Snow Removal and Ice Control for Ground Transport Channels and Terminals

Eugene Y. Huang, Michigan Technological University, Houghton, Michigan

A study was undertaken to determine the current state of the art of snow removal and ice control for ground transport channels and terminals in the Upper Great Lakes Region of the U.S. Selective interviews were made of engineers and individuals in the region who were intimately involved on a daily basis with local snow and ice problems. A seminar-workshop was also held to provide information exchange and experience sharing by those who had considerable interest in or working knowledge of these operations in the area. This paper is a brief summary of the findings of the research effort.

The Upper Great Lakes Region of the United States, embracing northern Minnesota, northern Wisconsin, and the Upper Peninsula and northern portion of the Lower Peninsula of Michigan (Figure 1), covers an area of 300 Gm^2 (116 000 square miles) and harbors a population of approximately 2.9 million. The region is predominantly rural and somewhat underdeveloped, and is located in the snow belt of our northern border where the annual snowfall averages between 1.3 m (50 in.) and in some areas as much as 7.4 m (290 in.) in a single season (Figure 2). The first snow varies with the locality and, from available records, dates from October 1 in Upper Peninsula of Michigan to October 16 in northern Minnesota and Wisconsin. The average annual number of days in which snow falls ranges from 80 days in the extreme upper part of Michigan to about 50 days in the other parts of the region. In addition, the entire area is exposed to winds that traverse the lake from most of the directions of the compass. These winds, coupled with a fairly low mean temperature, pile the heavy snowfall into drifts that may reach heights up to 3.0 m (10 ft) or even 4.6 m (15 ft).

The movement of people and goods within the region and to and from locations outside the region depends largely upon a network of land transportation routes, including both highways and railways, and limited air transport service. Water transport is easily interrupted by bad weather and winter ice, and is confined only to low-grade freight for which speed is less important than quantity movement, even under suitable operating conditions. Because of the public's complete dependence upon the uninterrupted use of the highways, railroads, and airports during the long and severe winter months, snow removal and ice control for these facilities are vitally important. The amount of money expended each year for these activities varies a great deal from place to place, depending in large measure on the length and intensity of storms and the amount of snowfall in a particular area. It is estimated, however, that it amounts to many millions of dollars each year for the entire region.

The current practice for snow removal and ice control has developed, generally speaking, through trial and error methods within a particular area, and by training operators on the job in the procedures which the local experience has determined best suited to the conditions. While very little organized research has been conducted, the present state of the art seems in most instances adequate for meeting the local demand for maintaining the desired service conditions for the ground transport facilities in the region. In an effort to evaluate the performance of these operational systems, an investigation was undertaken to determine the current state of the art, with an objective of identifying problem areas, as well as future research needs. Initially, a literature review was conducted to determine various aspects of the problem, including basic approachs of snow removal and ice control and the present-day procedures and equipment employed. Selective interviews were made of engineers and individuals in the region who were intimately involved on a daily basis with local snow and ice removal problems. In addition, a seminar-workshop was held to provide information exchange and experience sharing by those who had considerable interest in or working knowledge of, these operations in the area. The participants included city and county road commission engineers, engineering administrators and research personnel from state highway agencies, airport maintenance engineers, and other qualified persons. This paper is a brief summary of the general findings of the aforementioned research effort.

Snow Removal Practices

Snow removal from land transportation channels and terminals may be accomplished by mechanical clearing of snow in its solid state, or by melting and draining it off at water. Because the energy

Figure 1. The Upper Great Lake Region.

