

Calibration Accuracy of Material Application Equipment

Synthesis Report

The logo for CLEAR ROADS features the words "CLEAR" and "ROADS" in a bold, white, sans-serif font, separated by a stylized black and white graphic element that resembles a road or a snowplow blade. The entire logo is contained within a black rectangular border.

CLEAR ROADS

research for winter highway maintenance

CTC & Associates LLC

**Project CR17-S1
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Executive Summary

Accurate calibration of materials application equipment is the primary means through which a transportation agency can avoid overapplication of salt and other anti-icing/deicing materials on roadways. Methods of effective calibration for salt spreaders have been examined extensively and presented in many published reports and manuals for transportation agencies. Manufacturers include comprehensive guides with their equipment, and many organizations have developed equipment calibration training for their crews. Thus, instruction and guidance is widely available. Clear Roads member agencies were interested in learning more about calibration accuracy of equipment over time, including the practices and experiences of agencies that could help identify factors that may diminish equipment accuracy over weeks and months of use in extreme conditions.

Through a survey of Clear Roads member agencies and others reached via the Snow and Ice Listserv, this synthesis gathered information about the types of material application equipment that agencies use, schedules and methods of calibration, agency training protocols, respondents' perceptions of the accuracy of equipment, and the types and qualities of materials. Survey participants included respondents from 27 Clear Roads member agencies, Denmark, and one private American contractor. In addition, a literature search compiled relevant research about equipment calibration and related concerns.

Survey Respondents

Respondents are listed below:

- Arizona
- Colorado
- Delaware
- Idaho
- Illinois
- Indiana
- Iowa
- Kansas
- Maryland
- Massachusetts
- Minnesota (2):
MnDOT–Statewide,
MnDOT–District 7
- Montana
- Nebraska
- New Hampshire
- New York
- North Dakota
- Ohio
- Oregon
- Ontario, Canada
- Pennsylvania
- South Dakota
- Utah
- Vermont
- Washington State
- Wisconsin
- West Virginia
- Wyoming
- Denmark
- WVB Partners

Equipment

The first section of the survey asked respondents four questions about their agency's equipment: the type of application systems used to apply salt/solid deicer materials (manual, open- or closed-loop ground speed control systems), the type of application systems used to apply liquid materials, whether or not the agency used global positioning system/automatic vehicle locator (GPS/AVL) systems, and if so, whether that GPS/AVL system was further used to record data from sensors on the truck.

Solid Material Applicators

Twenty-nine of the 30 respondents answered the question about solid material applicators, with nearly 90 percent (26 respondents) using a closed-loop ground speed control system for solid materials. Three states reported using open-loop systems, while six indicated that they used all three kinds of equipment.

Liquid Material Applicators

There was greater variation among the responses for liquid application, with most (27) using a closed-loop system, but some also employing open-loop systems, gravity feed, and flow meters. Denmark's respondent noted that liquid application was "GPS-controlled."

GPS/AVL

Eighty percent of respondents (26) reported using GPS/AVL on their vehicles to some extent, including two in testing stages (Massachusetts, North Dakota). Four respondents did not use this system. The follow-up question concerning GPS/AVL revealed that of those 26 using the system to some extent, 13 also recorded sensor data from the trucks, while 11 did not. Denmark and Massachusetts reported the use of GPS-controlled spreading or data sent to cloud storage directly from the system.

This section revealed that respondents used a range of types of application equipment, with about half of agencies venturing into newer data-collecting technology: closed-loop systems with GPS/AVL expanded to gather truck bed-scale sensor and other data beyond vehicle location.

Calibration

Concerns among representatives of some Clear Roads member agencies about calibration accuracy of material application equipment generated the initial questions underlying this synthesis report. The questions in this section were designed to discover the extent to which calibration accuracy may be problematic among users of the equipment. This section posed five questions addressing particular aspects of calibration: frequency of calibration, what "calibrated" means, events that trigger calibration, who performs calibration within an agency, and how that calibration is performed.

Frequency of Calibration

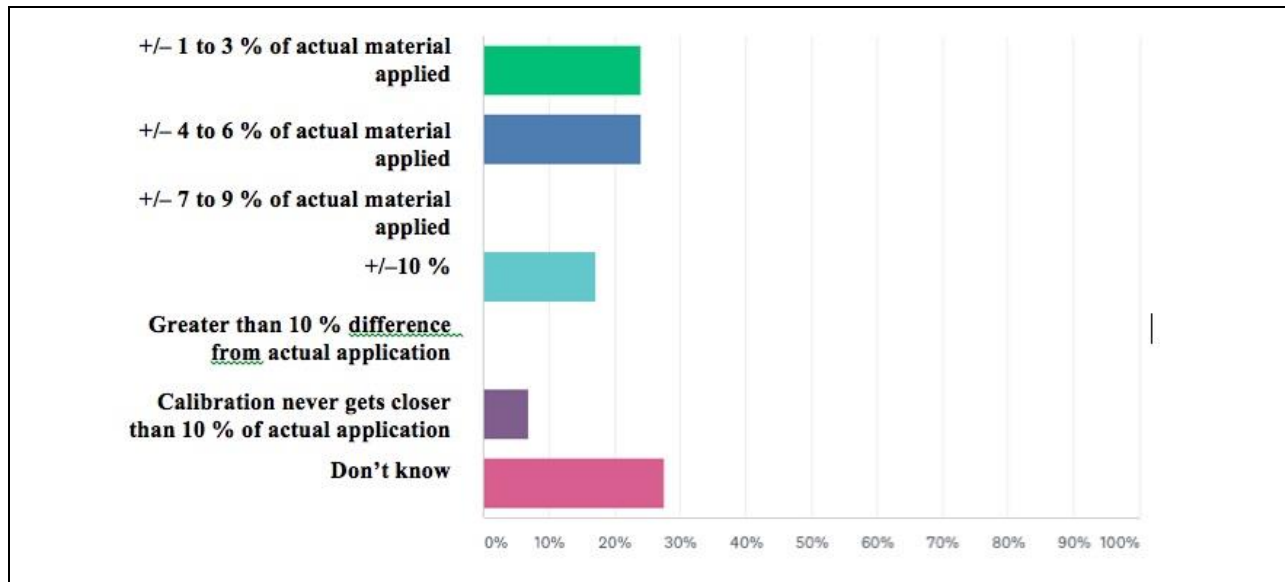
Ninety percent of respondents (27) reported that equipment was calibrated at least annually at the start of the winter season. Six respondents reported that additional calibration was performed after repairs or when inaccuracy was noticed. Colorado's respondent indicated that it was done "every 1–2 months." Several states reported that it was done "when it needs it." Thus, while one state calibrates frequently on a regular schedule, the vast majority of respondents calibrate equipment less often, potentially only once per year.

