants were brought together to discuss, dissect, design, and assemble two prototype designs that could be built, deployed and tested by next winter. All methods of snow and ice removal were on the table for discussion. Participants were encouraged to bring unconventional ideas to the discussion so as to push the envelope in developing the snow removal device. Once the plans are prepared, one device will be tested in Iowa and one in Indiana.

1. DEFINITIONS

The charrette participants defined the challenges and problems for snow removal as the following.

- Clear 12' lane in one pass
- Target speed should be 60 mph on urban interstates
- Seek travel speed of plow to within 10 mph of traffic speed
- Goal: keep cloud down with down deflection.
- 42" height on moldboard is optimum
- 20" height on experimental plow in Missouri. Take snow perpendicular to the right. Wyoming did some research in this area. Load sensors on plow. Measured horsepower consumption. Moved tilt angle back. Colored top of snow to test. Skew angle will move snow more rapidly to the right.
- 90° angle is the worst for launching snow. Just pushes snow ahead of plow.

1.2 PARAMETERS

- 102" width limit roadways
- If air blowers or brushes are used to clear snow, we can't pull more than 50 hp off the engine. Huge issue. Decreased hp means decreased performance of truck. For example, at 125 cu ft. per min. 65 hp is required to run 4-5 jack hammers. Airports are running 350 hp on compressors
- Focus on interstate condition. ½" max rut. Concrete or hot mix.

- Rock shoulders. How does air and brush work on gravel? Issue in many states. Currently, shoulder plowing uses shoes or hydraulics to keep plow off the rocks
- Cost: we can be in the 5x range on the plow unit. If resources are reduced or increase production capacity we can add some cost. If increased speed and efficiency are gained, agency can absorb some capital cost.
- Spreading material: Operators in some states are spreading 800 pounds /mile so they can see it in their rearview mirrors. Should be doing 200 pounds per mile or less. \$5 per lane mile to keep snow from bonding.
- 1/2" of ice takes 70 tons of salt per 2-lane mile to melt at 10 degrees
- On interstate, shoulders are treated to the same standards as mainline.
- The farther back you move the plow the faster you can drive.
- Goal: Reduce residue by 25 %
- Goal: One plow, one truck

1.3 PROBLEMS AND CHALLENGES

Once the group defined the problems that they face they were asked to identify methods to overcome the problems and challenges faced with snow and ice removal.

- Skew angle. Move the plow to negative angle.
- Horsepower. 300 hp is limit without \$20K upgrade. Emissions regulations.
- Challenge of removing snow on ice, removing ice, slush and deep snow.
- Dry snow- Hard to avoid cloud. Keep air out of it. Curved underbody plow with cover. Light fluffy snow will pack under truck with underbody blade. Wet snow will come off in a rooster tail.
- Differential blade wear is a problem. We need to control left and right down pressure. Ohio DOT uses a blade balance valve.
- There is a lot of plow chatter on the roadway when using a gravity plow. Plow chatter and blade chatter is a problem causing unnecessary wear and operator fatigue. Missouri DOT uses -5° to -10° attack angle to reduce chatter. This method also carries material to right faster. It is also useful when plowing wet pavement a lot.

- Missouri states that one way to solve some of these issues is to use a negative attack angle with skew and down pressure.
- Underbelly clearance is a problem, for example at railroad crossings. Need to ensure ability to lift underbody blade. High speed underbody plows have been in use in Iowa for 20 years. There is a need to raise drive shaft and fuels tanks. At higher speeds, there may be trouble getting snow to clear out fast enough to avoid packing underbody of truck.
- Must remember that plows are used for more than snow. They must have the ability to do other maintenance work and be versatile. Don't create new problems for other functions.
- Signs: Casting of snow and slush on roadway signs will not be tolerated. New retro-reflective signs need to last 10 years.

1.4 General Issues

Once the problems were stated and defined, the discussion continued with other issues being focused on.