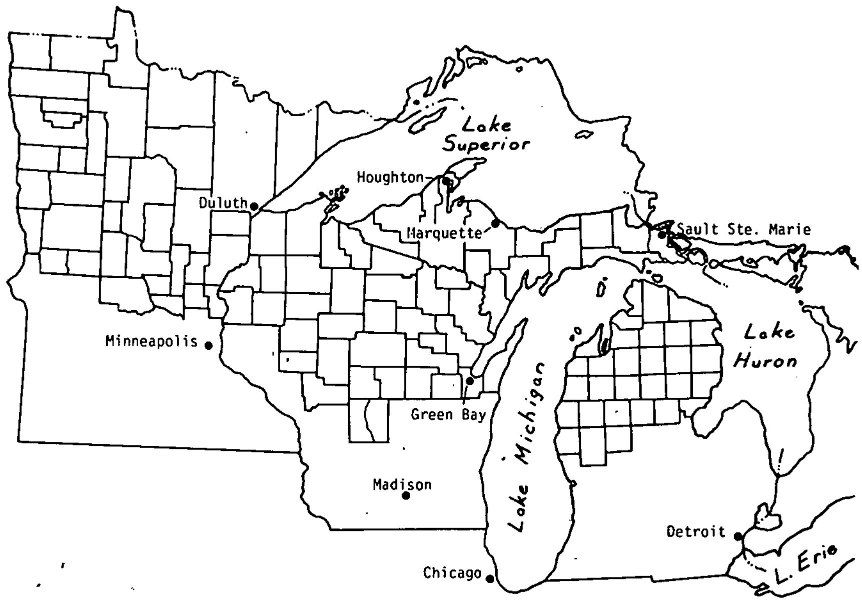
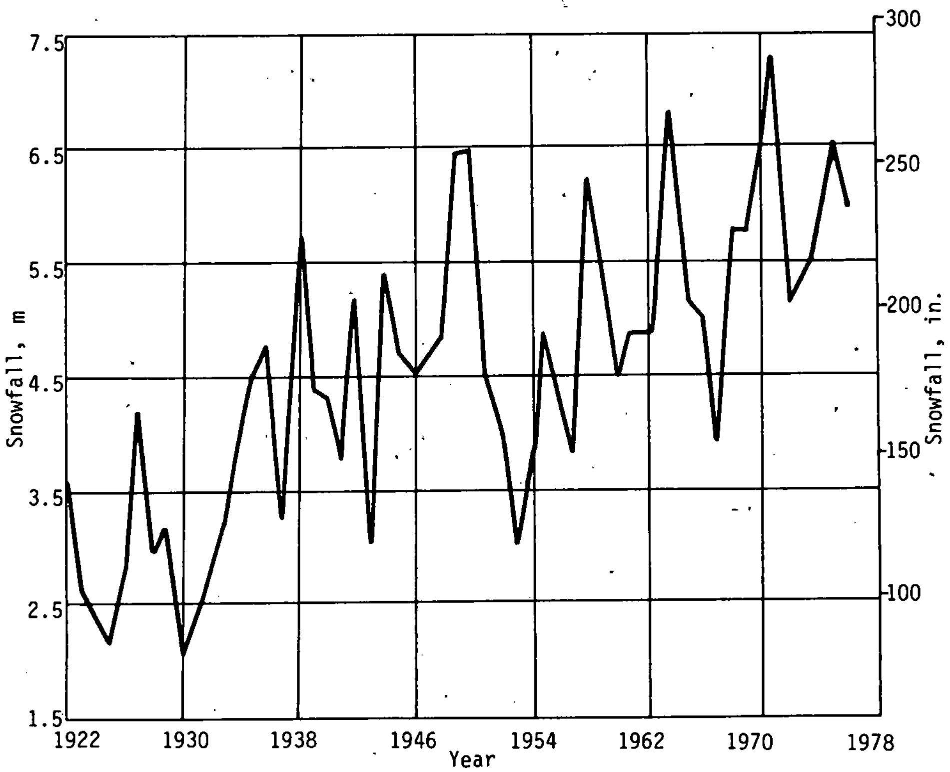


Figure 2. Snowfall in Houghton County, Michigan (1922-1976).



requirement for mechanical removal is much less than that for melting, bulk removal is commonly done by plowing. Melting is needed, however, in situations where no storage space is available in the vicinity of a transport channel or terminal, or long hauls are required for its disposal.

Equipment commonly used for clearing snow mechanically includes various types of self-propelled power units equipped with one or more attachments. Typical equipment embraces trucks equipped with underbody blades and front mounted one-way plows, with or without wing plows; V plows with or without wing plows; motor graders equipped with V- and wing plows, or one-way and wing plows; and rotary plows mounted on chassis. Among the power units, truck equipment is the most commonly employed. Trucks of 2.3 to 4.5 Mg (2 1/2 to 5 tons) are used extensively for light snow removal, but preference under heavy conditions is often given to trucks of 14 to 18 Mg (15- to 20-ton) or more capacity. The proper kind of equipment depends upon the type and location of channel or terminal facilities; the storm conditions, particularly the amount and nature of snow drifting tendencies; the condition of traffic; and upon the specific standard of clearing which may or must be adopted.

Snow removal is essentially an emergency operation, and work is strongly affected by organization and training factors. The nucleus of the work force is formed, as a rule, by the regular maintenance personnel of an agency, supplemented with other workers who may be called into service in times of heavy snow. It is essential that all personnel be instantly available for work, and for each person to be thoroughly familiar with his particular phase of the operation, as well as the peculiarities of the area in which he is assigned. Since snow removal often involves long hours of disagreeable and uncomfortable work, good morale is important, thus the selection of supervisors and operators is an important feature of the organization. In order for the organization to operate efficiently, constant training of personnel is also necessary. Many snow removal agencies hold training sessions prior to the winter season. The purpose is to teach those who are experienced in the many intricacies of the various pieces of equipment, and those who have had previous experience the latest development in equipment and organization methods.