What "Calibrated" Means

The question of what "calibrated" means revealed a wide range of responses. Half of respondents (15) could report that a calibrated machine was one that reported an application rate fairly close to the actual rate of material dispensed (plus or minus 1 to 6 percent). The other half reported application rates at either plus or minus 10 percent or above (7), or they did not know what calibrated means in their agency (8).

The bar chart on the following page illustrates these results.

Tolerances of Equipment Considered Calibrated



Events That Trigger Calibration

Certain events can trigger the need for calibration. Respondents noted the events they recognized as triggers in the next question. While most reported that calibration was done with the initial placement of a machine into service (27, 90 percent), major controller or sensor repair and an operator noticing a discrepancy between the controller setting and actual application amounts also rated high as reasons to recalibrate (22, 75.9 percent). Only nine respondents (30 percent) would calibrate when switching to a new material (such as from salt to sand/salt) and only five (16.6 percent) reported a new delivery of salt/deicer as a trigger for calibration. It is worth noting that the delivery of new material or switch to a different material is listed in many calibration guides (see Blackburn and Associates, 2008, 2009 in Literature Search) as a reason to recalibrate material application equipment.

Who Performs Calibration

Respondents reported that calibration is generally performed by mechanics, operators, and supervisors. Some agencies have specialized experts who calibrate (New Hampshire, New York State, Utah, and Idaho). Others agencies report that the vendor performs calibration (Massachusetts and Ontario), while Wisconsin has no centralized control over calibration, as it is done at the county level.

How Calibration is Performed

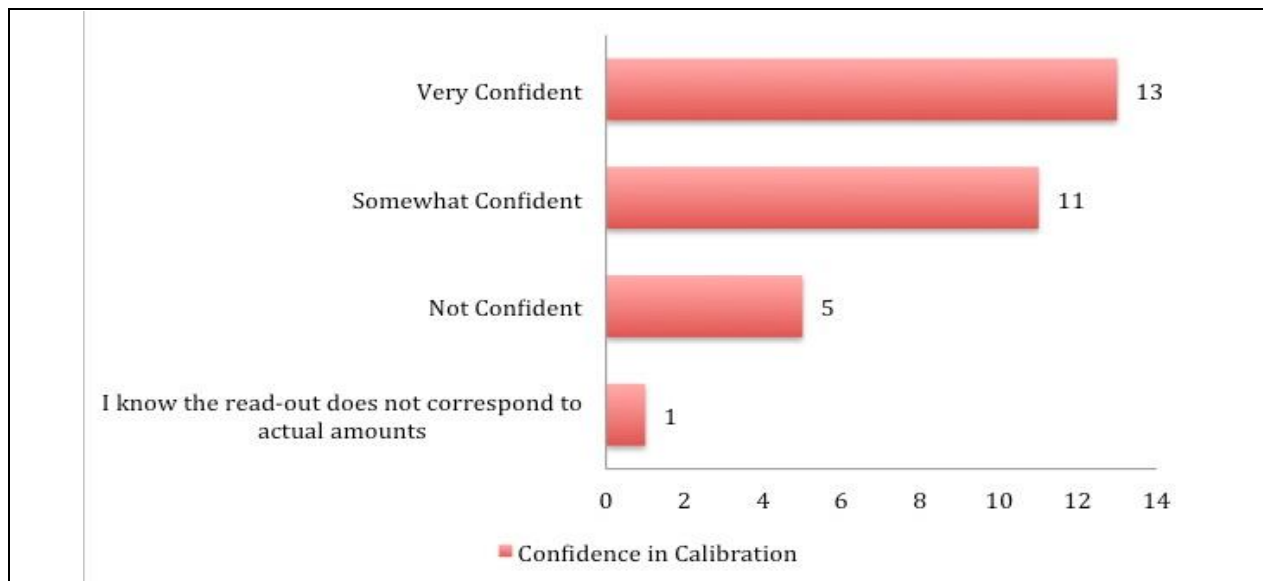
Thirty percent of respondents (9) follow the manufacturer’s procedures in calibrating their equipment, while 43.3 percent (13) follow a calibration guide created by their agency. Six of those respondents sent documents pertaining to those procedures (see Appendices B through G). More than a quarter of respondents (8, 26.6 percent) did not respond to this question. The survey provided a free-response space for respondents to elaborate on their answers. Those responses are included in the Survey Details (Table 2.7).

Confidence in Calibration Accuracy

This section of the survey’s questions addressed respondents’ confidence in the calibration accuracy of their equipment. It asked about their own levels of confidence, their perceived causes for equipment inaccuracy—arising from the equipment itself, materials, and other sources; maintaining correct gate height, and salt moisture content.