- Blowback and visibility. There is need for more work on aerodynamics in front of the plow. Snow pack can plug radiators and air intakes, which will slow trucks down. Run out of horsepower above 45 mph. Can't maintain the higher speed.
- Another danger is chunks of snow and ice coming off the plow at higher speeds.
- Residue left behind the plow, still need to remove.
- In Ohio, there are raised pavement markers, which can become hazardous to oncoming motorists if plow grabs them and throws them. The device needs to slide over them.
- Weight: front end limits – plows can be made too light or too heavy.
- There are rear end accidents in left lane – for example, semis hit snow plow trucks. Many times this is not a failure to see the plow, but of reaction time. Truck drivers are overdriving for conditions. Issues: Should we clear the passing lane first? This method moves fast traffic to the clearer passing lane. Another method is tandem plowing to prevent rear end crashes.
- Why front end plow? Under body plow can be used for average snowfall removal.

- The standards for snow and ice control are: No snow allowed on interstates.
 - Need for high speed, high production
 - Use all available tools including under body plow and rear wing
 - Secondary roads different standards

1.5 OPERATIONS

Following the discussion of problems and challenges and methods to overcome those problems, the charrette participants were asked about their operations for snow and ice control. The participants were asked to discuss their operations and how a new device may change those operations. They were also asked if there were changes in the operations that could be readily made. Their responses are as follows:

- Any new device will use hydraulics to manage down pressure, and sometimes carry the plow.
- Tilt control will be used. Tilt the blade to adjust to road surface.
- Rotate front plow to adjust attack angle. Combine with squeegee following. Adjust pressure on slush blade.
- Must be simple to operate and maintain. Lots of part-time operators.
- Cost control is a big issue. There is a lot pressure on maintenance agencies to contain costs. Any new device must be productive and keep costs down.
- Training is a big issue. It is hard to get drivers to go out without a front plow. Once they get use to it, they like it because the visibility is better. If no front plow is used on the new device, we will have to gain operator acceptance. This issue can make it a success or failure.

1.6 PRODUCTS: BENEFITS AND SHORTCOMINGS

Following the operations discussion, the participants were asked if there were any existing products available that may be used for the proposed snow removal device. If there are products available, what are the good things about them and what are the bad? The discussion went as follows:

- Joma blades– but their shoes fail and we have to replace the vulcanized rubber each time
 - These blades have been used in Cleveland OH. There costs 3 times regular blades but they lasts 3 times longer. To avoid excessive wear, you have to run 20° forward. The blades need wheels or shoes to keep full weight off rubber blade.

- Active Blade Adapter System (ABAS) – (This is a segmented blade device bolted to existing moldboard. The blades move up and down with the contour of the road surface.)
 - Tried in Cleveland and other Ohio DOT sites
 - In service in Bedford Iowa (Iowa DOT)
 - Too heavy
 - Raises plow 5 inches.
 - According to Bill Schuler of Iowa DOT this system works very well on rough pavements. Runs smoother at 50 mph than a regular plow at 30 mph. We had to drill vertical holes to relieve tension on rubber. Is it possible to pump liquid chemicals through these holes?

- There are two types of active adapters. One works on a tension/compression basis. The other has a shear action on the rubber block.

- Schmidt-Wausau: has poly-moldboard

- In Bedford, Iowa District, we can run the plow at 50 mph with good vision if rotate the c-blade far forward. You need to keep snow out of the top of the plow.

2. NEW IDEAS

Following the product discussion, the participants were asked about any new ideas that they have thought of but for whatever reason hadn't tried. All ideas were to be on the table, regardless of budgets, political issues, other limitations, etc. The goal of this discussion was to get the participants thinking of new methods and concepts that could work for snow and ice removal. Once these ideas were discussed and dissected, then they could be parsed down into practical applications.

- Using multiple blades. First blade placed 2" or so off ground, followed by other blades.
- Michigan DOT runs front plow 2" off ground. Uses underbody plow to clear remainder of snow and ice from the roadway.
- Devices would require down pressure with hydraulics.
- Underbody plow doesn't move truck over when it hits an obstruction at high speed like front end plow.
- Michigan and Ohio have used rubber blade with carbide backing.
- Missouri stated that neoprene blades have been used in St. Louis at low speeds. These blade don't work well at high speeds
- Could brushes be used at high speed? Need to investigate this.
- Poly moldboard that can be tightened up.
- Inject brine up front to hold down plume. Spray the cloud? Spray the roadway in front? May help reduce the blow back in problem. Ohio and Iowa running brine trailers
- Indiana — has outsourced snow plowing.

