Table 5 EQUIPMENT GUIDELINES

Equipment Description	Lane miles per unit of equipment		
	City and Urban	Major Interstate	Rural
Heavy Duty Truck[1] with Spreader[2]	30	20-40	40-60
Heavy Duty Truck with Plow(s)	30	20-25	25-30
Light Duty Truck with Plow[3]	15	50-100	---
Heavy Duty Front-End Loader (greater than 1 cu. yd)	100	100	200
Light Duty Front-End Loader (up to 1 cu. yd)	100	200	400
Road Graders	200-400	100-400	100-400
Heavy Duty Snow Blowers [4]	---	300-1000	300-1000
Light Duty Snow Blowers	200-400	---	---

1. Includes large 4-wheel drive vehicles.
2. May be a combined spreader and plow.
3. May include loaders or sanitation vehicles or other plow-equipped multi-purpose vehicles.
4. May be mounted on heavy duty front end loader.

is provided for each 1.5 urban complex interchanges, two urban simple interchanges, or four rural interchanges. The truck requirements for a given road section are calculated by the equation:

$$N_t = \frac{D}{15C} + \frac{N_{A_u}}{1.5} + \frac{N_{B_u}}{2} + \frac{N_{A_r}}{2.5} + \frac{N_{B_r}}{4}$$

where

N_t = number of trucks

D = distance to be plowed in lane miles

15 = average plowing speed in mph

C = cycle time in hours

$N_{A_c} = N_{B_u}$, N_{A_r}, and N_{B_r} = the number of complex (A) and simple (B), urban (u) and rural (r) interchanges.

Of course, any equipment guidelines must be adapted for the particular needs of each unit or road section within an organization. Past experience in each road section, both with the durability or the equipment and with the productivity, has a large influence in determining the numbers, types, sizes, and the particular manufacturer of the various equipments. Much of this past experience can be based upon the various management reporting systems, such as how long it takes a driver to complete his given piece of work, or the maintenance record on a particular piece of equipment.

When equipment requirements are being established, due consideration must be given to the use of outside contractors who may have equipment available during the winter months for augmentation of the existing fleet of equipment in a given jurisdiction. When equipment needs are examined from a total cost point of view (taking into account year-round labor requirements, equipment depreciation, maintenance and garaging requirements), many organizations find that outside, rented contractor equipment (with operators and oftentimes supervisors) provides a cost-effective solution to the winter maintenance problem.

The primary thrust of any winter maintenance program should be to utilize all equipment effectively yet, at the same time not abuse it. Each organization should strive to use its most effective equipment to its maximum capacity at all times and to supplement its use with lesser capacity equipment as required during heavy storm periods. This heavy-duty, first-line equipment (spreaders with ground-speed controllers, and trucks with underbody scrapers, large front-end plows and wing plows) should always be maintained in top working condition.

Labor Requirements

Specific manpower requirements for a given road section are a function of the equipment requirements and a large number of other local variables. General practices that have evolved concerning what constitutes one-man and two-man operations are worth noting, however. The practices of the State of Minnesota Department of Highways are the examples cited here.[5]

Vehicle operation by one man is permissible:

- Whenever weather and road conditions permit a safe operation;
- For single operations such as sanding or chemical application;
- When snowfall does not result in large windrows on traveled surfaces.

Two-man operation of vehicles is used:

- If poor visibility due to blowing snow may affect a safe operation;
- For snowfall that produces large windrows requiring more than one operation to clear the traveled portion of roadway;
- On certain hazardous roadways with extensive left-turn slots;
- For operations involving use of a wing plow; or
- Any other operation considered unsafe for one operator.

Combined one- and two-man operations are used when they are safe and traffic conditions have normalized so that operations are less restricted. The types of work performed under this arrangement are as follows:

- Removal of snow from shoulders and adjacent slopes to provide additional space for the next storm;
- Removal of snow from intersections and other locations where high banks interfere with visibility;
- Resumption of normal maintenance operations; and
- Performance of any operation that will return traffic movements back to normal.

Equipment Reliability

Careful attention should be paid to routine maintenance of all equipment and especially the first-line equipment which is crucial to the winter operations program. The equipment maintenance program should focus on minimizing downtime for the first-line equipment so that it is available during the time of greatest need. Such a maintenance program requires that routine overhauls be completed during the summer and fall months, that key components of the equipment be stockpiled at the locations where it might be needed and that the maintenance personnel are available who can, by all means within their capability, get key pieces of equipment in operation in the event of breakdowns.

TRUCKS

Trucks are the backbone of all snow and ice control programs. Used for plowing and/or spreading chemicals and abrasives, they come in all sizes and capacities depending upon their use. They range from small four-wheel drive utility plows to tractor-trailer rigs for chemical/abrasive spreading on long, straight stretches of road. The choice of a truck is often controlled by its intended year-round purpose, which can result in equipment that is less than optimal for snow and ice control.

The five-ton two-axle heavy-duty truck shown in Figure 15 is the overwhelming choice of all snow and ice control organizations. Specifications for this type of truck are summarized in Table 6. Ideally, for snow and ice control this type of truck is equipped with a chassis-mounted spreader and a plow or combination of plows. The chassis-mounted spreader makes fuller use of the truck's rated capacity than does a truck with a dump body and a slip-in spreader. Chassis-mounted spreaders, however, require dismounting of the spreader in the spring and replacement with a dump body for summer operations.

The advantages of equipping such a truck with a dump body and a slip-in type spreader are two-fold. The twice annual changing over of spreader bodies is eliminated, and, through the use of a suitably designed storage rack, the slip-in spreader can be removed during those periods in the winter when there is little snow, and the trucks can be used for other operations. A disadvantage of the slip-in type spreader is that it does not make full use of the capacity of the truck. Because the tare weight of the truck, dump body, and empty spreader is greater than that of the truck and chassis-mounted spreader, less capacity is available for material for a given gross vehicle weight. Additionally, the center of gravity of a loaded slip-in spreader is higher than that for a chassis-mounted spreader. A solution to this problem is the use of a tailgate type spreader in conjunction with a dump body.

Many organizations utilize lighter-duty trucks of from 2-ton to 3-ton capacity for plowing operations. These trucks are seldom equipped with spreaders and are often used for other maintenance operations, e.g., as sanitation trucks, for landscape work, during sign and lane marker painting operations, and for general utility work. Specifications for this medium-duty truck are shown in Table 6.

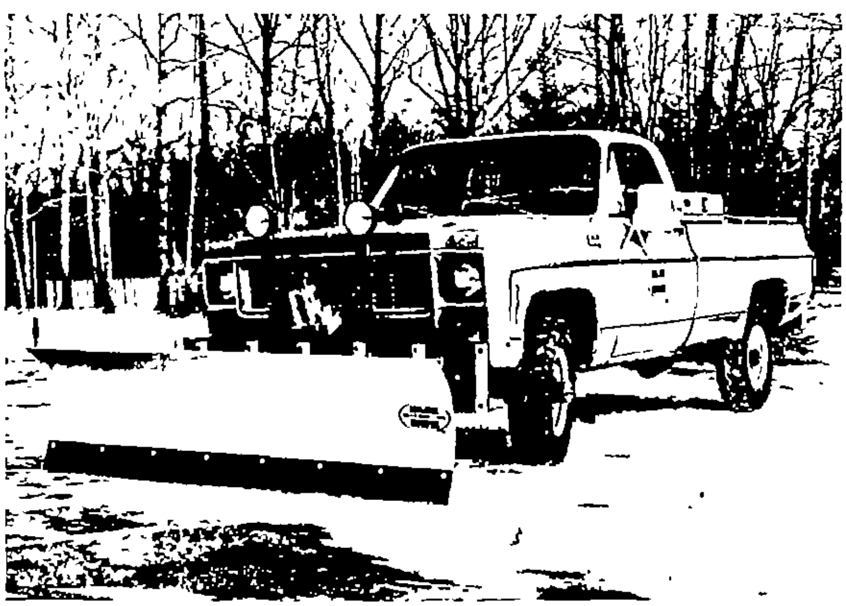
The versatile four-wheel-drive, three-quarter ton pickup truck is being used increasingly for plowing. Equipped with a two-way power angling plow, it is useful for plowing in tight areas, such as in service areas

Table 6 TYPICAL DESIGN SPECIFICATIONS FOR TRUCKS COMMONLY USED FOR SNOW PLOWING AND FOR SPREADING OF DEICING CHEMICALS

Specification	Light-duty truck	Medium-duty truck	Heavy-duty truck
Truck capacity (nominal rating)	.75 ton	2-3 tons	4-5 tons
Gross vehicle weight	7,500 lb	24,000 lb	35,000 lb
Axle capacity			
front	3,500 lb	7,000 lb	12,000 lb
rear	5,300 lb	17,500 lb (two-speed)	23,000 lb (two-speed)
Engine			
type and fuel	6-cylinder/gasoline	V-8/diesel	V-8/diesel
horsepower	125 maximum net	150 net	200 net
cubic inch displacement (CID)	300	525	635
torque	230 ft lb	320 ft lb net	465 ft lb net
Transmission	4-speed manual (2-speed transfer case)	5-speed (fifth direct)	5-speed (fifth direct)
Steering	power	power	power
Brakes	self-adjusting (cab-adjusting dual hydraulic emergency)	full air brakes	full air brakes
Springs			
front	1,750 lb	4,050 lb	6,000 lb
rear	2,700 lb	10,500 lb	11,600 lb
auxiliary	550 lb	2,250 lb	2,250 lb
Electrical system			
alternator	55 A	70 A	70 A
batteries	12 V - 70 Ah	Dual 155 Ah	Dual 204 Ah
lights	spot light, plow lights, rotating beacon	Body markers, cab clearance, plow lights, rotating beacon	Body markers, cab clearance plow lights, rotating beacon
Chassis wheel base	131 in.	154 in.	162 in.
Frame section modulus	5.5 in.^{3}	19 in.^{3} reinforced (36,000 psi steel)	15.5 in.^{3} (115,000 psi)
Rim size	16.5 in. x 6.0 in.	20 in. x 7.0 in. cast spoke	20 in. x 8 in. cast spoke
Tire size and ply	tubeless 8:00 x 16.5 8 ply rating	9:00 x 20 12 ply rating	11:00 x 20 14 ply rating
Miscellaneous			
mirrors	dual 7 in. x 11 in.	16 in. x 7 in. West Coast	16 in. x 7 in. West Coast
heater	heavy duty	heavy duty	heavy duty
anti-freeze protection	10°F below anticipated minimum	10°F below anticipated minimum	10°F below anticipated minimum
engine block heater	yes	yes	yes

Courtesy of Root Spring Scraper Company, Kalamazoo, Michigan.