Respondents’ confidence in their equipment’s accuracy varied widely, with 13 respondents (43.3 percent) reporting they were “Very Confident” about their equipment accuracy. This is fewer than half of respondents, but it is a strong statement: 43.3 percent of respondents considered their agencies’ procedures to be effective and believed that those procedures allowed them to control and account for the amount of salt/deicer materials they applied on the highways in winter maintenance operations. Another 11 respondents were “Somewhat Confident” of their equipment calibration, while five were “Not Confident,” and one reported knowing that “the settings do not correspond to applied amounts.” The bar chart below illustrates the results:

Confidence in Calibration Accuracy



Reasons for Inaccuracy: Equipment

Respondents were offered nine possible equipment-based causes of inaccuracy (one was “Other factors,” which allowed an opportunity to comment). The most frequently chosen possible causes were “Age/wear of equipment” (19, 63.3 percent), followed by “Calibration procedure not followed completely” (13, 43.3 percent) and “Equipment not calibrated frequently enough,” (11, 36.7 percent). “Other equipment problems” and “Other factors” were chosen by 17 respondents (12 and 5 respondents, respectively). Their diverse comments are presented in Table 2.10, ranging from “sensor failure” (7), to “gate height” (4), to “driver misuse and training” (2), and salt moisture (3).

Reasons for Inaccuracy: Materials

Further possible causes of equipment inaccuracy, in this case arising from materials or other sources, were presented in this question as eight scenarios as well as an opportunity to comment. The two top

causes selected were “Flight on auger not full” (16, 53.3 percent) and “Skill of the person calibrating” (15, 50 percent). The next most frequent choices were “Material sticking to bed”(13, 43.3 percent) and “Variation in salt moisture” (13, 43.3 percent). Eleven (36.7 percent) chose “inconsistencies (volume vs. weight) in material measures,” which could also be associated with moisture content in some cases.

It is worth noting that calibration procedural inconsistencies were selected by half or nearly half of respondents in both of these calibration questions. They perceived that calibration was not performed frequently enough, that the calibration procedures themselves were not followed completely, and that the skill (or presumed lack of skill) of the person who calibrated the equipment may have been a cause of equipment inaccuracy.

Maintaining Gate Height

Ensuring that the gate height of the vehicle is maintained in the position it was placed when calibration was performed is crucial, yet many respondents noted that it was a common problem. This survey question asked respondents to describe how their agency maintains the gate height in the correct position throughout operations. Answers were varied, from securing the gate with bolts, marking the correct height, installing gauges, installing gate sensors to frequent training (“We tighten [the bolts] and told the crews not to touch the adjustments”). Some agencies use only one opening for most runs (Washington State, WVB Partners). A few agencies have obviated the problem by using a dual auger system that uses only one gate opening (New York State) or trucks that use horizontal spreader boxes with a swing-out tailgates (Maryland). Vermont and Arizona use sensors. Supervisors inspect the gate height in some states (Indiana, Wyoming).

Regardless of agencies’ means of control, consistent gate height is an essential part of equipment calibration accuracy. Comments from respondents are presented in Table 2.12.

Salt Moisture Content

The moisture content of salt affects how it flows through equipment, how it spreads on the road, and how much it weighs. Excessive moisture can adversely affect spreader function and accuracy; salt moisture content is one of the more readily controllable variables that may advance or hinder an agency’s ability to maintain equipment accuracy.

Thirty percent of respondents did not know the typical moisture content of their delivered salt. Three of those respondents (Iowa, Nebraska, New York State) earlier selected “Variation in salt moisture” (in Table 2.11) as one possible cause of equipment inaccuracy. Eight respondents (26.6 percent) reported salt moisture content above two percent. Forty percent of respondents (12) reported using salt with moisture content of two percent or less. Wisconsin’s respondent noted that by contract their salt suppliers are penalized if they deliver salt with moisture content above two percent. The table on the following page summarizes salt moisture content reported by respondents.

Salt Moisture Content

Salt Moisture Content	State/Other Respondent	Total Respondents
0 to 0.5%	South Dakota	1
0.6 to 1.0%	Maryland, MnDOT–Statewide, Vermont, West Virginia, Wisconsin	5
1.1 to 2.0%	Illinois, Indiana, Massachusetts, MnDOT–District 7, Ohio, Pennsylvania	6
2.1 to 3.0%	Wyoming	1
3.1 to 5.0%	Arizona, Colorado, Montana, New Hampshire, Oregon, Washington State	6
Over 5.0%	WVB Partners	1
Don't know	Delaware, Idaho, Iowa, Kansas, Nebraska, New York State, North Dakota, Ontario (Canada), Utah	9

Overall Calibration Experience

Respondents' comments on their overall experience regarding calibration could easily be categorized into descriptions of success or of persistent challenges. Five respondents described their agencies' successes and some offered advice about procedures that have proven beneficial to their operations. Twelve respondents described their prevailing problems in attaining accuracy and/or aspects of their operation they thought hindered effectiveness and needed to change. Respondents' comments are presented in Tables 2.14 and 2.15.

Respondents from agencies who described their operations as successful recounted their routines of calibration, their use of materials management strategies, and other focused procedures that allow them to control the multiple variables that affect calibration accuracy. Those controllable variables include training, complete and frequent calibration, close attention to daily material usage, the use of technology to provide real-time information and other practices.

Beyond their discussions of calibration inconsistencies, respondents who recounted agency challenges also mentioned lack of sufficient training and human error, sensor failures, salt bridging and failing to flow out, augers and chains not consistently full of material, operators driving too fast or using excessive spinner speeds and incorrect spinner direction, the agency's lack of a scale to verify amounts, and insufficient supervision of operators.

Identifying Solutions

Survey questions in this section examined methods of verifying calibration and application rates, respondents' perceptions of equipment quality, scales, and calibration training.

Verifying Accuracy of Calibration

Respondents were asked how their agencies verified the accuracy of equipment calibration. More than half (16, 53.3 percent) reported the use of scales to verify calibration. Those who used scales listed **loader scales** most frequently (13, 43.3 percent), followed by **in-ground scales** (4, 13.3 percent) and **bucket counts** (4, 13.3 percent). Several agencies used more than one method to verify calibration. Tables 2.16 and 2.17 present this information.

Fourteen respondents (46.7 percent) reported that they did not use scales. Many of these respondents provided details about their agency's method of verifying application rates in a free-response question.

Methods of Verifying Accuracy of Application Rates

The range of methods respondents reported their agencies use to verify the accuracy of application rates was wide, from rough visual inspections (Ohio) to AVL/mobile data computer (MDC) systems on each truck to monitor application rates (Idaho).