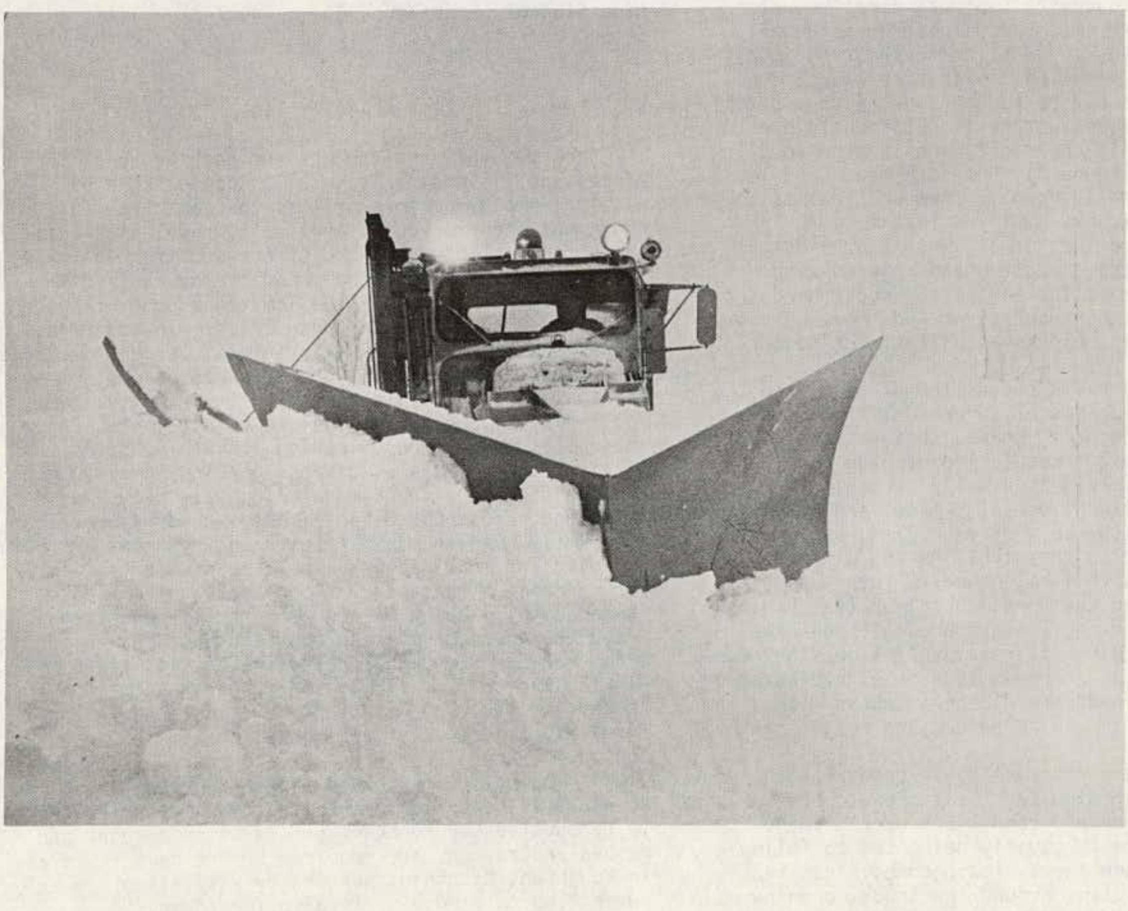
In addition, an advanced warning and information system to make snow removal operations readily responsive to public needs is extremely important. To determine the expected magnitude of the problem, arrangements are usually made with local U.S. Weather Bureau offices and airport weather observation stations for complete daily weather reports, and for special and detailed forecasts in case of an approaching storm. In highway work, many agencies maintain a weather reporting service, with all maintenance units reporting adverse weather or road conditions to a central office. The collected data is then rebroadcast through local radio stations to serve as a source of information for the traveling public.

Snow Removal on Rural Highways

Removal of snow from rural highways in the Upper Great Lakes Region is performed essentially by the long established method of plowing. While the basic approaches are similar to other parts of the country, the types of equipment and techniques for their use sometimes differ because of the unique geographic location and climatic condition of the region. Due to the severity of the quickly successive storms, snow handling equipment must be provided in order to cope with the worst conditions promptly and efficiently. Furthermore, since the winter work extends to about six months, and sometimes from October through early May, many engineers feel that specialized equipment is highly important. It is generally recognized, for example, that winter maintenance equipment such as trucks and graders must be greater, heavier, and more powerful than those for summer work such that converting summer maintenance equipment for winter work is regarded as impractical and wasteful.

For rural roads with high traffic volumes, the current practice generally requires that "bare pavements" be provided as expeditiously as possible. "Bare pavements", however, may be specified only

Figure 3. Truck - Mounted V-Plow with Side Wing.



near the centerline to give traction in both directions for low traffic volume roads if it is impractical to clear the entire traveled way. The priority of snow removal is established on the basis of the types of facilities and their traffic volumes. In Michigan and Wisconsin, county road agencies are usually contracted to perform winter maintenance on the state highway system in addition to work with the local roads under their jurisdiction. During critical storms, priority is always given to the maintenance of state highways. Moreover, in the Michigan state highway system, those channels carrying 1 000 vehicles or more per day have higher priority, and work on these sections is continuous after each storm until the pavement is completely cleared. For state highways carrying less than 1 000 vehicles per day, clearance of snow and ice is required until 1.8 to 2.4 m (6 to 8 ft) of the bare pavement is obtained. In regard to the county and local road system, school bus routes are generally priority roads for snow removal. In addition, many miles of local roads carrying only a small volume of traffic during the winter months are maintained with a compacted snow surface, which under sustained cold weather is capable of carrying vehicles so long as it is properly sanded to provide sufficient traction.

For a snowfall with little wind to drift, plowing is started as soon as travel becomes difficult. Trucks with one-way plows and underbody blades are commonly used because of their rapid movement, up to 56 to 64 kilometre/hour (35 to 40 mph) on fairly smooth road surfaces, thereby casting snow far onto the roadsides. These plowing units can also clean the snow closer to the road surface than V-plows do. The maximum depth of snow which can be moved depends on the power or traction of the vehicle and the height of the plow. In case of heavy snowfall with drifts involving an accumulation of 0.3 m (1 ft) or more, trucks equipped with V-plows, sometimes also with side wings are employed. These units usually operate at speeds up to 48 kilometre/hour (30 mph) without wings in operation. With side wings, the speed of operation may be reduced, but a considerably added width of plowed surface is obtained in one trip. Usually, only the right wing is used to allow traffic to pass (Figure 3), but both right and left wings are occasionally used if snow and traffic conditions permit. Trucks employed in this work are usually all-wheel drive, of at least 7 or 9 Mg (8- to 10-ton) rated capacity, and powered with either diesel or gasoline engines. Trucks used for plowing generally carry abrasives and, for heavy units, with concrete blocks as ballast for better traction.