FIGURE 15 FIVE-TON, TWO-AXLE, HEAVY-DUTY TRUCK WITH UNDERBODY SCRAPER



Courtesy of Meyer Products, Inc., Cleveland, Ohio

FIGURE 16 FOUR-WHEEL-DRIVE, 3/4-TON PICKUP TRUCK WITH PLOW and rest areas on turnpikes, and is sometimes even used for main-line operations. A typical unit set up for plowing is shown in Figure 16; the specifications for such a vehicle are shown in Table 6.

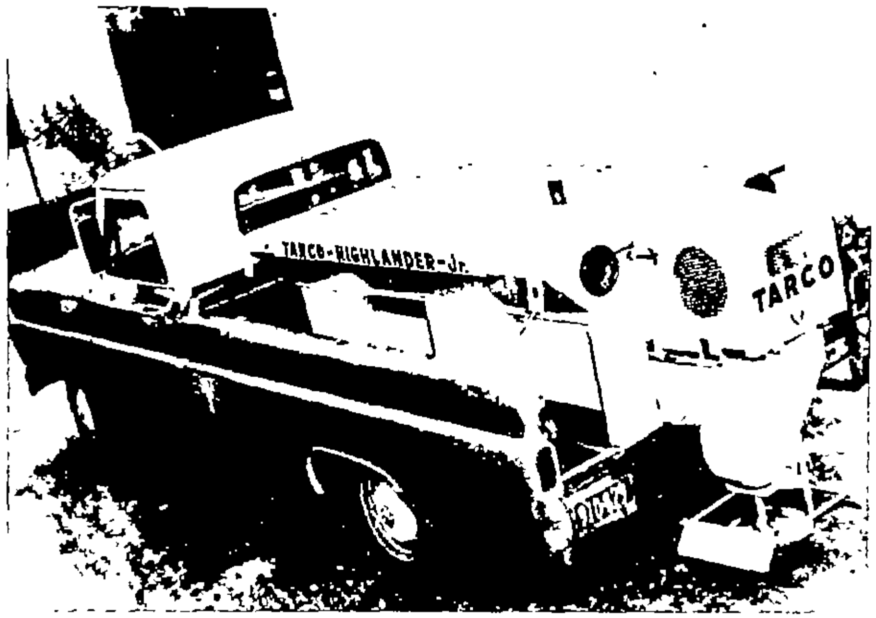
In some organizations, a small three-quarter ton pickup truck is equipped with a 1.5-yd^3 spreader as shown in Figure 17. Often used by the foremen for patrol, these units are useful for quick application of chemicals as needed and, often when larger spreaders breakdown, for backup.

Each truck should be equipped with lights and other safety equipment in accordance with all state and federal regulations. As a minimum these should include:

- chassis delineation lights,
- a revolving flashing light mounted on the top of the cap,
- two alternately flashing warning lights mounted near the top extreme corners of a chassis-mounted hopper or on the upper extreme of the back end of a dump body,
- a set of headlights that clear the front-end plow,
- a fixed spotlight aimed at the tip of any wing plow to be attached,
- reflector flare and fuses,
- first aid kit,
- two-way radio,
- wheel chocks,
- cab map lights,
- flood light on spreader discharge area, and
- two large outside-mounted rear view mirrors.

With the advent of the current fuel and material shortages, more care should be given to the selection and specification of trucks and their components. The sharp increase in fuel costs make the diesel almost mandatory in trucks above the 15,000-lb. G.V.W. class. Certainly, soft undercoating and optional tougher paints and primers should be specified for all state and municipal equipment whenever possible. The lower mileage/time usage ratio of municipal trucks favors the selection of fiberglass cabs and other non-corrosive components.

Choice of the smallest displacement engine that will do the job effectively will result in continued fuel savings. Modern multi-range automatic transmissions are slowly coming into their own. These units, coupled

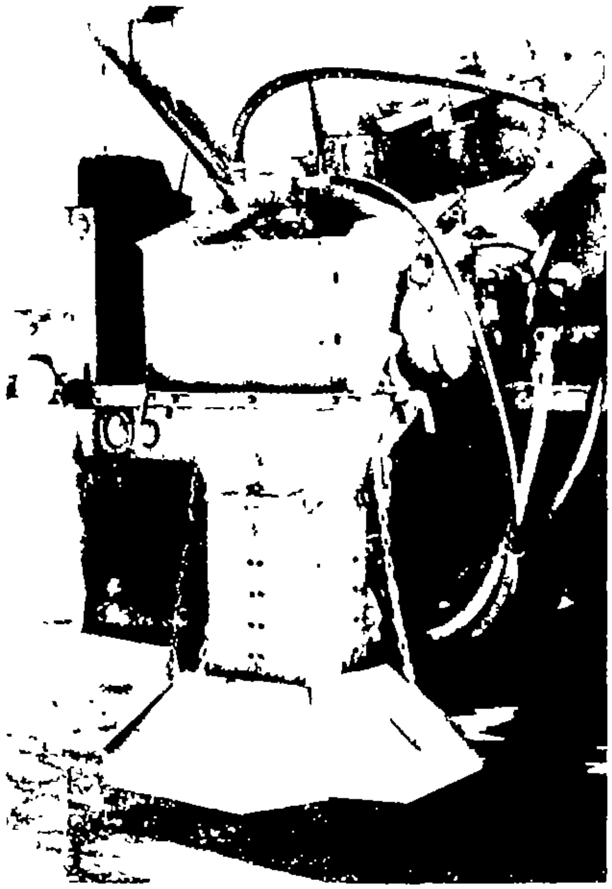


Courtesy of Tarrant Manufacturing Co., Saratoga Springs, N.Y.

FIGURE 17 THREE-QUARTER-TON PICKUP TRUCK WITH 1.5-YD ^{3} SPREADER

Courtesy of Tarrant Manufacturing Co , Saratoga Springs, N Y.

FIGURE 18 VEE-TYPE HOPPER SPREADER



Courtesy of Massachusetts Department of Public Works.

FIGURE 19 DETAILS OF SPINNER AND SPREADER with the proper engine, can save fuel, increase equipment longevity, and reduce operator training time and fatigue.

Increased complexity in mandatory safety and emission equipment requires more preplanned maintenance in order to reduce downtime. Comprehensive maintenance manuals should be specified when new equipment is procured, especially for components like the new anti-skid devices that may be unfamiliar to maintenance personnel. Perhaps additional training for mechanics at the time of purchase should also be considered. This is also a very good time to review requirements for spare parts with an eye on the increasing lead time necessary to obtain replacement parts.

With increases in truck costs of 1%/month or more predicted for the next few years, it behooves the buyer to choose trucks and options that will yield maximum service and longevity. In general, this means selection of trucks of simplest, most rugged designs and that are most easily maintained.

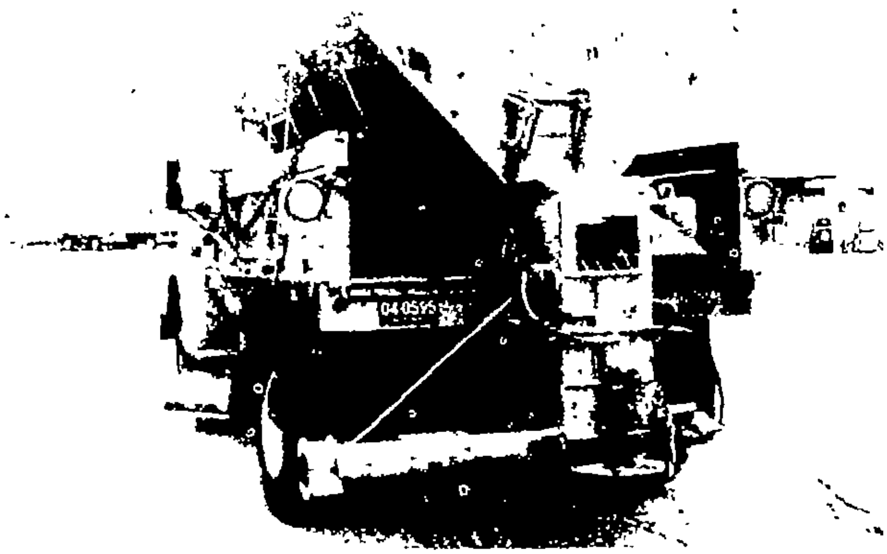
SPREADERS

Snow and ice control programs that use granular chemicals and/or abrasives require a means of applying these materials on the roadway within closely controlled areas. There are several techniques.

Earlier when sand, cinders, and/or salt were used, a laborer (sometimes two) standing near the back of a dump truck would fling shovelsful of material in a spreading pattern over the back end of the truck as the driver slowly proceeded down the highway. Later, as rock salt came into more general use, some organizations installed a large funnel on top of a 2-in. I.D. tube, which discharged salt behind the left rear wheel of the truck. Salt scooped into the funnel by a laborer was discharged out of the tube into a windrow that was laid down behind the left rear wheel and near the center or crown of the road. The trucks could be driven at a higher rate, and considerably more road could be treated during a storm. Often the truck was equipped with a built-up canvas cover to protect from the elements those rugged individuals who shovelled.

Meanwhile, dry fertilizer spreaders were being developed for the agricultural industry. These designs were adapted quite naturally to the spreading of rock salt and abrasives. The modern outgrowth of these spreaders is the focus of our attention in this manual. The most popular basic types of spreaders generally found in snow and ice control programs are described.

By far the most popular type of spreader has a Vee-type hopper, which is either chassis-mounted or slips into a dump body and has a hydraulically powered, chain-type conveyor. A slip-in unit is shown in Figure 18. Chemicals and/or abrasives removed from the hopper by the conveyor fall down a chute onto a rotating spinner which distributes the material onto the roadway. Details of the spinner and of the spreader are shown in Figure 19. A system of flaps is often used to limit the spread pattern from the spinner, particularly for application of salt on high-speed roads.



Courtesy of State of Michigan Department of Highways

FIGURE 20 MODIFICATION TO SPREADER

Courtesy of State of Michigan Department of Highways.