Twenty-five respondents provided descriptions of their verification procedures; their methods are diverse and included the following:

- AVL systems
- Drop tests or bucket counts
- Paper logs
- Assessment of stockpiles after storms or at season's end
- Check the amount of material used and miles driven with controller settings
- Visual inspection and judgment based on past experience
- Regular calibration, monitoring, and cross-checking loads with daily totals

Table 2.18 presents respondents' descriptions of their verification methods.

Equipment Recommendations

Two survey questions asked respondents if they had experiences with spreader systems that proved reliably accurate over time or that proved to be unreliable. Some respondents recommended designs or models that other respondents reported to be problematic. This suggests that there are other controllable variables at play affecting equipment's reliability, such as training, calibration methods and frequency, material quality, and attention to application discrepancies.

Table 2.19 lists respondents' general design recommendations.

Scale Calibration and Models

Those respondents who reported agency use of scales to verify calibration accuracy were asked how often their scales were calibrated, as well as the scale brand and model, if it functioned well. Six respondents (Arizona, Delaware, Maryland, Ohio, Ontario, and Vermont) indicated that they calibrated their scales **annually**. Colorado reported scale calibration is performed **every two to three months**. South Dakota's respondent noted that the scales were calibrated "when we notice the drop scale not measuring correctly." The scales in Montana are calibrated using a "handheld portable scale," but the frequency was not provided.

Only the respondent from South Dakota provided the name and model of the scale system the agency uses: Scale Tec drop scale PN 7300114-Kit-IV-Steel Calibrator with GT400. The respondent noted the average cost of the system (approximately \$3500).

Employee Training and In-House Equipment Calibration

A free-response question asked respondents how their agency provided calibration training for people who performed calibration within the agency—that is, in those organizations in which calibration was not typically performed by the vendor or some other outside party.

Responses included four methods: manufacturer or vendor training, in-house training with agency teaching tools, the manufacturer’s manual, and other methods.

More than half of respondents’ agencies (16, 53.3 percent) provide in-house training in equipment calibration. Some take advantage of training from the vendor and also have their own training courses. New York State uses its own instructors to calibrate the equipment. The table below presents the results of this survey question:

Agency Calibration Training Methods

Training Method	State/Other Respondent	Total Respondents
Manufacturer/Vendor Training	Arizona, Delaware, Iowa, Nebraska, North Dakota, Ohio, South Dakota, Vermont, West Virginia, Wisconsin, Wyoming, WVB Partners	12
Training Classes	Colorado, Idaho, Illinois, Indiana, Iowa, Oregon, Maryland, MnDOT–District 7, Montana, New Hampshire, Ohio, Vermont, Washington State, Wisconsin, Wyoming, WVB Partners	16
Use the Manufacturer Manual	Kansas, Nebraska	2
Other Methods	Maryland (experts teach others), New York State (instructors calibrate equipment)	2

Table 2.21 presents respondents’ comments regarding employee training.

Specifications and Documentation

Respondents were asked to send documentation that their agencies use for calibration. Many noted that they use the manufacturer’s manuals for their equipment models. Six state DOT respondents—Iowa, Montana, New Hampshire, Oregon, South Dakota and Utah—sent documents specific to their agency’s calibration procedures. These documents are included as Appendices B through G.

Respondents’ Closing Comments

Respondents were given an opportunity to offer closing comments at the end of the survey. Their offerings—brief comments and advice—are presented in Table 2.22.

Conclusions

The survey revealed a wide range of material applicator equipment calibration practices and challenges among the thirty respondents. The underlying questions that initiated this synthesis report were concerned with equipment accuracy and the possibility that effective accuracy might be very difficult to attain and maintain. Responses from the participants indicate this is not the case: nearly 27 percent of respondents reported they were “Very Confident” in their equipment’s calibration accuracy and material application rates. More than half counted themselves “Very Confident” or “Somewhat Confident.”

The survey responses indicate that attaining calibration accuracy requires the management of multiple controllable variables. It requires effective training, careful completion of the calibration processes, attention to salt quality, and frequent calibration and recalibration after certain events (such as repairs and when new/different materials are delivered—more often than the present norm). Respondents’ answers

indicate that at many agencies, some of those variables may not be effectively controlled. While it is possible that some equipment designs and models may be more easily calibrated than others, those agencies reporting successes operate with diverse equipment.

The survey's wide range of questions and answers, as well as respondents' many extended comments on their operations, provide a window into effective calibration practices for winter maintenance agencies. The survey responses strongly suggest that best practices arise from close attention to managing the multiple controllable variables that directly affect accurate material application.

The literature search provides an overview of calibration guidance and research, and also supports a holistic approach to all aspects of equipment calibration and accurate material application: the people, the machines, the materials, and the procedures.

1 Introduction

Accurate calibration of materials application equipment can provide transportation agencies with an ongoing record of the amounts of material used throughout the winter season. Accurate calibration is the primary means through which winter maintenance crews can avoid overapplication of salt and other materials on roadways. Methods of effective calibration have been examined extensively and presented in many published reports and manuals for transportation agencies. Thus, instruction and guidance is widely available. Clear Roads member agencies were interested in learning more about calibration accuracy of equipment over time: the practices and experiences of agencies that could help identify factors that may diminish calibration accuracy.

Through a literature search and a survey of Clear Roads member agencies and other winter maintenance experts, this synthesis gathered information about the types of material application equipment that agencies used, schedules and methods of calibration, agency training protocols, respondents' perceptions of the accuracy of equipment, and types and qualities of materials. The survey of practice and literature search are presented here.