Because of the rapid succession of storms in the region, and the problems of severe drifting associated with these storms, special efforts are needed to prevent the rapid accumulation of high snow banks along road sides. This is usually accomplished through the intelligent use of V-plows and wings to properly disperse the snow at each pass, so that the snow is not pushed up too high. As the windrows increase in size with time, however, rotary plows are needed to widen the roads and clear the shoulders for future snow storage (Figure 4). Although the speed of these machines is relatively slow, they can nevertheless move an enormous tonnage of age-hardened snow. After the roads are widened, trucks with side wings are then called on to reduce the height of the side banks.

Rotary plows are also useful in opening roads when drifts are too high for the V-plow to break through. In such severe conditions over a large area, a rotary plow is usually delegated to follow a V-plow unit. When the V-plow becomes stuck in a drift, the rotary plows around the truck, opening the rest of the drift, thus permitting the plow to proceed.

To control the drifting problem, portable and permanent snow fences are erected at critical locations parallel to and usually not closer than 23 to 30 m (75 to 100 ft) from the roadway centerline on the side of the roadway from which prevailing winds blow. These fences facilitate drifting of snow but confine it to the space between the fences and the roadway instead of covering the roadway. Since wind velocity, slope of ground, height of fence, and other factors influence the effectiveness of a snow fence, each location is studied as a separate problem and determined by a trial-and-adjustment method.

Motor grades equipped with V-plows and side wings are also widely used in removing snow. For light snowfall, a motor grader with its moldboard and wing can clean the pavement and shoulder in one trip, although the movement may not be as fast as a truck plow unit. Motor graders are usually employed, however, in locations where truck units with one-way plows and underbody blades cannot handle the situation alone. A motor grader can break the path with its V-plow, and use the moldboard to clean the road surface. Where the drifts are deep, the operator may choose to pull up the side wing and moldboard, pouring all the power into the V-plow. He may also use only the V-plow to wedge back snow that is already piled high from previous operations, then make another pass with the moldboard down to shave the snow closely. Motor graders are particularly useful in breaking up impacted snow on the pavement. With their wings, motor graders are also employed to cut down snowbanks, throwing the snow farther away from the roadway, thus giving truck plows enough room for the next layer of snow during the successive storm. One advantage of using motor graders for snow removal is that one man can operate both the moldboard and side wing of a grader. For a truck-plow unit, a second operator is usually needed to handle the wing.

Snow Removal in Cities and Villages

Snow removal from streets and parking areas in cities and villages is generally accomplished by plowing, employing more or less the same types of equipment and procedures applied to rural highways. In most cases, however, the strategy of removal also includes provision for the immediate or early disposal of snow because of the limited amount of space available for storage in these areas. In addition, high-speed plowing is usually infeasible due to close maneuvering requirements, the presence of obstacles, and the danger of violent casting to property.

The usual operation consists of plowing the snow into piles or windrows, loading it into vehicles, and hauling it to places of disposal. Plowing is in general performed by truck-mounted one-way plows, with or without underbody blades. Motor graders are also frequently used in many cities. Rotary plows are not employed for routine work; they are used primarily for widening streets or parking areas. The windrows pushed up by plowing may be temporarily deposited along the edges of streets or, in urban areas with wide roadway, along the centerline to facilitate parking and traffic flow. The gathered snow is then loaded for disposal without delay, a procedure particularly important if additional snowfalls are expected. Since parked cars often interfere with the plowing operation, extended parking during heavy snowfall is generally prohibited by city ordinances. In communities where heavy snowfall is frequent and removal operations are required before dawn, such as in Houghton, Michigan, parking on city streets between 2:00 to 7:00 a.m. is also forbidden.

Figure 4. Rotary Plow Dispersing Windrow Formed by V-Plow.

Plowed snow is commonly disposed of by hauling it in trucks to convenient dumping areas such as lakes, rivers, vacant lots, or outlying districts where it will not be objectionable. The trucks are loaded by rotary plows, fitted with chutes for the operation, and by bucket loaders. Flushing of snow by means of mobile snow melters, a method being experimented with by a number of large north American metropolitan areas where problems of snow disposal are created by increasing transport distances to fewer available dumpsites, is seldom considered in the Upper Great Lakes Region since the area is predominantly rural and does not lack space for snow disposal.

While "bare pavements" are required for the major streets in many cities in the region, there are numerous small communities that have adopted the policy of maintaining a snow cover for their streets during the winter months. In these places, the snowfall is generally so heavy and the cold is so intense that the snow does not melt appreciably until spring. Under these circumstances, it is not so much a question of completely removing the snow as it is making the streets passable. The roadway is thus only smoothed out by plowing after each storm, and the surface is sanded regularly to provide traction.

As in rural work, the snow removal strategy in cities is formulated well in advance of the snow season. It is essential that every responsible member of the organization knows his duties and has the necessary equipment in good condition and available for immediate use. In common practices, a city is divided into a number of districts, each having its equipment and operators assigned for the snow season, under the supervision of a foreman. The same operators are usually assigned to the same equipment and districts to provide familiarity with road and traffic conditions, drifting tendencies, and other particular problems in the area. In addition, auxiliary equipment and personnel are stationed at convenient locations and held in readiness to give assistance in case of need. Before the snow season, markers are placed at drainage structures, hydrants, guardrails, and other required points, to guide equipment operators, and to help avoid damage both to equipment and objects marked. A commonly used marker consists of a 5 cm by 5 cm (2 in. by 2 in.) stake with the top painted different colors to indicate the type of object.