FIGURE 21 LUMP BREAKER

The Michigan Department of State Highways has engineered a versatile modification of this basic design as shown in Figure 20. Through remote control of a flap in the discharge chute, the material leaving the end of the chain belt can be directed either onto a spinner, which gives a full-width spread pattern, or onto a transverse auger, which moves the material through the tube shown in Figure 20 to an impeller mounted onto an end of the auger shaft. This impeller discharges the material to the rear as the truck proceeds forward. The rearward velocity of the material closely matches the forward velocity of the truck; since the material lands on the road at zero velocity with respect to the road, it does not bounce or slide off the driving lanes. The discharge scroll on the left-hand impeller is pointed downward approximately ten degrees, and the discharge end has been modified slightly to ensure that material is not thrown up into the air before it lands on the road surface. By reversal of the transverse auger, the material can be discharged in a windrow from the opposite end of the transverse tube shown in Figure 20.

An additional feature of the spreader used by the State of Michigan Department of Highways is the lump breaker shown in Figure 21. This breaker rotates as the flite chain moves, and the fingers crush all of the lumps before they pass through the spreader gate. Spreaders should be equipped with screens with 2.5 to 3 inch openings on the top of the hopper to ensure that all material entering is of sufficiently small size so that it will pass through the narrower tailgate opening at the discharge end of the chain-belt conveyor. On large spreader units, a pointed bridge roof is installed over the chain-belt conveyor to keep the full load of the salt or abrasive material from resting on the chain belt. This bridge makes it easier for a hydraulic system to start moving material when the hopper is fully loaded.

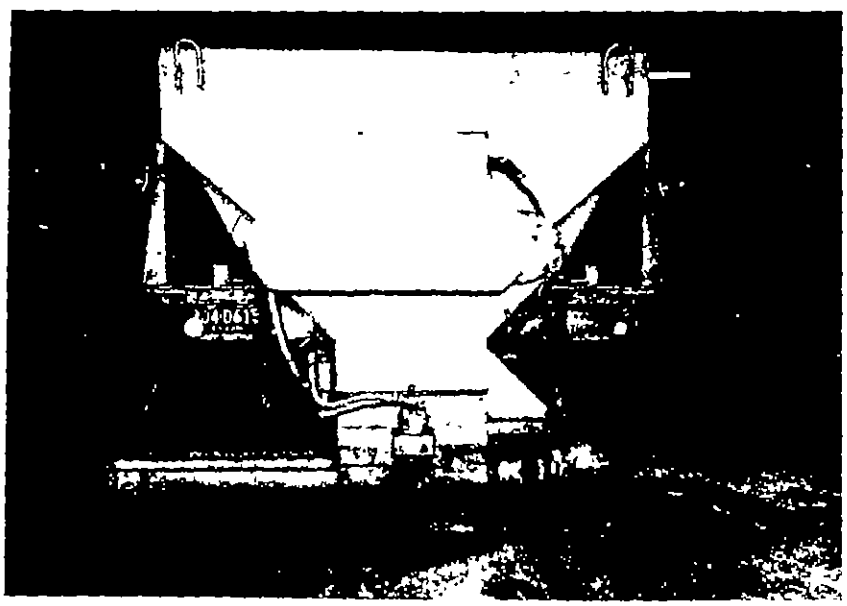
Spreaders with chain-type conveyor belts have a controllable gate at the discharge end to limit the amount of material leaving the hopper on the chain-belt. An index system painted on the back of the hopper is used for setting the opening of this gate.

Some manufacturers offer auger-type spreaders, in which a single auger located axially along the bottom of the Vee-bottom hopper conveys salt to the chute above a distribution spinner. Usually these spreaders are equipped with a separately driven agitator located above the main auger to prevent the material from bridging over the auger and stopping flow.

Several manufacturers offer a Vee-type hopper model with a chain-belt conveyor that discharges material out of the front end of the hopper and into a chute that carries the material sideways to a spinner located midway between the front and rear axles of the truck. An advantage to this type of delivery is that salt or abrasive materials are discharged in front on the drive wheels of the truck, thereby insuring added traction particularly on icy roads. Another advantage is that the spreader unloads from the rear toward the front, and the remaining load always remains better distributed between front and rear wheels of the truck.

Courtesy of Swenson Manufacturing Company, Lindenwood, Illinois.

FIGURE 22 ONTARIO SPREADER



Courtesy of State of Michigan Department of Highways.

FIGURE 23 REAR VIEW OF MICHIGAN W-BOTTOM SPREADER

Short Conveyor Belt Spreader

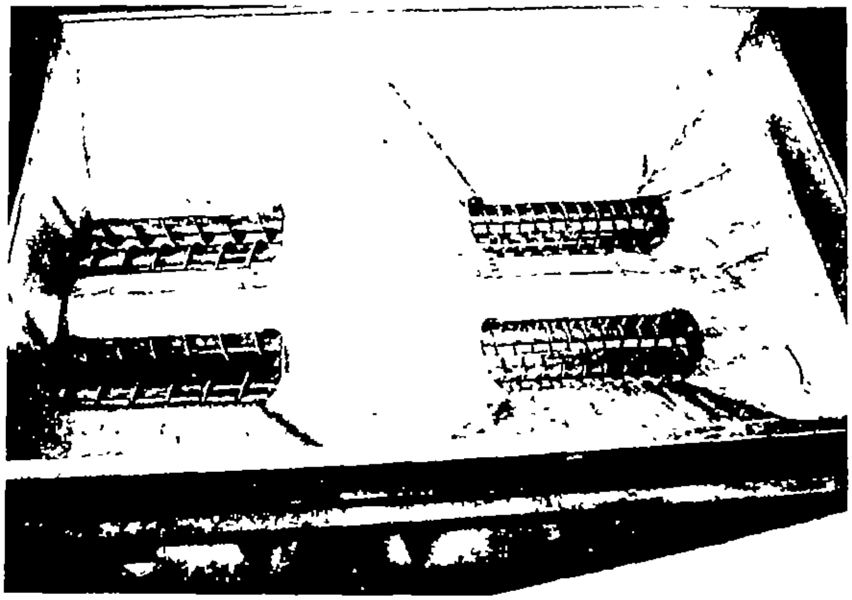
A spreader built to the design specification of the Province of Ontario is shown in Figure 22. This spreader has a pyramid-shaped hopper with a capacity of 4 yd^3. Because the amount of material in contact with the short side-delivery chain belt is small, the starting load on the hydraulic system is considerably less than that in a full-length chain-belt conveyor. The spinner on this type of spreader is located between the front and rear wheels of the truck on the driver's side, and material is discharged in front of the drive wheels. A small deflector is used to limit the distribution of material on the road surface.

Low Center of Gravity Spreader

The Michigan State Department of Highways has developed an interesting W-bottom spreader with double dual augers shown in Figure 23 and 24. The important feature of this type of spreader is that for a given load size, the hopper has a lower center of gravity than does a comparably sized Vee-bottom spreader, and better use is made of existing volume within the truck. Each pair of augers rotates in opposite directions, and all augers rotate at the same speed. They feed a common chute, which in turn feeds a cross auger or spinner as already described. The quantity of material is regulated by the speed of the augers and restrictors located in the exit discharge of the auger.

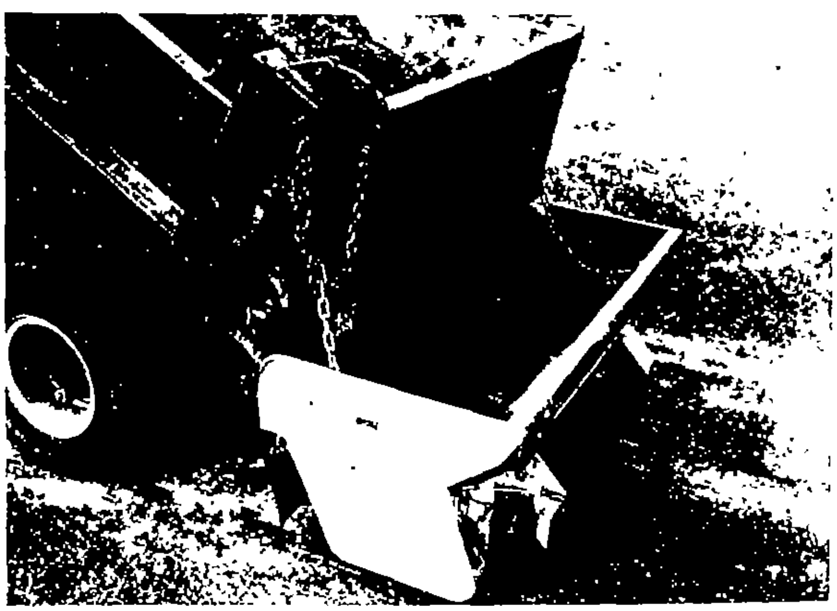
Spreader Towed Behind a Dump Truck

The spreader unit shown in Figure 25 is towed behind a standard dump truck and provides a mechanism whereby chemicals and/or abrasives are applied in proportion to the distance which the vehicle travels. This unit, developed in Europe and now finding application in this country is a genuine ground-speed-controlled spreader. The dispersement of the material from its hopper is effected by a rotating roller, which is driven by the wheels of the spreader. The rate of material spread is controlled by a rubber flap which presses against the material-dispensing roller. In operation, the truck driver raises his dump body to discharge approximately 1.5 yd^3 of salt or sand into the spreader hopper. The roller is then engaged to the wheel drive and salt is dispensed in proportion to the rotation of the spreader wheel. No operating controls are needed in the driver's cab. The driver need only stop occasionally to refill the hopper by raising his dump body. An advantage of this type of spreader is that the salt is laid down directly under the spreader and it is not thrown to either side. It is good for applying salt to ramps, interchanges, parking areas, and other places where the material should not be spread around very much. It is also very effective in applying salt to an area such as a passing lane which needs treatment long after the traffic lane has become dry. Some organizations find this type of spreader useful for combating the early fall storms or the late spring storms, which are usually small, and when the larger spreaders are not mounted on truck chassis. It is also useful during periods when the large heavy-duty spreaders are inoperative.



Courtesy of State of Michigan Department of Highways

FIGURE 24 INTERIOR VIEW OF HOPPER, MICHIGAN W-BOTTOM SPREADER



Courtesy of the Epoke Company, Denmark.