2 Survey of Practice

2.1 Overview

An online survey was distributed to the Clear Roads member state representatives and also posted on the Snow and Ice Listserv. It gathered information about the calibration accuracy of solid and liquid material application equipment, including agency practices and perceptions. Twenty-seven states responded to the survey, with Minnesota submitting two responses (one reflecting MnDOT's statewide practices and one specific to MnDOT's District 7). In addition, the Snow and Ice Listserv posting resulted in one international response and one from a private American company, for a total of 30 responses. Respondents are listed below:

- Arizona
- Colorado
- Delaware
- Idaho
- Illinois
- Indiana
- Iowa
- Kansas
- Maryland
- Massachusetts
- Minnesota (2):
MnDOT–Statewide,
MnDOT–District 7
- Montana
- Nebraska
- New Hampshire
- New York
- North Dakota
- Ohio
- Oregon
- Ontario, Canada
- Pennsylvania
- South Dakota
- Utah
- Vermont
- Washington State
- Wisconsin
- West Virginia
- Wyoming
- Denmark
- WVB Partners

The full text of the survey questions appears in [Appendix A](#). A summary of the survey responses begins on the following page.

2.2 Equipment

The **Equipment** section of the survey requested information about the types of material application equipment that respondents used for solid and liquid materials. Further questions addressed the use of Global Positioning System/Automatic Vehicle Locator (GPS/AVL) systems on vehicles and spreaders.

Table 2.1 presents the results of survey questions 2 and 3, which requested information about the types of applicator systems used. Each system type question offered four possible responses: manual, open-loop ground speed control, closed-loop ground speed control, and other/comments. Respondents could select as many systems as their agencies used.

Table 2.1 Applicator Systems for Solids and Liquids
(Asterisks in the “Other” column indicate comments from respondents, discussed below.)

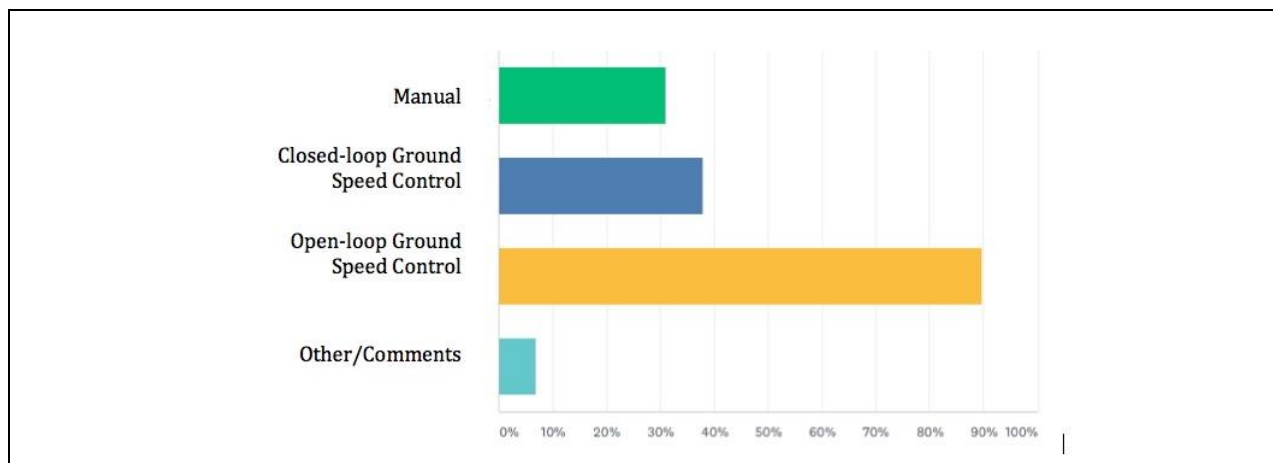
State/Other Respondent	Solid Applicator Systems				Liquid Applicator Systems			
	Manual	Open	Closed	Other	Manual	Open	Closed	Other
Arizona			X				X	
Colorado	X	X	X		X	X	X	
Delaware			X				X	
Idaho			X				X	
Illinois	X		X		X		X	*
Indiana		X	X			X	X	
Iowa			X				X	
Kansas			X				X	
Maryland		X				X		
Massachusetts			X				X	
MnDOT–District 7	X	X	X		X	X	X	*
MnDOT–Statewide		X			X			
Montana			X	*			X	
Nebraska	X		X		X		X	
New Hampshire			X				X	
New York State			X				X	
North Dakota			X					
Ohio			X				X	
Oregon	X	X	X		X	X	X	
Pennsylvania		X					X	
South Dakota	X		X		X		X	
Utah	X	X	X				X	
Vermont			X				X	

State/Other Respondent	Solid Applicator Systems				Liquid Applicator Systems			
	Manual	Open	Closed	Other	Manual	Open	Closed	Other
Washington			X				X	
West Virginia		X	X		X	X	X	
Wisconsin	X	X	X				X	
Wyoming		X	X		X	X	X	
Denmark							X	
Ontario	X	X	X				X	
WVB Partners			X				X	
Total Respondents	9	12	26		9	7	27	

Solid Materials Application

Twenty-nine of thirty respondents answered the question about solid material application equipment. The use of a closed-loop ground speed control system for solid material application was prevalent among respondents, with twenty-six (nearly 90 percent) indicating they used this system for solid material application. Among those twenty-six, three states also indicated use of open-loop systems (Wyoming, West Virginia, and Indiana), while six respondents noted that they used all types: manual, open- and closed-loop systems (Colorado, MnDOT–Statewide, Ontario, Oregon, Utah, and Wisconsin). Three respondents chose manual and closed-loop systems to describe their equipment (Illinois, Nebraska, and South Dakota). Pennsylvania and the MnDOT–District 7 respondents indicated the use of only open-loop ground speed control systems. Figure 2.1 illustrates the distribution of types of equipment respondents used for solid material application.