Snow Removal in Airports

Snow removal in airports involves several types of equipment similar to those for removing snow from highways and streets. The operation is somewhat different, however, because of the extensive width of the surfaces to be cleaned, and because of the fact that a time limit is imposed to make the facilities operational. Consequently, proper removal techniques, and efficient organization of equipment/manpower are even more important than those required for clearing snow from other types of ground transport facilities.

Among the various areas to be cleaned in an airport embracing runways, taxiways, parking aprons, and other pavement areas in the terminal, runways are as a rule given priority. Snow removal usually starts when the accumulation reaches a depth of approximately 5 cm (2 in.). The equipment most commonly used consists of truck-mounted one-way plows, with or without underbody blades, which are teamed with rotary equipment, also mounted on trucks. The truck units may have a gross weight as much as 25 Mg (27 ton) to provide weight and power for high-speed operation, and are equipped with chains for better traction. The clearing procedure is largely controlled by the condition of the wind. Without crosswinds, plowing generally begins from the centerline of the runway, where right-cast one-way plows, operated in tandem, move the snow progressively outward to both sides of the runway. Rotary plows are then employed following the one-way plows to clear the windrows from the edge and from around the runway lights. In areas of heavy snowfall, extra widths beyond the runway are also cleared for storage of snow during the rest of the winter season.

With crosswinds, plowing will generally start from the upwind edge, working across the runway toward the downwind edge, so that snow is moved with the wind, and drifting is minimized by limiting the windrows to windward. For these operations, reversible type of plows are particularly desirable because the plow direction can be reversed to cast the snow downwind on the return trip as well as the initial pass. In general, operation of one-way plows is not influenced by adverse winds to the same degree as rotary type of equipment. When it is impractical to move the snow with the wind, dispersal of windrows by rotary plows may have to be postponed until there is a shift of wind direction. Wind conditions are also considered in planning a clearing operation of other areas in an airport. When equipment is unable to cope with the snow during storms of unusual intensity, priority treatment is usually given to the in-the-wind runway and taxiways serving it.

The clearance of large aprons and other areas may sometimes be hampered by parked aircraft or vehicles, as snow cannot be removed by pushing it from one side of the area to the other by one-way plows. In this case, removal is accomplished by loading the snow into trucks by front-end loaders, and hauling it to suitable disposal places. Following the operation of one-way plows, motor graders are sometimes utilized to keep the plowed area as bare as possible. With moldboards, motor graders can usually remove the small amount of snow on the pavement that the one-way plows cannot move. Motor graders are also used to clean the snow when it is falling lightly or the accumulation is not appreciable.

For the snow removal program to function efficiently, the airport manager and his crews must be constantly prepared for immediate action. Complete weather reports, as well as special and detailed forecasts in case of an approaching storm, are obtained from the weather station at the airport in order to be aware of developing conditions. Two-way radios are commonly used as dispatching equipment. These units provide the necessary communication between the central office and individual operations in the field. They are of particular value in dispatching equipment in trouble spots during a storm, and in summoning aid in case of equipment breakdown or empty fuel tank.

Snow Removal on Railroad Tracks and Terminals

Removing snow from railroad tracks and terminals requires an array of mechanical devices most of which are specifically designed for this purpose. In plowing snow from main line and branch line tracks where accumulation is deep enough to impede or stop progress of trains, various types of V-plows and rotary plows are employed. These plows are usually mounted on a specially built car with heavy steel frame construction and powered by locomotives which are capable of supplying a tremendous amount of propulsive force for the clearing operation. In addition, truck-mounted units similar in design to those used widely on highways and equipped with flange caster wheels, are used both for off-track and on-track operations. These units may be powered by either gasoline or diesel engines, and provide a mobile task force which can be shifted from point to point as trouble develops.

Some locomotive-powered V-plows have a separate hinged nose section which can be lowered or raised between or above the rails, and movable hinged wings which can be adjusted out from the side of the plow. Plows without wings will throw the snow clear of the right-of-way. On main line track, these plows are usually operated between 32 to 56 kilometre/hour (20 to 35 mph), depending on the locality and depth of snow. Rotary snowplows are used principally for clearing snow drifts that are too deep and compacted for ordinary railroad snowplows to handle. The speed of operation depends on the depth and density of snow, but usually reaches about 11 to 16 kilometre/hour (7 to 10 mph). Rotary units may load snow into cars, trucks, or blow it into open fields. For clearing operations on lines, ample space is usually available alongside the tracks for snow storage.