FIGURE 25 SPREADER TOWED BEHIND A DUMP TRUCK

The principal advantages of this type of spreader are that they are inexpensive to buy and maintain when compared to a chassis-mounted spreader (they cost about one-third that of a slip-in hydraulically controlled spreader); they make good use of existing dump trucks, particularly the 2-3 ton size; and they can be ready for service in just a few minutes. The disadvantages are that they do not spread while backing up, they cannot spread material on more than one lane at a time (not useful for multilane expressways), and the truck must raise the dump body periodically to fill the spreader. (This operation requires that the truck pull off of the highway and stop. Filling on the run is dangerous because the raised dump body may catch overhead branches, wires and bridges).

Spreader Modifications for Different Materials

Hydraulic spreaders utilize a hydraulic motor attached to a 50:1 gear reduction unit, which drives the chain belt. The heavy starting loads and the slow speeds at which the motor runs during spreading of chemicals at low rates place an extreme load on this motor. The Massachusetts Department of Public Works uses a three-speed gear box between the hydraulic motor and the 50:1 gear reduction unit, which drives the chain-belt. This gear box has 3:1 reduction, a 2:1 reduction, and a direct drive. The 3:1 reduction is used during salt spreading, the 2:1 reduction is used for spreading a mixture of sand and salt (50%), and the direct drive is used for spreading sand. With the 3:1 reduction, the hydraulic motor runs at an efficient torque and speed, and the chain belt is pulled at a speed that allows the spreader to deliver material at a rate as low as 75 lb per lane mile when the tailgate opening is 1 in.

The hydraulic system used to drive these spreaders is also used for controlling plows that may be attached to the truck. The preferred pump-drive system is one attached through a coupling to the crankshaft pulley at the front end of the engine. The engagement of the pump occurs by means of a mechanical coupling, which must be made up when the engine is stopped, or by means of a mechanical clutch that can be shifted manually or by air pressure. Some hydraulic systems are driven from the truck power take-off located on the transmission. The hydraulic oil reservoir should be of sufficient size that the oil can be cooled to a steady-state operating temperature during the worst operating conditions. Often, these reservoirs are mounted on the chassis directly behind the cab.

Some spreader units, particularly older units, and most of those with small capacity, are powered independently by a small air-cooled gasoline engine, which is coupled through a centrifugal clutch. Remote on-off controls and throttle setting are the major means of regulating these spreaders.

GROUND-SPEED CONTROLLERS

A recent addition to the control system for hydraulic chemical spreaders is a control unit, which synchronizes the spreader feed mechanism with the forward motion of the truck. This automatic type of control relieves the driver of the burden of manual control of the application rate of salt

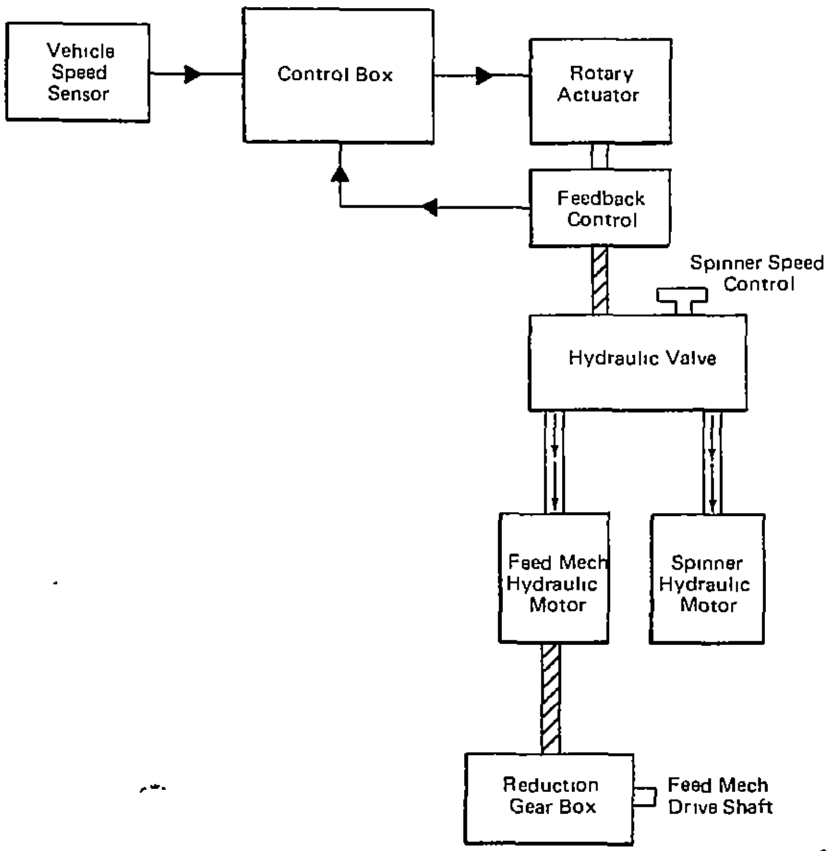


FIGURE 26 OPEN-LOOP GROUND-SPEED CONTROLLER: SENSOR AND CONTROL CIRCUIT

and/or sand or other chemicals during a storm; thus he is free to focus his attention on driving, plowing, and other responsibilities.

Ground-speed controllers are a most important piece of equipment for controlling the rate of chemical application. More importantly, they enable spreading of chemicals only when the truck is in motion and go a long way toward eliminating the wasteful spreading of chemicals that inevitably occurs when a vehicle is stopped, for one reason or another, and the spreader continues to operate. Further, these ground-speed controllers are capable of spreading chemicals in proportion to the speed at which the truck is traveling. At slow speeds, a small amount of chemical is spread, whereas, at high speeds, larger quantities are released. The net effect is that a uniform quantity is spread on each mile the truck goes.

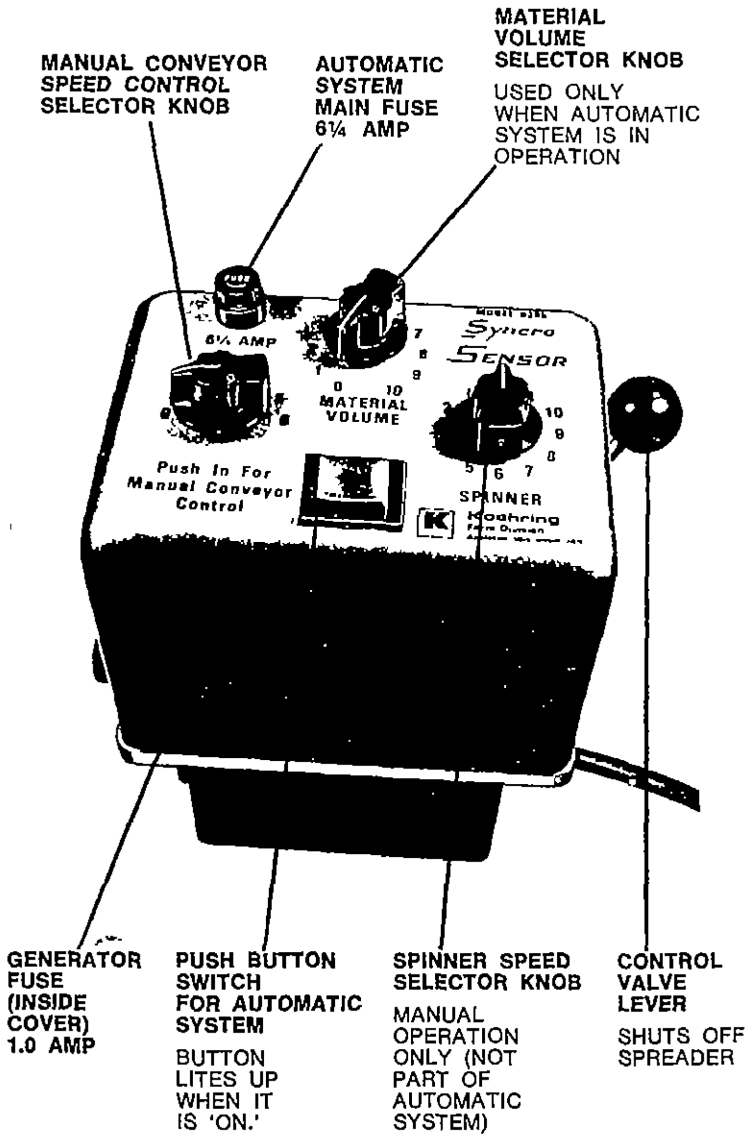
The basic operating principles of all ground-speed controllers require that the rate of forward (or backward) motion of the vehicle be measured. In most control systems, the rate of forward motion is monitored at the back end of the transmission by the speedometer cable pickup, which senses rotation of the drive shaft. Other points at which truck motion can be sensed are in the front wheel or an idler wheel that rides on top of one of the rear wheels and drives a rotary motion sensor. The purpose of the sensor is to provide a signal proportional to its rotary motion. One commonly-used sensor includes an eight-pole permanent magnet that, as it rotates past a fixed coil, produces the desired signal. Another sensor uses a photoelectric cell located directly opposite a tungsten filament lamp. Between these two units and attached to the rotating element of the sensor is a card with multiple, evenly spaced perforations around its perimeter. As it passes between the photoelectric cell and the incandescent light, this card interrupts the light, thus providing for the photodetector, pulses of light that are in proportion to the rotational speed of the sensor.

There are two basic types of ground-speed controllers: the open-loop and the closed-loop.

Open-Loop Control System

This type of controller utilizes a single sensor usually attached at the speedometer cable takeoff point on the transmission. Pulse signals from this sensor are fed to the control circuit shown schematically in Figure 26 where the signal is amplified, compared with a calibration signal and with a control signal, which is in proportion to the desired amount of salt. This signal is then used to control a motor that opens or closes the hydraulic valve controlling rate of chemical flow from the spreader.

A typical open-loop controller is shown in Figure 27. This unit is designed to sit on top of a standard in-the-cab hydraulic control valve for a hydraulic spreader. A desirable feature of this control unit is that the operator can control manually the operation of the spreader in the event of a failure in any part of the control system.



Courtesy of Koehring Farm Division, Appleton, Wisconsin.

FIGURE 27 TYPICAL CAB CONTROL UNIT FOR OPEN-LOOP GROUND-SPEED CONTROLLER

The advantages of the open-loop control system is that it is simple and requires only one sensor. The disadvantages of the open-loop system are that it cannot compensate for changes in temperature of the hydraulic oil or other degradations in the hydraulic system, and temperature sensitivities of the electronics in the control circuit may provide inaccuracies in the calibration.