2.1 CONCLUSIONS

The following conclusions were drawn from the morning's discussion.

- Underbody plow is probably solution to high speed plowing. At higher speeds, there is so much mass truck won't shift.
- Moldboard with trip mechanism is not likely solution to high speed plowing.

- Negative blade angle with skew and down pressure. There is a possibility to investigate here.
- Multiple blades. Shallow plow or plow with cover.
- Alternative. Slush blade in front. Tilt moldboard forward to engage slush blade. Put cylinder on bottom and rotate down whatever blade you need.
- Different than plow discharge. Rooster tail comes off end of plow.
- Two prototypes should be totally different. Wide spectrum of conditions.
- State Maintenance Engineer goals
 - Wider path
 - Plow slower for safety
 - More production, more capacity
 - Reduce costs of snow removal

3.0 WORK PLAN

The discussion continued with participants developing the work plan for a snow removal device. The focus here was to not focus on a plow, but any device that could remove snow and ice from the road surface.

The methods of snow removal are different for urban service and rural service. There may have to be different designs for these operations.

- Interstate urban device
- Rural Device

The participants focused their ideas on efficiency, following the contour of the road surface, and discharge of the snow. Their ideas are as follows:

3.1 Efficiency

- 1300° exhaust temperature on back of moldboard to increase fuel economy.
- Reduce friction. Increases production. Makes plow scour. Reduces horsepower needs. Keeps cloud down.
- Inject brine at bottom. Reduces friction on bottom of plow. The plow then tends to hydroplane.
- Inject brine through the back of the moldboard.

3.2 Clear roadway in one pass. Contour-following

- Rotating multiple cutting blades/squeegees that can adjust the angle of attack.
 - Mounted behind plow
- Air auger 10” cylinder with spiral air flutes. Pulsating air nozzles. Compress fines.
- Air jets with auger
- Brooms: Poly with steel. Paint crew model. Thermo plastic markings may change the cost equation for brooms. Paint crews are grooving in the markings to avoid the plow. How fast can a broom turn?
- Belt with brushes that continually move material to right. Follow up with a squeegee. Will need enough width to move the snow. Doug Burke
- An alternative would be to place in front of the blade. Use the blade if you need it. Follow with squeegee. Probably not feasible
- Broom shaped like an auger
- Put behind plow at any mounting location as a groomer to pick up residual.
 - Power washer effect.
- Carbide-tipped ¼” cables hung like a rake behind the plow. Followed by squeegee. All three work independently. Spring loaded cables or squeegee to apply pressure idea from Bill Schuler. Grooves hard pack so chemicals can work.

3.3 Discharge/Plume reduction

- Curved blade
 - Horizontal curve in front
 - Horizontal curve under truck.
 - 3 blades under, like a railroad switch
 - Pivoting under body blade with curved fenders behind each front wheel.
Option: add a belt.
- Deep J blade with rubber to 6” of road. Add belt or auger to move snow down the chute. Sharp skew angle.
- 3-point hitch option with pivoting blade.
- Flexible, composite material with flutes that can be slide shifted from left to right.

- Auger with melter unit

Following the examination of the ideas put forth by the group, the discussion focused on what type of device the group should pursue. With the parameters being kept in mind that the research must be able to be implemented and a prototype device must be available for testing next winter. There will be two prototypes to be tested next winter in Iowa and Indiana.

3.4 PROTOTYPE A

This was the first design discussed.

- Underbody pivot plow design:
 - Test mounting arrangement
 - 13' clearing path—telescoping?
 - Test curvature of moldboard to move snow off the road
 - 8 way blade control
 - RR switch idea
 - Test multiple edges
 - Test adjustable angle of attack
 - Test left and right design if possible
 - Adaptable for summer shoulder work

Question: what is the wheel base?