Another piece of railroad equipment for handling snow is the flanger, used mainly to clear snow which is not too deep over the rails and to follow up on heavy plowing. A flanger is a metal scoop type blade mounted under the center of a car. It can be adjusted pneumatically or hydraulically to cut 5 cm (2 in.) below the rail top, thereby providing flangeways for the wheels so as to increase adhesion of locomotives and reduce resistance to car wheels, guarding against the freezing of snow following sleet or cold rain. Flanger cars are usually attached to the rear of passenger or fast freight trains, and operated at a speed of 48 to 64 kilometre/hour (30 to 40 mph). A

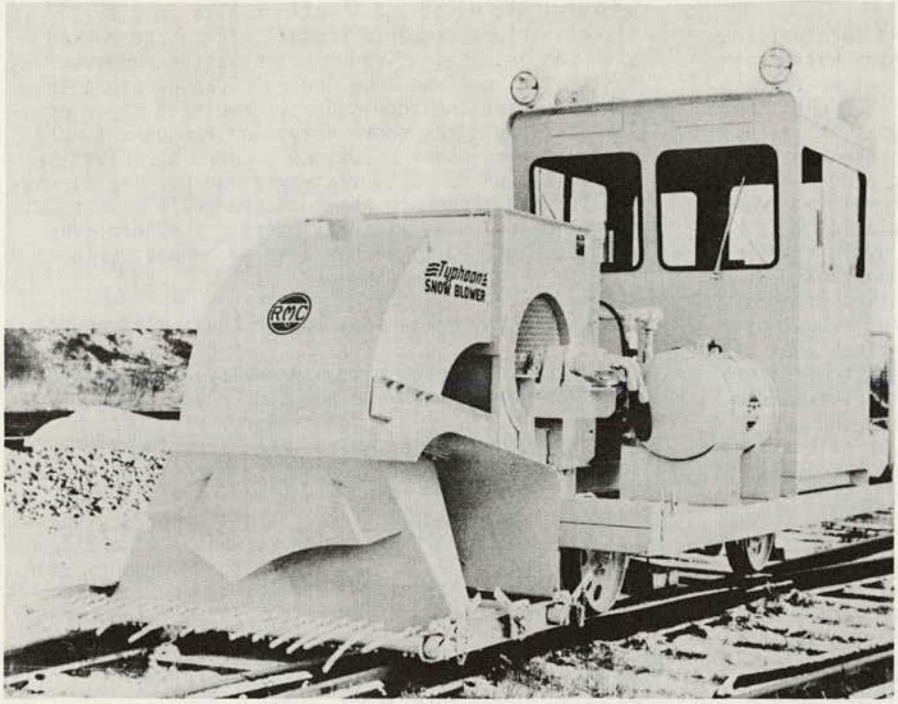


Figure 5. Self-Propelled Snow Blower for Removing Snow from Switches.

fairly fast operating speed is required so that the snow is thrown as far as possible as it is scooped up by the blades. At 56 kilometre/hour (35 mph), the snow can be thrown about 12 m (40 ft) outward.

It is generally recognized by railroad men that snow and snow removal present more problems in terminals and yards than on line of road, because combating snow on line usually involves only plowing the tracks clear, whereas in most terminals entire removal of the snow from the yards is necessary. For clearing operations in terminals, track-mounted spreaders are often used, in addition to the V-plows and rotary plows. These spreaders are built primarily as ballast spreading machines, but can be used in place of, and sometimes in conjunction with, snowplows. The spreader has a wide wing spread, making it adaptable for spreading snow across yard tracks. It can be used as a snow plow by equipping it with a detachable high plow, making the machine a combination unit which can both plow and spread snow. When thus equipped, one spreader will often do the work that is otherwise required to be done by a plow and a spreader working as separate units. The principal use for spreaders is in railroad yards where the tracks are cleared by pushing the snow off one track to another successively throughout the width of the yard to a point where it can be piled or loaded.

One of the serious threats to railroad operations is the stoppage of switch movements by packed snow or ice, and various types of snow melting devices are used to keep switch points sufficiently free of snow to insure operation. This is usually accomplished by the application of heat to the rails in the point area to raise the temperature of the steel parts and thus melt the snow. Portable devices, such as snow melting cans, are used to pour a flaming liquid on snow or ice to be removed. These cans are equipped with a pilot wick on the discharge nozzle which ignites the fuel immediately as it leaves the nozzle. Electric tubular heaters, placed under the stock rails and controlled by hand or thermostatic switch from interlocking towers, are permanent melting devices. In addition, gas heaters consisting of burners laid outside the head of the stock rail, lighted automatically or by hand, direct flames against and underneath the stock rail. Sometimes, physical removal of snow from switches is made by mechanical or manual means. In regions where temperatures are low and the snow is dry and powder-like, mobile air compressors are used to blow the snow from tracks and switches. A typical self-propelled machine, as shown in Figure 5, utilizes a centrifugal fan which blows air through a nozzle at a high velocity. The nozzle is adjusted hydraulically from top-of-rail elevation to 0.3 m (12 in.) above the rail. Steel cable fingers loosen the snow immediately ahead of the nozzle. This allows the snow to be blown clear of the track and dispersed into the atmosphere where wind currents carry it away for settlement over a larger area.

As in any other snow-fighting campaign, effective snow removal from railroad tracks and terminals requires advance planning and centralized direction. Preparations for these operations usually begin long before the first snow falls. Printed instructions are issued which make specific assignment of men and equipment for each location. At prewinter meetings of key personnel, the plan is reviewed to make certain that each man understands what has to be done in advance and exactly what his responsibilities will be when snow starts to fall. Snow fences are placed at strategic locations to reduce wind velocities and cause the snow to drift before it reaches the roadway. In actual operation, special emphasis is placed on obtaining weather reports regarding approaching storms, keeping the equipment in operation at the earliest possible moment after the start of a storm, and operating it at frequent intervals to keep the situation under control. In addition to track and yard areas, platforms, walkways, and driveways are kept clear for the convenience and safety of employees and the public, and to prevent damage claims. Equipment for these areas usually include dump trucks equipped with one-way plows, mechanical brooms or sweepers, front-end loaders, and other conventional snow removal machines.