Closed-Loop Control System

A closed-loop control system utilizes two sensors, one usually attached to the transmission takeoff point of the speedometer and the other attached to the output shaft of the feed mechanism of the spreader unit. The control system operates on the principle shown schematically in Figure 28. The signal from the truck-speed sensor is compared with the control input signal (which is proportional to the desired amount of salt) and to a feedback signal from the output shaft of the feed mechanism. The signal from the forward-motion sensor of the truck tells the control system that spreading can commence. The control setting on the controller tells the controller how to set the hydraulic valve opening for the speed at which the truck is moving. The sensor on the output shaft of the spreader feeds back a signal which indicates to the controller whether or not the spreader is spreading the desired amount of material. With this type of controller, a feed mechanism control accuracy of ±2% can be achieved under all driving conditions in the vehicle speed range from approximately 0.2 to 45 mph.

Figure 29 shows a ground-speed controller unit that utilizes a photoelectric feed mechanism and vehicle-speed sensors and that has a manual override capability for controlling the hydraulic circuit in the event of a failure.

Some ground-speed controller units are equipped with a control feature that allows an additional amount of salt to be spread on critical areas such as at intersections, on bridges, or on steep portions of hills. This "blast" switch usually provides approximately 20% additionaly material for one-time application to critical areas.

LIQUID DISPENSING SYSTEMS

Many jurisdictions have been experimenting recently with prewetting of salt with various materials in order to speed up its action, particularly at temperatures near the lower limits at which salt is useful, and to keep the material from bouncing off the road when it is spread. This technique is discussed in Chapter IV.

A typical truck-mounted calcium-chloride dispensing system shown schematically in Figure 30 has a 60-gallon stainless steel or fiberglass tank fitted into the area between the truck dumpbody and the spreader hopper.[6] The positive-displacement pump shown is sometimes replaced with an electrically driven, magnetically coupled, all-plastic pump and a solenoid control valve. A spray bar (sometimes fitted with fan nozzles) dispenses liquid calcium chloride into the discharge chute of the spreader.

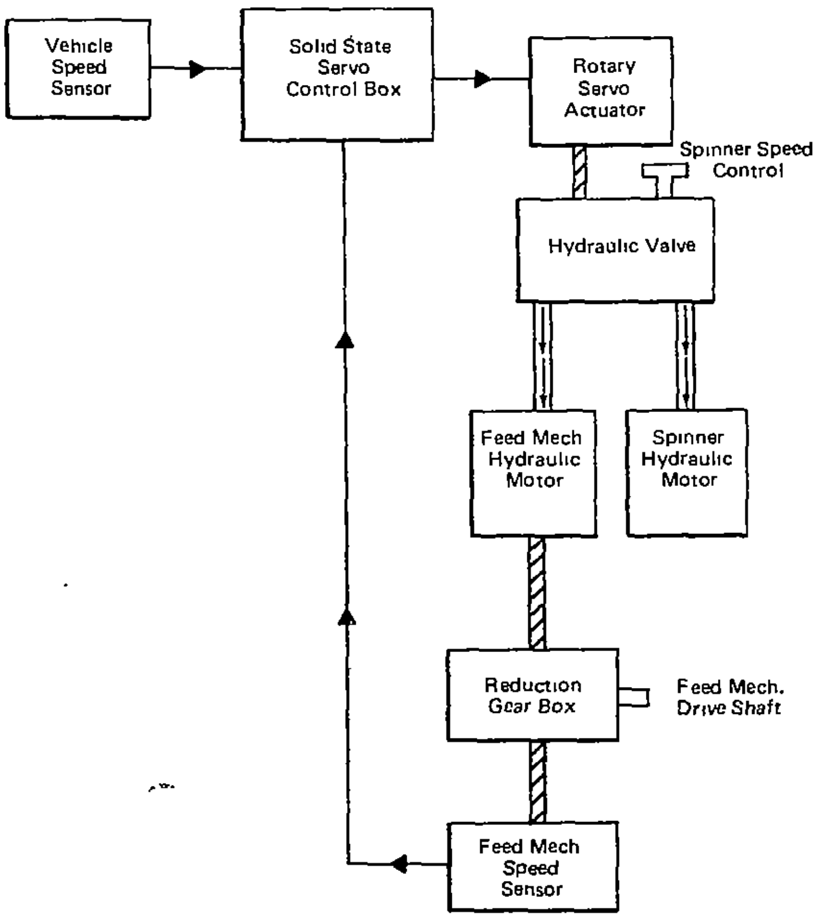
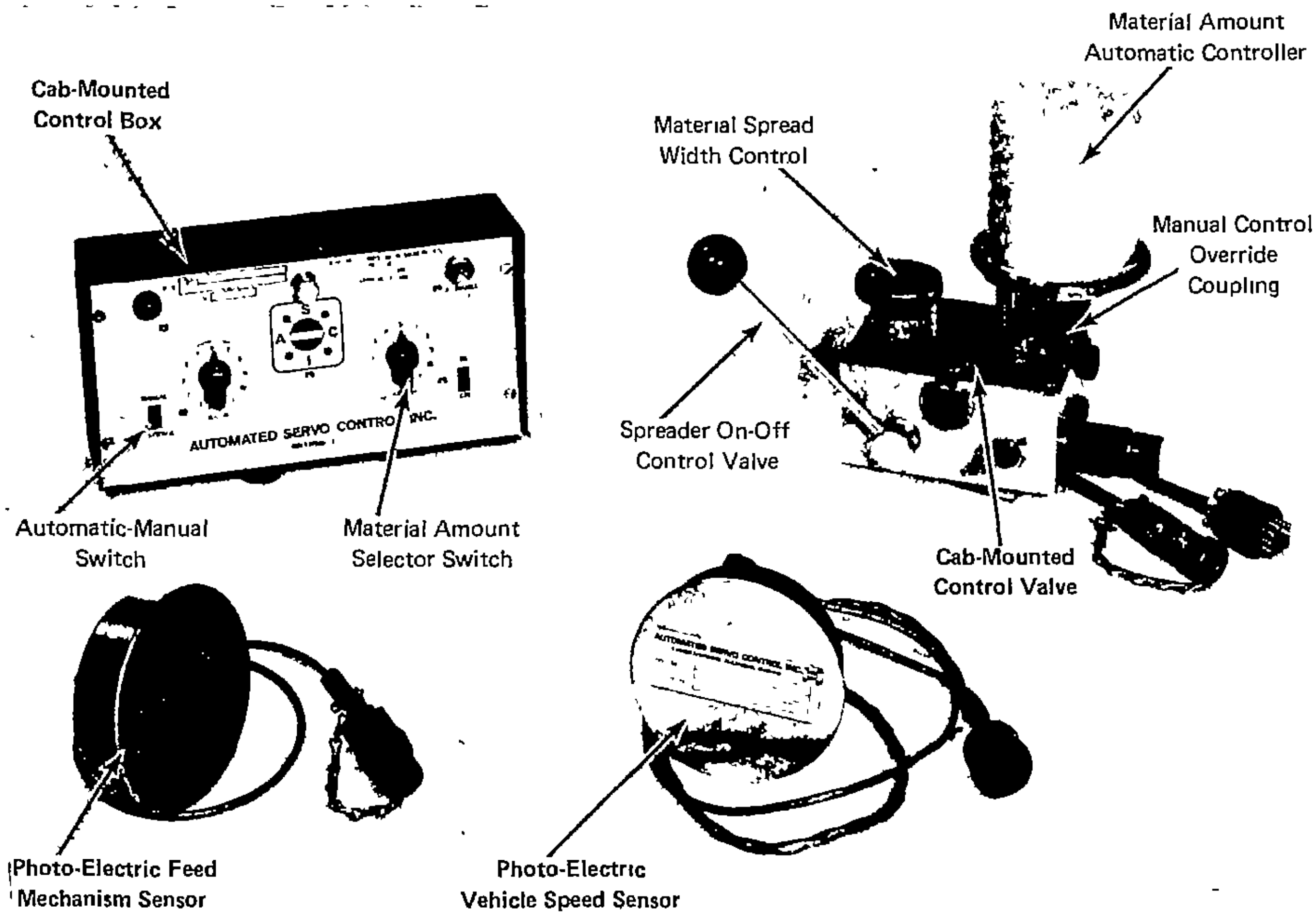


FIGURE 28 CLOSED-LOOP GROUND-SPEED CONTROLLER: SENSOR AND CONTROL CIRCUIT



Courtesy of Swenson Manufacturing Company, Lindenwood, Illinois.

FIGURE 29 GROUND-SPEED CONTROLLER WITH PHOTOELECTRIC FEED MECHANISM, VEHICLE-SPEED SENSORS, AND A MANUAL OVERRIDE

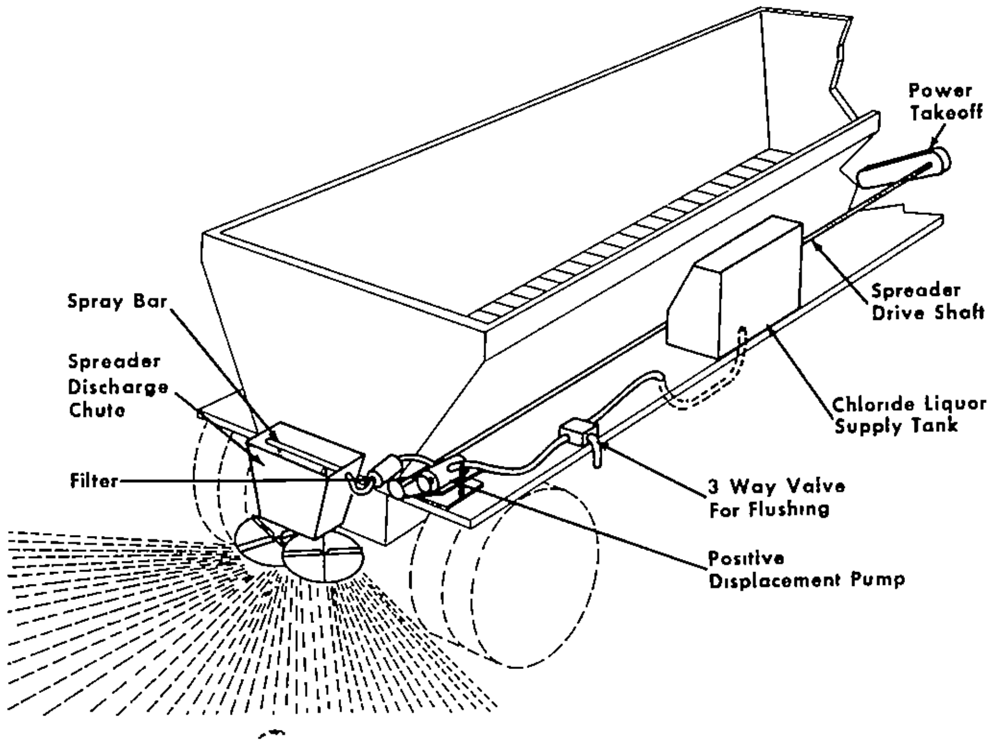


FIGURE 30 TRUCK-MOUNTED CALCIUM CHLORIDE DISPENSING SYSTEM[6]

A disadvantage of prewetting salt with calcium chloride solution or other solutions is that it requires additional equipment, special operating procedures, and storage tank for 4,000-8,000 gallons of liquid material at each maintenance depot. Each truck-mounted system must be flushed at the end of a storm. Also, the addition of calcium chloride accelerates the corrosion of equipment because it attracts water moisture from the air.