Figure 2.1 Types of Solid Material Application Equipment Used



Comments from respondents reveal that their closed-loop ground speed control systems are easily used in “manual” mode if the driver chooses to disengage the automatic spreader system, as in the case of treating

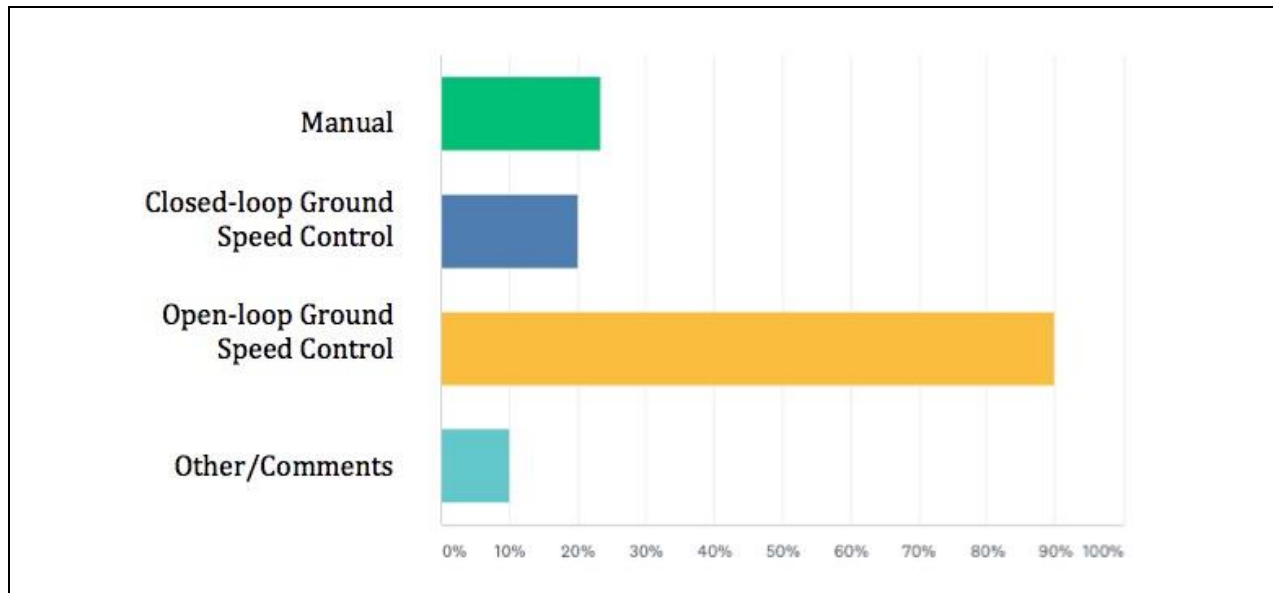
stretches of roadway that require heavier application of material or instances of noticeable calibration discrepancies. Organizations using the closed-loop system thereby always have, in effect, a “manual” system available for their use. No respondents solely use a manual system for solid material application. The “Other” category represents respondents (MnDOT–Statewide and Montana) who included comments about their choices. The MnDOT–Statewide respondent noted the option of drivers to use the “manual” mode of their closed-loop systems, while the Montana respondent wrote that the agency uses a salt/sand mixture exclusively and calibrates for it rather than for straight salt application.

Liquid Application

Thirty respondents provided answers about liquid application equipment, which vary from the responses about solid application. Seven respondents (23.3 percent) reported the use of “manual” gravity feed systems. Six (20 percent) reported using an open-loop system, while the majority—27 respondents (90 percent)—use a closed-loop system for liquid application.

Four respondents provided additional comments. The MnDOT–Statewide respondent described the use of gravity-fed liquid to pre-wet the salt at the spinner to “reduce the bounce of the material as well as activate the salt so it is already starting to melt the ice/snow.” Iowa’s respondent noted that there are some gravity feed units, but most operate with a flow meter. Illinois’ respondent indicated the use of GPS/AVL for gathering solids application data and reported future plans to include liquid application data. The respondent from Denmark described their liquid application as “GPS-controlled.” (This respondent skipped the question about application of solids.) Figure 2.2 illustrates the distribution of types of equipment respondents used for liquid application.

Figure 2.2 Types of Liquid Application Equipment Used



GPS/AVL Systems

Table 2.2 presents the results of questions 4 and 5, which requested information about respondents’ use of GPS/AVL systems on vehicles and spreaders. Those who indicated they used GPS/AVL for vehicle location were also asked if their systems recorded sensor data from vehicles, such as information from bed-scale sensors.

Of the thirty respondents, 24 (80 percent) reported the use of GPS/AVL on their vehicles. Four respondents—three states (Indiana, Kansas, and Montana) and the private sector respondent—did not have this system; Massachusetts and North Dakota were in testing or pilot stages. New Hampshire has 64 of its fleet trucks equipped with GPS/AVL.

The primary advantage of the GPS/AVL system is the ability to track the location of maintenance trucks on their routes. However, it is also possible to use this system to gather data from various sensors on the trucks, such as those on bed scales. The second GPS/AVL survey question addressed this use.

Of the 24 respondents who indicated the use of GPS/AVL on their trucks, 13 (54.2 percent) reported that they also used this system to record sensor data from the trucks. Of the remaining GPS/AVL users, a group of 11 reported *not* collecting sensor data via that system. Two respondents (Denmark and Massachusetts) reported that sensor data was collected in other ways. The spreading of material in Denmark was described as “GPS-controlled,” while Massachusetts’ respondent noted that the controller closed-loop data is sent to the cloud.

Recent research has examined the use of GPS/AVL systems’ expanded data-gathering functions as a substitute or backup to material applicator controller readouts of amounts of salt/deicer applied by winter maintenance trucks. A research project in Ohio studied the accuracy and effectiveness of combined distance and weight data (from on-board bed scale sensors) gathered via GPS/AVL to determine the amounts of salt/deicer that trucks applied. Researchers also investigated the factors that could interfere with or otherwise degrade the data. This study is included in the Literature Search.