Ice Treatment Procedures

Ice on transportation channels and terminals may be formed by packed snow or slush which hardens in place before it is removed, by frozen water from melted snow or ice which drains across or onto the surface, or by sleet or rain freezing as it falls. While some of the formations can be prevented by effective snow removal techniques and proper drainage provision, ice coatings on roadways resulting from precipitation or unpreventable accumulation must be controlled or treated in some way to avoid traffic hazards caused by skidding. The common treatment procedures consist of (1) the application of abrasives on the icy surfaces, and (2) the removal of ice by mechanical or/and chemical means. The types of treatment depend largely on the ambient temperature and the adhesion characteristics of the ice. From the viewpoint of transportation safety, channel and terminal areas must be treated wherever slippery conditions exist and for as long a period as necessary.

Application of Abrasives

Abrasives commonly applied on icy roadways to improve traction and braking performance of vehicles include sand, cinders, stone screenings, slag, and other appropriate materials. The abrasive material must have grains that are clean, hard, sharp, and free from clay lumps. Experience has also shown that material containing an excess of fines does not provide good traction. Likewise, coarse material is likely to whip off the surface, thus it is ineffective in combating skid hazard. An abrasive generally favored by engineers in the Upper Great Lakes Region is an angular coarse sand, although consideration of local availability and unit cost often determine the choice of many other materials.

Abrasives in bulk are commonly placed in bins, sheds, and covered stockpiles prior to the first storm in the fall. Occasionally, they are also stored in the open. Since these materials almost always contain moisture, calcium chloride at a rate of 29.6 to 59.3 kg/m^3 (50 to 100 lb per cu yd), depending on the type of abrasives, is usually incorporated and mixed thoroughly with the abrasives to prevent the grains from freezing together in the stockpile. The treatment also serves as an aid to anchoring the material in the ice or packed snow, thereby keeping it from being blown off the surface. The loading of abrasives into trucks for application is speedily done by gravity discharge, conveyor, or bucket loader. In addition, abrasives in small quantities are often placed in barrels along the roadway or in locations where hazardous conditions exist. These materials are provided for use by the public, if necessary, before regular application can be made by the maintenance forces.

Abrasives are distributed from trucks with a mechanical spreader operated by a power take-off with the control mechanism in the truck cab. The amount of abrasive to be used varies with the type of ice and the weather conditions. The areas where immediate treatment is needed after icy conditions develop include hills, curves, schools, approaches to railroad crossings, and intersections. As in snow removal operations, priority of the treatment work is established in advance on the basis of such items as volume and type of traffic, geometric design, and topographic conditions. In general, major channels and traffic areas are treated with abrasives for the entire length or surface, whereas spot treatments are often made on less important facilities, depending on the needs in a particular situation.

Abrasives are used extensively for ice treatment on rural highways, and sometimes also on city streets before complete removal of ice and packed snow can be made. Clogged catch basins and sewer systems, as well as complicated clean-up operations at the end of the snow season, have been major problems in some areas where heavy and frequent treatment had been made. Chlorides treated abrasives are prohibited on runways, taxiways, and parking aprons in airports, inasmuch as these chemicals may promote corrosion of metal aircraft parts. The abrasives are often heated to anchor them on runway surfaces.

Ice Removal by Mechanical and/or Chemical Means

Mechanical means commonly employed for removing ice from paved areas include trucks equipped with underbody blades and motor graders. The underbody blade is a hydraulically operated scraping device fitted beneath a heavy truck; the blade can be hydraulically loaded to give vertical pressure at different angles of attack. To get good results it has been reported that the gross weight of the truck must be over 10.9 Mg (12 tons). Motor graders that are capable of exerting a sufficient vertical pressure on the moldboards are also used for the same purpose.

The effectiveness of mechanical ice removal is largely dependent upon the ambient temperature and the condition of the ice. In general, ice on the pavement can be completely removed at a temperature near its melting point. At temperatures below this point, often only the top portion of an ice layer can be successfully removed by scraping. The lower portion may sometimes be so tenaciously adhered to the pavement that it is practically impossible to break it away from the pavement without damaging either the pavement or the blade. Because of the inadequacy of mechanical equipment of exposing bare pavement, chemical means are widely employed either alone or in combination with mechanical means for better results.

For highway and street work, both calcium chloride and sodium chloride are extensively used for ice removal. Raw sodium chloride in the form of rock salt is used for clearing the pavement of ice or compacted snow when the temperature is above -6.67 C (20 F) or at approximately -6.67 C (20 F) and rising. The chemical is applied by mechanical spreaders at a rate ranging from 28.2 to 84.6 kg per lane per km (100 to 300 lb per lane per mile), depending on the degree of control required, traffic volume, climatic conditions, weather predictions and other considerations. For a very thin film of ice on a rural two lane highway, the chemical is spread nearly over the full pavement width. For a heavy accumulation of ice on the same facility, the application is concentrated near the high point of the pavement crown, allowing the brine to loosen the accumulation of ice from the pavement surface as it works to the pavement edge. The accumulations of loosened ice or snow is then removed by mechanical means to prevent refreezing to the pavement.

For temperatures below -6.67 C (20 F) and lowering, but not less than -17.78 C (0 F), calcium chloride is added to the sodium chloride, in amounts usually no more than 25 percent of the weight of sodium chloride. The calcium chloride starts and accelerates brine action at this temperature range where sodium chloride alone is less effective. For temperatures at -17.78 C (0 F) and lowering, raw chlorides are usually ineffective, and treated abrasives are applied at critical areas to provide suitable traction.