SNOW PLOWS

After snow has begun to accumulate there comes a time when chemical operations must cease and plowing must begin. This usually occurs when about 0.5 in. of snow has accumulated and more is predicted. A multitude of plows are available for snow and ice control work, and the particular design should be chosen to match the type of snow condition expected in the area, the nature of the road system (high-speed arterial, or downtown, or residential areas), and the truck that will be used to propel the plow. Summarized in the following paragraphs are description of the major types of plows presently in use.

High-Speed Plow

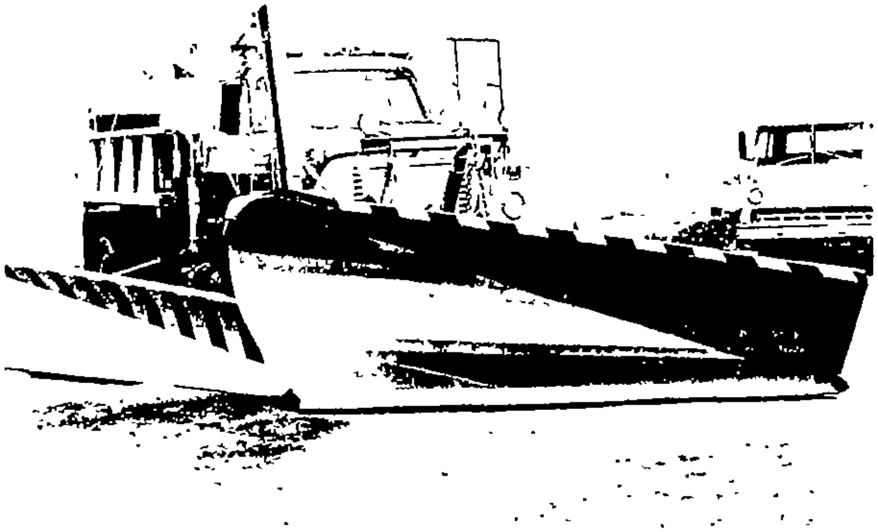
The high-speed plow shown in Figure 31 is characterized by a conical-shaped moldboard, which is small on one end and large on the other end. This type of plow is typically used on very large vehicles (weighing 5 tons or more) and plows the snow in only one direction, usually to the righthand side of the road, although some lefthand, high-speed plows are in service. The moldboard is contoured so that the snow leaves from the large end on the blade and is directed out to the side. In light blowing snow, this feature improves the visibility of the driver so that he can achieve a higher plowing speed. The contoured moldboard provides maximum lateral casting distance, and minimum power is also required to push the plow.[7]

Two-Way Plow

A popular plow for all-around use is the two-way, power reversible, straight-edged plow with a constant cross section moldboard shown in Figure 32. This popular plow is made in sizes ranging from 8 feet up to 14 feet in width and is used on vehicles ranging in size from utility vehicles up to the largest four-wheel drive plow trucks made. The power-angling characteristics are useful for plowing either to the right or to the left on multiple-lane roads and, upon occasion, are used for pushing snow directly ahead of the truck (e.g., for clearing of parking areas). The constant cross section of the moldboard limits the speed at which this type of plow can be used in light snow, because the snow has a tendency to come up over the front of the moldboard at high speed thus reducing the visibility of the driver.

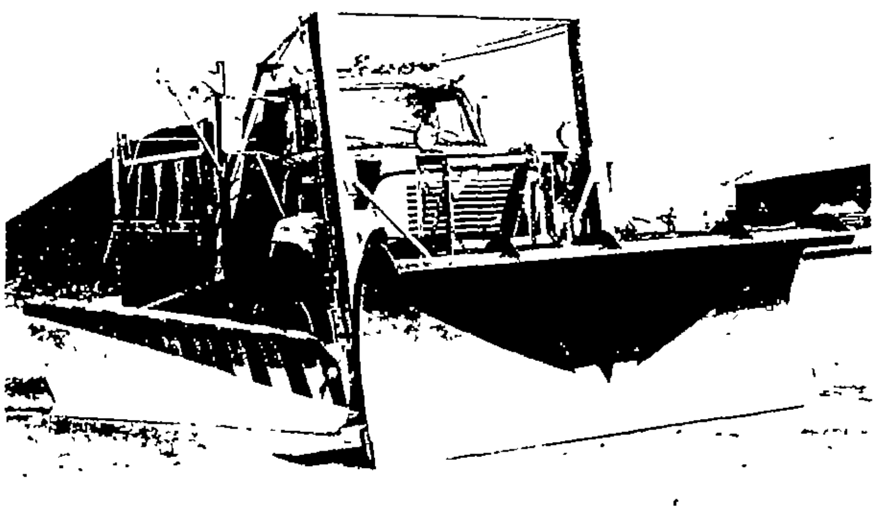
Two-Way High-Speed Plow

A compromise between the high-speed and the two-way plow is the two-way, high-speed plow. This plow has a straight cutting edge and a double-formed moldboard, which is capable of casting snow either to the right or to the left depending upon the orientation of the plow.



Courtesy of Frink Sno-Plows, Clayton, New York.

FIGURE 31 HIGH-SPEED PLOW



Courtesy of Frink Sno-Plows, Clayton, New York

FIGURE 32 TWO-WAY PLOW

Vee Plow

In areas where moderate drifting may occur, a Vee plow shown in Figure 33 is useful for bucking through the drifts. Typically a Vee plow is mounted on a large four-wheel drive truck, and is used in combination with dual wing plows to keep open areas subject to minor drifting.

Wing Plow

The wing plow (Figure 33) is a versatile piece of equipment, which can be used for pushing back high drifts or the accumulated snow left over from earlier storms along the edge of the road. In tandem it is also used often for plowing light snow on a multi-lane highway. In this operation, the snow collected by the truck's front-mounted two-way plow is caught by the wing plow and pushed back further, thus increasing the width of road cleared in a single pass by one truck. In trucks equipped with one or two wing plows, a second operator is required to operate the wing plow particularly when winging-back accumulated snow in the vicinity of road signs, culverts, and guard rails.

Underbody Scrapers

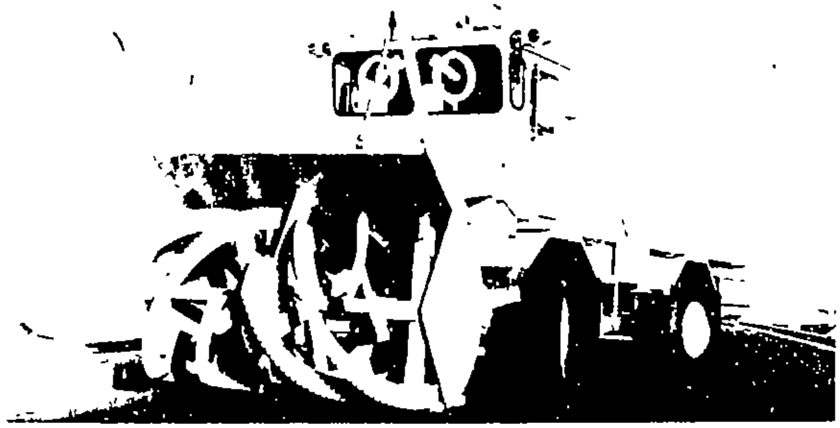
Trucks equipped with underbody scrapers are useful for removal of hard pack snow from roadways (Figure 33). These plows are capable of exerting downward pressure on the cutting edge of the plow and breaking through ice and hard pack under some circumstances. Underbody plows are also useful for removing light accumulations of snow (up to 2 in.). The remote control feature of the angle of the underbody plow is desirable.

Additional Features of Plows

All snow plows must be able to be lifted from the surface of the roadway by the operator through remote control, usually accomplished by a hydraulic control system operated from the cab. In addition, plows should have a mechanism, whereby the moldboard or the whole plow itself trips when it meets an immovable object, such as a manhole cover, frozen rock or a post, thereby minimizing the shock transmitted to the truck and driver and the damage that might be incurred by the plow itself.

All front-mounted plows must have a hitch firmly attached to the frame of the truck and to which the plow itself can be attached rapidly when needed. A wide variety of hitches are available, many of which are fabricated or modified in the maintenance shops of the various municipalities. Many organizations find that plow cutting edges that have tungsten carbide inserts eliminate the need for changing cutting edges, give far longer service, and are well worth the additional purchase cost.

For areas where the minimum temperature is 28-32°F, rubber cutting edges for snowplows have been used with some success for removing freshly fallen or slushy snows from roads equipped with raised reflectorized traffic markers.[8,9] Even in this temperature range, salt or other chemicals



Courtesy of Frink Sno-Plows, Clayton, New York.

FIGURE 33 SNOW-BLOWING MACHINE

Courtesy of Frink Sno-Plows, Clayton, New York.

FIGURE 34 FRONT-END LOADER EQUIPPED WITH SNOWBLOWER UNIT must be used to keep the snow from packing and to produce slushly snow which can be easily plowed. Rubber or polyurethane cutting edges are not useful when the temperatures are below the critical temperature range of 28-32°F and steel or carbide-insert blades are needed to remove the snow.

GRADERS

In some municipalities, road graders that are used during the summer for grading shoulders are used in the winter time for snow-plowing operations. With two axles, single- or four-wheel drive, or three axles with two rear drive, these graders can be equipped with a heavy-duty two-way front-mounted plow. Such a unit is useful for both straight-line operations and for clearing parking lots and other large areas. The easily controlled scraper blade is often the only piece of equipment that is capable of removing hard pack and ice from roadway surfaces.