3.5 PROTOTYPE B

- Front plow design
 - Bill: adjust all parameters because conditions always change.
 - Flexible mold board –
 - Control plume
 - Control casting
 - Adjustable attack angle
 - Adjustable pressure
- 8 way blade
- Front brine injection
- Minimum 3 cutting edges (This is in development by a vendor)
 - Carbide
 - Rake: carbide tipped cable or earth tooth
 - Squeegee
- ABAS-like system makes operator feel more comfortable at higher speeds

3.6 PROTOTYPE C

- Truck-mounted rear plow – slide on like a Truck mounted attenuator (TMA) (probably something similar to underbody)
 - 13' clearing span
 - Safer and meets more of our objectives
 - Flexible mold board –
 - Control plume
 - Control casting
- Adjustable attack angle
- Adjustable pressure
- 8 way blade
- Front brine injection
- Minimum 3 cutting edges (This is in development by a vendor)
 - Carbide
 - Rake: carbide tipped cable or earth tooth
 - Squeegee
- Moldboard may be similar in depth to underbody
- Extend chute for spreader
- Issue: how can we pull a brine trailer?
- Can we put the plow on the tongue of the brine trailer
- Allows for bringing in contract trucks and drivers
- Negative load on hitch. Big issue.
 - Note: Take tripping mechanism out of plow when operating at an angle.
 - Build in a shear-point concept to eliminate a catastrophic event. Shear bolts

3.7 PROTOTYPE D

Philosophy: Front plow that usually runs in non-contact mode
Underbody or trailer unit with the features below

- Trac 3 fusion blade idea
- Develop a 3-blade mechanism
 - Carbide
 - Rake
 - Squeegee
- 13' clearing capability. Extension moldboard
- Shape to obtain optimal cast and plume control
- Not on front: amid ships or trailer
(It was noted that the rake in front of moldboard has not been effective in previous versions.)

3.8 PROTOTYPE E

- Trailer–Test bed to test blades
 - Trailer with truck towing underbody blade
 - Test combinations of blades
 - Provides ability to test various combinations, gets away from under the truck constraints.

A discussion ensued of the merits of all prototype designs. A vote was taken and it was decided that due to the parameters of constructing two prototypes in time to test for next winter and with the limited budget that Prototypes B and C would be constructed and tested. The project will now begin to test a front plow design and a truck mounted rear plow design. Iowa will test the rear mounted plow and Indiana will test the front plow designs.

The Indiana group will test Prototype Device B as follows:

PROTOTYPE B

- 13' clearing span
- Front plow design
 - Adjustable attack angle
 - Adjustable pressure
- 8 way blade
- Front brine injection
- Multiple (Minimum of 3) cutting edges (This is in development by a vendor)
 - Carbide
 - Rake: carbide tipped cable or earth tooth
 - Squeegee

The Iowa group will test Prototype Device C as follows:

PROTOTYPE C

- Truck-mounted rear plow – slide on like a Truck mounted attenuator (TMA) (probably something similar to underbody)
 - 13' clearing span
 - Safer and meets more of our objectives
- Adjustable attack angle
- Adjustable pressure
- 8 way blade
- brine injection
- Minimum 3 cutting edges (This is in development by a vendor)
 - Carbide
 - Rake: carbide tipped cable or earth tooth
 - Squeegee
- Material chute extension for spreader

The next step for the project team will be to assemble design drawings of the two prototype designs to be constructed. The ISU/CTRE team will begin the design of the prototypes as soon as possible. The group will stay in contact via email and other means, to inform one another on the progress of the project.



Picture 1: Participants examining ABAS system



Picture 2: Examining squeegee blade system



Picture 3: Squeegee blade system



Picture 4: Discussing new approaches



Picture 5: Explaining the ABAS system



Picture 6: Iowa DOT snowplow with squeegee blades



Picture 7: Iowa DOT snowplow with ABAS system



Picture 8: Discussing squeegee blades



Picture 9: Checking out the snowplows



Picture 10: Snowplow with squeegee blades



Picture 11: More group discussions



Picture 12: Checking out the snowplows



Picture 13: More snowplow discussions