In addition to ice removal operations, chlorides are used to prevent ice formation on highway or street pavements. This practice is used when snow compacts under traffic and adheres to the pavements, during freezing rains or immediately following plowing operations if snow still remains on the pavement. Experience has shown that traffic packed snow usually occurs between -7.78 to 1.11 C (18 to 34 F), and blading operations will begin when approximately 1.27 cm (0.5 in.) has accumulated on the pavement. Sanding and salting operations will follow the blading as closely as possible with only minimal chemical treatment to sufficiently remove the small amount of snow left after blading. When the temperatures are -6.67 C (20 F) and rising, the minimum amount of 84.6 kg of sodium chloride per km (300 lb per mile) should be sufficient. If the snowfall continues, this application will aid in preventing the snow from bonding the pavement. The procedure will eliminate the necessity of using excess amounts of chemical and blading off of varying amounts of loose slush and snow after the chemical action has taken place. As the storm continues, underbody blades will be kept in operation to hold the accumulation of packed snow on the highways to a minimum. This may make salting and sanding operations unnecessary except for hills, curves, railroad crossings and intersections. At such locations, a stronger mixture of chemical may be necessary during a heavy snowfall.

In the case of freezing rains and sleet storms, sodium chloride or a mixture of sodium chloride and abrasives are spread as soon as ice appears on the pavement. Generally, one application of 56.4 to 112.7 kg of chloride per km (200 to 400 lb per mile) on the middle of a two-lane pavement will suffice to dissolve existing ice and provide a bare pavement when the storms have passed. Blading operations are usually needed to remove the accumulated slush and snow from the pavement to prevent refreezing. In the event of rapidly dropping temperatures, little chemical reaction can be obtained by sodium chloride alone. Under this situation, ice can usually be removed by a mixture of sodium and calcium chloride, or by hydraulic blades at an appropriate pressure.

Although chlorides have been used for many years to de-ice highways and streets during winter months, questions have been raised recently concerning the wisdom of unrestricted spreading of excessive quantities of these chemicals into our natural environment. Because chlorides are readily dissolved in water, and because snow or ice is the solid form of water, any chloride-snow mixture will eventually result in disappearance of the salt into solution. Dissolved chlorides may enter streams, rivers, lakes, and water supplies situated close to the channel and terminal facilities resulting in water pollution. High chloride concentration can cause injury to vegetation, vehicle corrosion, and pavement damage. It is the general opinion of many road maintenance engineers in the Upper Great Lakes Region, however, that the use of deicing chlorides, in combination with mechanical means, is the most practical and economical method of removing snow, ice, and slush from highways and streets. Sensible use of chlorides to maintain bare pavement can also save vehicle operating costs and reduce accidents. The fact that deicing chlorides can be misused and mishandled, culminating in less than satisfactory results is recognized. Consequently, it is generally agreed that these chemicals must be used sparingly in accordance with established rates of application based on local experience and variations in temperature, precipitation, pavement conditions, and other pertinent factors. To insure proper distribution, the spreading equipment must be carefully calibrated individually. Unused chemicals must be covered or enclosed in waterproof sheds and never be allowed to be stored in open fields to protect the environment from chloride contamination.

In current practice, calcium chloride and sodium chloride are not allowed as deicing agents for airport pavements because of their detrimental effects on the bodies and hydraulic systems of aircraft. Some non-corrosive chemicals have been tested in the region, but none has been found entirely satisfactory. Many airports use motor graders for clearing ice on pavements. Heated abrasives are also applied on critical areas to provide traction.

Future Research Needs

The operational systems of snow removal and ice control for ground transportation channels and terminals in the Upper Great Lakes Region have been developed through many years of experience in the field and, in most instances, have been adequate to keep the facilities in serviceable condition during the long winter months. Very little organized research has been conducted, however, to determine the effects of the properties of snow and ice, climatic conditions, terrain, traffic, geometrics, equipment, personnel, and location factors on these operations. From the viewpoint of systems planning, there is a general lack of an analytic approach that would describe and define in quantitative form the factors that affect the formulation and use of the systems for removal of snow and ice from transport channels and terminals in terms of benefits accruing to the users of these facilities. From a detailed evaluation of the input data of this investigation, the following specific areas of research seem to be needed in the development of new techniques and quantitative data for improved systems performance.

1. Establishment of performance and efficiency criteria of various types of equipment commonly used for snow removal in terms of properties of snow and ice, power efficiency, casting distance, volume or weight removed per hour per horsepower for different speeds, and other factors. Possible improvements in design and operation for better performance and higher efficiency should be considered.
2. Re-evaluation of the effectiveness of chloride salts and other chemicals for snow and ice control, as well as their social and environmental consequences in the Upper Great Lakes Region. Investigations should include a study of particular situations where treatment is seemed necessary, the proper amount of application in each case with regard to ambient temperature, pavement condition, snowfall rate, traffic volume, etc., and control procedures to minimize environmental contamination.
3. Development of models and techniques for the analysis of operational systems for maximum effectiveness of snow removal and ice control in the Upper Great Lakes Region. The analysis should be based on considerations on detailed systems characteristics, local climatic and geomorphologic conditions, properties and conditions of snow and ice, types of transportation facilities, volume of traffic, population characteristics, economic conditions, environmental consequences, and cost structure.

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