FRONT-END LOADERS

The rubber-tired, front-end loader is the equipment of choice for handling snow and ice control materials such as sand, salt, and mixtures thereof. The articulated (hinged in the middle) version of this machine provides maximum maneuverability for a given size machine. Such machines can be used year-round for a variety of construction and maintenance tasks.

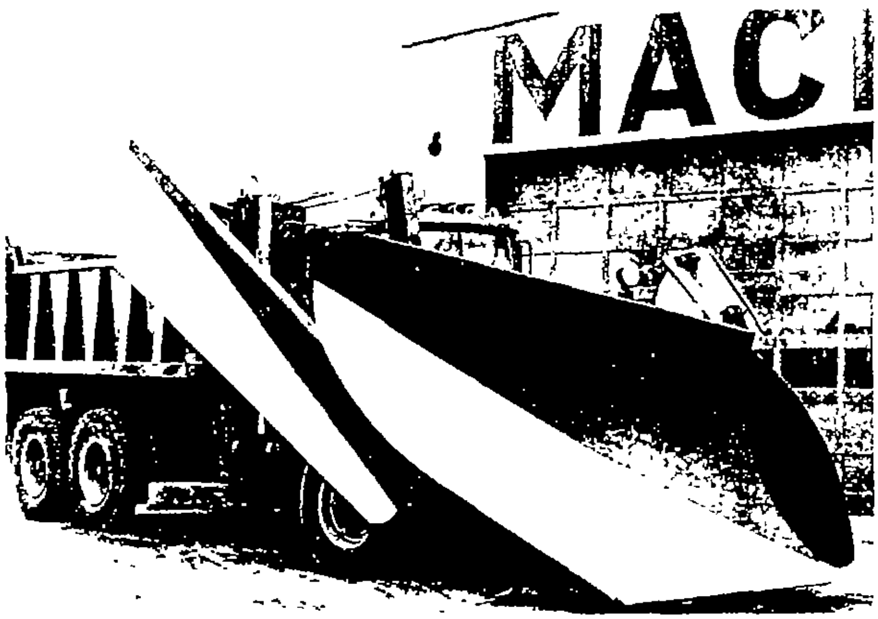
Considerable versatility in a plowing operation is provided when a large front-end loader is equipped for plowing as shown in Figure 34. This unit is capable of maneuvering in very tight quarters, and the articulated model can make a sharp, 90-degree turn, an extremely useful feature for urban snow plowing.

When a front-end loader is provided with two or more different bucket sizes, savings of time and wear on equipment are achieved. A small-volume bucket will prevent overloading of the machine during the summer season, and a larger bucket will increase productivity when salt, sand and snow are being handled during the winter season. For a plowing operation, a machine rated at 2-2.5 yd^3 is preferred. For general loading operations, a machine rated at 1.5 yd^3 and equipped with a 2-yd^3 bucket is preferred.

SNOW BLOWERS

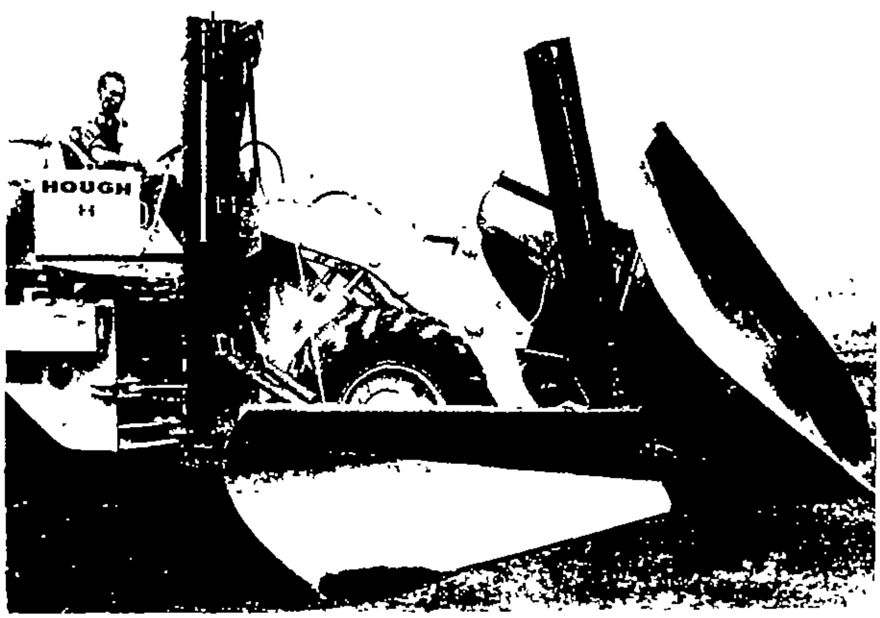
In many instances, snow blowers are the only means whereby roads can be maintained open. These conditions occur in the high mountain passes where heavy snowfalls occur, in areas where heavy drifting is frequent, and in areas where rapid removal of accumulated snow is required, such as on airport runways. For these heavy-duty applications, large snow-blowing machines similar to the ones shown in Figure 35 have been developed. Equipped with two large diesel engines, this unit is capable of casting as much as 3,000 tons of snow per hour a distance up to 125 feet.

For lighter-duty operations, units of smaller capacity are utilized. Smaller units are used for road clearing and for loading trucks when clearing areas (such as downtown areas) in which snow cannot be stored.



Courtesy of American Snoblast Corp., Denver, Colorado.

FIGURE 35 VEE PLOW, WING PLOW, AND UNDERBODY SCRAPER ON TANDEM-DRIVE TRUCK



Courtesy of Root Spring Scraper Co., Kalamazoo, Michigan.

FIGURE 36 FRONT-END LOADER EQUIPPED FOR PLOWING

A popular new concept in light-duty snow blowers is the self-powered unit that is attached to the lift forks of a front-end loader as shown in Figure 36. The unit shown has its power unit located immediately behind the augers and blower. Other models, powered by hydrostatic units, have a power unit mounted on the back end of the loader and rely upon heavy-duty hydraulic motors for powering the augers and blowers. A particular advantage of the front-end loader unit is that it can cut down high drifts (snow depths up to 12 feet) by raising the blower unit on the loader arms and cutting into the drift at successively lower levels. Front-end mounted units are made with capacities of up to 1,500 tons per hour and can cast the snow as far as 100 ft.

CHAPTER VI

SPREADER CALIBRATION

Calibration of all chemical spreaders is the most important action that an agency can take to control and reduce the amount of harmful deicing chemicals that enter the environment. Calibration of spreaders not only controls and reduces the amount of material used but it also saves money by providing the desired level of service with less deicing chemicals. The objectives of a thorough calibration program are very accurate knowledge of the amount of chemical delivered by all units at each spreader setting and identification and repair of all spreader units than cannot be controlled within the range of prescribed spreading.

Spreaders should be calibrated annually before the winter season begins. The calibration should be rechecked during the winter if any of the major parts of the hydraulic system are replaced, if the moving mechanical parts of the spreader are damaged or replaced, or if for any reason the spreading rate becomes suspect.

Spreaders should be calibrated not only for the amount of salt dispensed each mile the truck travels but also for the pattern of distribution of material on the road surface.

In this section, two basic ways of calibrating chemical spreaders for the amount per mile traveled are described. One method, a yard calibration, involves measurement of the amount the unit delivers over the complete range of control settings of the spreader. The second, an in-service calibration, is a calculation based on actual spreader operation, i.e., total load delivered over a stretch of road of known length.

YARD CALIBRATION

Spreaders Without Ground-Speed Controllers

The calibration technique described in this section is based primarily on methods developed by the Salt Institute under their Sensible Salting Program, with modifications incorporated by the Michigan Department of State Highways and others. This technique is applicable to hopper-type spreaders and truck-tailgate spreaders, both of which rely upon the rotation of a mechanical element (an auger shaft or flite-chain sprocket shaft) for feeding chemicals and/or abrasive materials from the vehicle to the distribution mechanism of the spreader. Although applicable to hydraulically controlled spreaders, the technique is adaptable also to independently powered spreader units.

Equipment Required

The equipment required for calibration of salt spreaders includes:

Area ____________ Truck No. ____________ Salt Sand Special Blend ____________ (Circle One)

Location ____________ Spreader No. ____________ Size of Load (11) ________ (Tons) X 2,000 ____________ (Lbs)

Gate Setting ____________ (inches)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
Control Setting	Auger or Chain-Sprocket Speed (RPM)	Discharge Weight (Lb/Rev)	Discharge Rate (Lb/Min) (2)X(3)	Amount Spread (Lb/Mile)						Size of Load (Lbs)	(11) (4)	Distance for Full Load (Miles)					
				15 mph	20 mph	25 mph	30 mph	35 mph	40 mph			15 mph	20 mph	25 mph	30 mph	35 mph	40 mph
				(4) X 4.00	(4) X 3.00	(4) X 2.40	(4) X 2.00	(4) X 1.71	(4) X 1.50			(12) 4.00	(12) 3.00	(12) 2.40	(12) 2.00	(12) 1.71	(12) 1.50
1																	
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	

By ____________ Remarks ______________________

Date ____________ ______________________

FIGURE 37 CALIBRATION WORKSHEET – SPREADER WITHOUT GROUND-SPEED CONTROLLER

- A scale for weighing the amount of salt. The scale can be a hand-held or platform type and should be capable of weighing quantities between 0 lb and 100 lbs, with a resolution of 2.0 lb. The accuracy of the scale should be verified either by the agency's department of weights and measures or with several calibration weights.

- A means for collecting up to about 100 lb of chemical material (a square yard of canvas with grommets at each corner or a burlap sack). For any collector weighing more than about 0.5 lb, the tare weight should be determined.

- A stop watch or a watch with a second hand for timing shaft revolutions.

- A shaft tachometer (if shaft rotation speed is too fast to follow by counting).

- A means for placing a mark on the end of the auger or flite-chain sprocket shaft. A marking pen, a dob of paint, a file mark or a prick punch mark will do.

- Calibration worksheets like those shown in Figure 37.

- A clipboard or other means for holding calibration worksheets while data are being assembled.

Calibration Procedure

The following procedure is recommended for calibration of spreaders that do not have ground-speed controllers.