Table 2.2 Use of GPS/AVL for Vehicle Location and Sensor Data

Uses GPS/AVL?	State/Other Respondent	Total Respondents
Yes	Arizona, Colorado, Delaware, Denmark, Idaho, Illinois, Iowa, Oregon, Maryland, MnDOT–District 7, MnDOT–Statewide, Nebraska, New Hampshire (64 trucks), New York State, Ohio, Ontario (Canada), Pennsylvania, South Dakota, Utah, Vermont, Washington State, West Virginia, Wisconsin, Wyoming	24
No	Indiana, Kansas, Montana, WVB Partners	4
Other	Massachusetts (testing), North Dakota (in pilot stage)	2
GPS/AVL Records Sensor Data?	State/Other Respondent	Total Respondents
Yes	Arizona, Idaho, Illinois, Iowa, Maryland, MnDOT–District 7, MnDOT–Statewide, Nebraska, New Hampshire, New York State, Ontario (Canada), South Dakota, Vermont	13
No	Colorado, Delaware, Indiana, Kansas, Montana, Ohio, Oregon, Utah, Washington State, West Virginia, Wisconsin, Wyoming, WVB Partners	13
Other	Denmark (GPS-controlled spreading), Massachusetts (closed-loop data to cloud)	2

2.3 Calibration

As discussed previously, winter maintenance agencies use several types of systems—manual, closed-loop and open-loop ground speed control. Even the older, least automated manual systems require calibration by a mechanic or other professional to control the amount of salt or other material the trucks lay down per lane-mile. The amount of material that equipment spreads depends upon the state of the salt (and other solids) itself: grain size, moisture content, even age. The amount spread also depends on the parts of the system, which will vary in size, speed, and in many other small ways, affecting how much material is applied. Each new calibration of equipment incorporates those many variables, resulting in a system attuned to particular materials and machinery. There is an expectation that the amount of material applied to roads and the data the system generates will be accurate if the calibration is effectively performed by a trained person.

Concerns about the calibration accuracy of material applicator equipment generated the initial questions underlying this synthesis report. The twenty-five survey questions were designed to discover the extent to which calibration accuracy is problematic among Clear Roads member agencies (and others) and to gather data about agencies’ equipment, procedures, and materials.

The following five survey questions addressed general aspects of calibration:

- **Frequency of calibration**
- **What “calibrated” means**
- **Events that trigger calibration**
- **Who calibrates**
- **How calibration is performed**

Frequency of Calibration

Ninety percent of respondents (27) reported that equipment was calibrated at least annually, at the beginning of each winter season. Several (20 percent) indicated that additional calibration was performed when equipment was repaired or inaccuracy was noticed (Illinois, North Dakota, Ohio, Ontario, Oregon, Washington State). Colorado DOT calibrates every one to two months, while Pennsylvania and Utah respondents reported that it was done “when it needs it.” New Hampshire’s respondent reported that annual calibration will begin next year (2019): “[I]n the past it was done when the truck needed it.” North Dakota’s respondent reported that calibration is done “every one to two years,” and after hydraulic, auger or chain work is done.

Table 2.3 Frequency of Equipment Calibration
(Asterisks indicate respondent comments, discussed above)

Calibration Frequency	State/Other Respondent	Total Respondents
Annually, at the beginning of each winter season	Arizona, Delaware, Denmark, Idaho, Illinois, Indiana, Iowa, Kansas, Oregon, Maryland, Massachusetts, MnDOT–District 7, MnDOT–Statewide, Montana, Nebraska, New Hampshire*, New York State, North Dakota, Ohio, Ontario (Canada)*, South Dakota, Vermont, Washington State, West Virginia, Wisconsin, Wyoming, WVB Partners	27
Every 3–4 months	None	0

Calibration Frequency	State/Other Respondent	Total Respondents
Every 1–2 months	Colorado	1
Other regular schedule	None	0
When it needs it	Pennsylvania, Utah	2
Don't know	None	0
Other/comment	North Dakota*	1

What “Calibrated” Means

While calibration was performed by every agency, what it means for equipment to be considered “calibrated” includes a wide range of measure. Half of respondents reported that their calibrated equipment read-outs were within one to six percent of actual material applied. Of that group of 15, eight respondents reported only a plus or minus one to three percent variance between read-out and actual material applied. Seven respondents reported a plus or minus four to six percent variation. The remaining 50 percent of respondents reported either a plus or minus ten percent or greater variance (seven respondents), or that they did not know how closely the read-out compared to the actual amount of material applied to roadways (eight respondents).

Thus, 26.7 percent of respondents reported relatively close tolerances of calibration (plus or minus one to three percent). Another 23.3 percent reported plus or minus four to six percent read-out tolerances, while 50 percent of respondents experienced a wide variation from the read-out or had no information about the correspondence between equipment read-out and applied material.

Several respondents reported variation across agency garages and included qualifying comments: the MnDOT–Statewide respondent reported that a five to ten percent variation is considered calibrated; Nebraska noted variations from one to three percent up to a ten percent among agency garages; Colorado noted that liquids were within one to three percent, while solids yielded a greater than ten percent difference—both were considered calibrated in the agency. Montana reported using a salt/sand mixture with a less than ten percent variation, but straight salt had a one to three percent variation from the controller read-out.