1. Clean the shaft end of the auger or flite-chain sprocket shaft. Place an index mark on the end of the shaft so that the number of revolutions per minute can be counted at each dial setting. If the shaft end is not exposed, mark the auger flite sprocket.

2. Remove the spinner disc or bypass the spinner motor with a hydraulic line.

3. With the spreader system running and empty, let the truck idle long enough to warm the hydraulic oil to a normal working temperature.

4. Place a half load of salt in the truck body to put a load on the spreader. This partial load will simulate actual working conditions.

5. Open the throttle so the engine is running at approximately working speed. If the truck is equipped with a tachometer, set the throttle at the engine speed normally used during salting.

6. For hopper-type spreaders, open the gate to the appropriate setting for the type of material for which the spreader is being calibrated (salt, premix of salt and calcium chloride, salt/sand, sand, or other abrasive). Trial and error adjustments may have to be made in the gate opening in order to get the desired spread rate.

7. Fill the spreader auger or conveyor with salt by rotating it a few turns.

8. Set the spinner motor control to its usual level.

9. When the auger is full, place the canvas or the bag under the discharge opening so that all of the salt discharged is caught. Allow the auger or the sprocket to make one full turn at a low setting and collect the salt that is discharged.

10. Weigh the salt, deducting the weight of the canvas square, bag, or other collector. Accuracy is important because this factor is used repeatedly in the calculations. For greater accuracy, repeat step 9 above several times and then take the average weight and enter it in Column 3 of the worksheet (Figure 37). Once the weight per revolution has been established that weight will remain constant throughout the calculating procedure.

11. To determine the number of revolutions per minute (RPM), use a stopwatch or a watch with a second hand; count the number of RPM's of the auger or flite-chain sprocket shaft at each control setting. If necessary, use a hand tachometer. Record these in Column 2 of the worksheet in Figure 37.

Calculations

The worksheet now contains two pieces of data needed for calculation of the amount of salt that will be discharged in 1 min. Multiply Column 2 by Column 3 and enter the result (discharge rate in lb/min) in Column 4.

To complete the calculation, you need to know the number of minutes required for the truck to travel one mile at various road speeds. These are tabulated in Table 7 and shown in Columns 5-10 of the worksheet. To calculate the amount spread per mile when the truck is traveling at 15 mph, multiply Column 4 by the constant shown at the head of Column 5 and enter the result in the proper place. Likewise, to determine the amount spread at 20, 25, 30, 35 and 40 mph multiply Column 4 by the constants at the top of Columns 5-10, respectively, and enter the results in the proper spaces. Perform these calculations for every control setting.

As an illustration of how the table is used, assume, for example, that the auger or flite-chain sprocket discharges 8 lb of salt (Column 3) each time it makes one full revolution at control setting number 3 and that the auger turned 10 times per minute (Column 2). Obviously, the spreader will put out 80 lb per minute at that setting (Column 2 times Column 3 and the result entered in Column 4).

At a speed of 15 mph as shown in Table 7 the truck moves one mile every 4 min. Therefore, 80 lb/min multiplied by 4 min equals 320 lb/mi. This value is entered in Column 5 for control setting number 3. This procedure should be repeated for each control setting and at the various speeds at which the material is spread. Record all data on worksheet (Figure 37).

The next set of calculations determines the distance that the spreader truck will travel for various control settings and vehicle speeds before the complete load is exhausted. These values are useful for checking the calibration and overall health of the spreader. In Column 11 of the calibration worksheet, enter the size of the load in pounds for the material (salt, sand or mixtures thereof). This should be the weight of the material when it is loaded level with the top of the screens or the top of the spreader hopper (provided this does not exceed the vehicle's legal gross weight). This value can be obtained either from the spreader manufacturer or by weighing a truck full of material and entering the amount in the line provided in Column 11. To calculate the time required to empty the spreader for various control settings divide Column 11 by Column 4, and enter the results in Column 12. The miles that a truck will travel at 15 mph before the load is exhausted is determined by division of Column 12 by the constant given at the top of Column 13. Likewise, the miles a truck will travel before its loads are exhausted at 20-40 mph are calculated in Columns 14 through 18, respectively, on the calibration worksheet. Results should be entered in this table to the nearest 0.1 mi.

Table 7 VEHICLE SPEED CONVERSION FOR SPREADER CALIBRATION

Vehicle speed (mph)	Time to travel one mile (min)
10	6.00
15	4.00
20	3.00
25	2.40
30	2.00
35	1.71
40	1.50
45	1.33
50	1.20
55	1.09
60	1.00

Truck Calibration Card

The last step in the calibration of spreaders is transfer of the results of the calculation onto a calibration card, which will be carried in the cab of the truck. This is simply done by copying the data from Columns 1 and 5-8 onto the pounds-per-mile side of the truck card shown in Figure 38. The calibration check data in Columns 13-18 should be transferred onto the miles-traveled-per-load side (the reverse) of the same calibration chart shown in Figure 39.

On the truck calibration cards, color coding is very useful. For example, those calibration values close to the most usually prescribed amount of salt could be indicated in green, those higher than the prescribed ones in red, and those rates lower than the prescribed rate in black. At a quick glance, the operator can tell when he is operating in the proper range.

The additional information called for on the truck calibration card should also be filled in. The calibration of the spreader is now complete, and the calibration worksheet should be placed on file either in the maintenance record for the truck or in the agency's office. The truck calibration card should be placed in a convenient location in the truck so that it is available for quick reference during a storm.

In some agencies, a template is made from a block of wood which has one dimension equal to the gate opening required for straight salt and another dimension equal to the opening required for another material such as sand. This template is often attached to the spreader calibration card.

Spreader With Ground-Speed Controllers

Spreaders with ground-speed controllers are calibrated by the same basic technique outlined in the previous paragraphs, but with several notable additions.

The equipment required in this calibration is the same used for the spreader without ground-speed controllers except for a modified worksheet. In addition, a pulse generator must be utilized for simulation of the truck's ground-speed sensor. It can be one provided by the manufacturer, a low-frequency audio pulse generator capable of 100 cycles per second or whose specification can be provided by the controller manufacturer, or a homemade pulse generator with a standard truck sensor driven by a variable-speed motor and equipped with a tachometer. These pulse generators are based on the fact that all speedometers rotate at 1,000 RPM when the vehicle is moving at 60 mph. Special precautions must be taken if the truck is equipped with a two-speed rear-end axle and does not have a compensated speedometer drive. If this is so, care must be taken to insure that the truck is used only in the rear-end speed setting for which the speedometer is calibrated correctly.

Measurement Procedures

The following procedures are followed for calibration of spreaders equipped with ground-speed controllers.

Spreader Calibration
Pounds per Mile

Material ____________________

Gate Opening ________________ Truck No ________________

Spreader Ident ________________ Load Size ________________

Control Setting	Amount Spread (Lb/Mile)					
	15 mph	20	25	30	35	40
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

Calibration by ____________________ Remarks ____________________

Date ________________ ____________________

**FIGURE 38 SPREADER CALIBRATION CARD (FRONT SIDE)
TRUCK WITHOUT GROUND-SPEED CONTROLLER**

Spreader Calibration
Miles per Load

Material ____________________

Control Setting	Distance Traveled per Load (Miles)					
	15 mph	20	25	30	35	40
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

FIGURE 39 SPREADER CALIBRATION CARD (REVERSE SIDE)
TRUCK WITHOUT GROUND-SPEED CONTROLLER

1. Disconnect the lead from the truck speed sensor and connect the pulse generator. Set the pulse generator for a speed setting of 30 mph.

2. Clean the shaft end of the auger or flite-chain sprocket shaft. Place an index mark on the end of the shaft so that the number of revolutions it makes per minute can be counted at each control setting. If the sprocket shaft end is not exposed, mark the auger flite sprocket.

3. Remove the spinner disc or bypass the spinner motor with a hydraulic line.

4. With the spreader system running and empty, let the truck idle long enough to warm the hydraulic oil to normal working temperature.

5. Place a half load of salt in the truck body to put a load on the spreader. This partial load will simulate actual working conditions.

6. For hopper-type spreaders, open the gate to the appropriate setting for the type of material for which the spreader is being calibrated (salt, premix of salt and calcium chloride, salt/sand, sand or other abrasive). Trial and error adjustments may have to be made in the gate in order to get the desired spread rate.

7. Open the throttle so that the truck engine is running at approximately working speed. If the truck is equipped with a tachometer, set the throttle at the engine speed normally used when salting.

8. Set the ground-speed controller at its lowest setting and activate the spreader auger or conveyer to fill it by allowing it to rotate a few turns.

9. Set the spinner motor control to its usual level.

10. When the auger is full, place the canvas or bag under the discharge opening so that all of the salt discharge is caught. Allow the auger or the sprocket to make one full turn at this low setting of the ground-speed controller and collect all the salt that is discharged.

11. Weigh the salt, deducting the tare weight of the canvas square, bag or other collector. Accuracy is important because this factor is used repeatedly in the calculations. For greater accuracy, repeat step 10 above several times and then take the average weight and enter it in Column 3 of the worksheet (Figure 40). Once the weight per

Agency ____________ Truck No ____________ Salt, Sand, Special Blend ________ (Circle One)

Location ____________ Spreader No ____________ Size of Load ______ (Tons) X 2 000 ______ (Lbs)

Calibration Speed or Pulse Setting ________ (mph)

Controller Type ____________ Gate Setting ____________ (inches) Minutes to Travel One Mile at Above Calibration Speed (5) ______ (Min/Mile)

(1) Control Setting	(2) Auger or Chain Sprocket Speed (RPM)	(3) Discharge Weight (Lb/Rev)	(4) Discharge Rate (Lb/Min) (2)X(3)	(5) Minutes per Mile (Min/Mile)	(6) Quantity Spread (4)X(5) (Lbs/Mile)	(7) Size of Load (Lbs)	(8) Distance for Full Load (7) (6) (Miles)
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

Speed (mph)	Time to go One Mile (Minutes)	Pulses for 6-Pole Sensor
10	6 00	1,000
15	4 00	1,500
20	3 00	2,000
25	2 40	2,500
30	2 00	3 000
35	1 71	3,500
40	1 50	4 000
45	1 33	4,500
50	1 20	5,000
55	1 09	5 500
60	1 00	6 000

By ____________ Remarks ____________________________

Date ____________ ____________________________

FIGURE 40 CALIBRATION WORKSHEET – SPREADER WITH GROUND-SPEED CONTROLLER