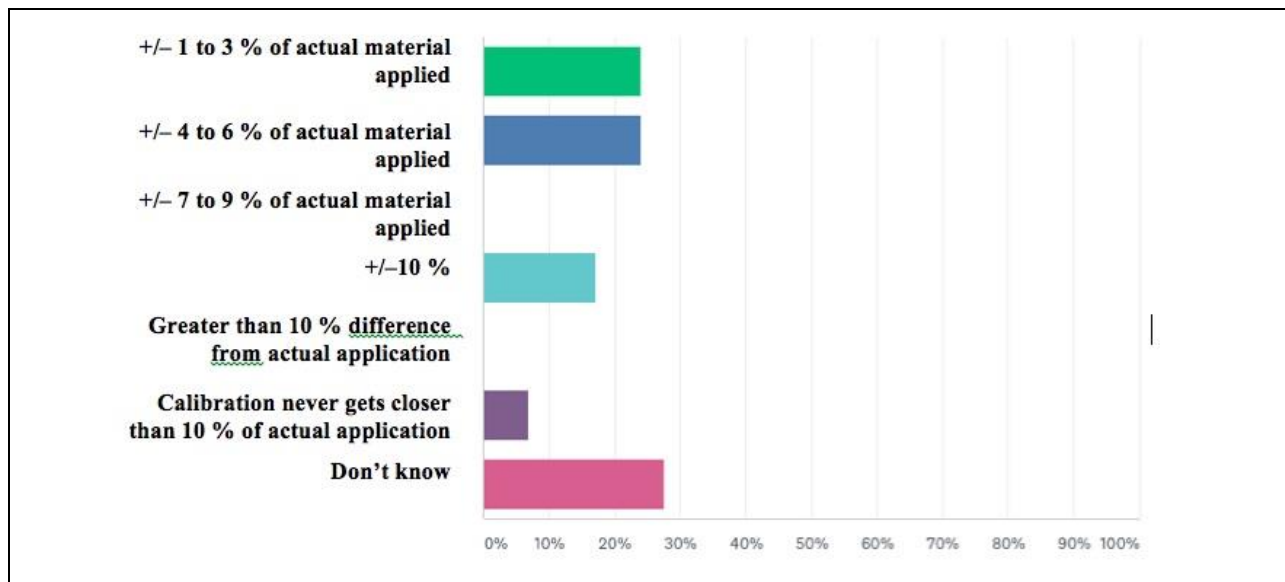
Thus, the responses to this survey question revealed that the calibration results among respondents vary widely. As a point of reference, the Blackburn and Associates 2008 research report on calibration accuracy, *Calibration Accuracy of Manual and Ground Speed Controller Salters*, and its accompanying 2009 calibration guide, *Calibration Guide for Ground-Speed-Controlled and Manually Controlled Material Spreaders* (produced for Clear Roads), indicated that a plus-or-minus four percent variation is widely considered calibrated. That research report is included in the Literature Search.

Table 2.4 shows calibrated equipment read-outs compared to actual material application as states have reported their experience. Below the table, Figure 2.3 illustrates the same information graphically as a bar chart.

Table 2.4 Controller Read-Out Tolerances of Calibrated Equipment
(Asterisks indicate respondent comments, discussed above)

Tolerance Considered Calibrated	State/Other Respondent	Total Respondents
+/- 1 to 3 percent of actual material applied	Idaho, Maryland, MnDOT–Statewide, Montana*, New Hampshire, South Dakota, Vermont, West Virginia	8
+/- 4 to 6 percent of actual material applied	Illinois, Kansas, New York State, Ontario (Canada), Oregon, Washington State, WVB Partners	7
+/- 7 to 9 percent of actual material applied	None	0
+/- 10 percent of actual material applied	Arizona, Massachusetts, MnDOT–District 7*, North Dakota, Utah	5
Greater than 10 percent of actual material applied	None	0
Equipment calibration never gets closer than 10 percent of material applied	Colorado*, Delaware	2
Don't know	Denmark, Indiana, Iowa, Nebraska, Ohio, Pennsylvania, Wisconsin, Wyoming	8

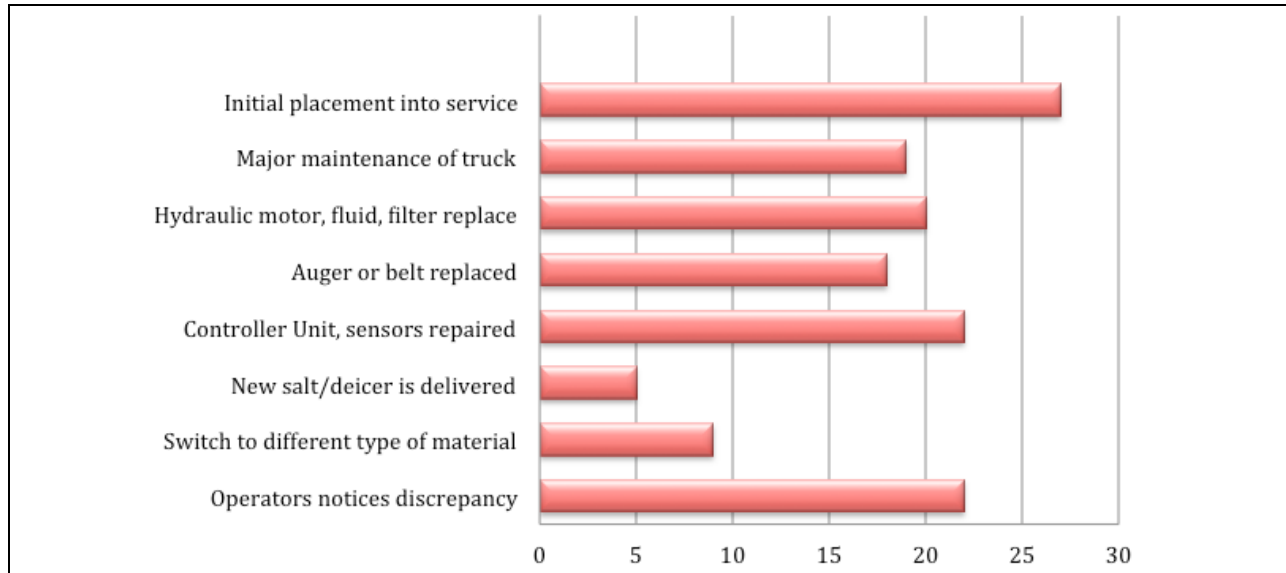
Figure 2.3 Tolerances of Equipment Considered Calibrated



Events Triggering Calibration

While annual calibration was reported as the norm among respondents, certain events or types of repair could create situations requiring new calibration of the equipment. The survey question asked respondents which events among a list of eight—ranging from major maintenance to delivery of new salt/deicing materials—would trigger a new calibration of equipment at their agency. Respondents could choose as many as they thought applied. Figure 2.4 illustrates the choices of the respondents in a bar chart.

Figure 2.4 Events Triggering Equipment Calibration
(Responses from a total of 30 respondents)



The events most likely to require an initial or new calibration of equipment among respondents' agencies include the machinery's first placement into service (27 respondents, 90 percent), repair of the controller unit or speed sensors (22 respondents, 75.9 percent), and an operator noticing a discrepancy between the amount of material the operator expected to be applied and what was applied (22 respondents, 75.9 percent). Closely following those events are hydraulic repairs (20 respondents, 69 percent), major maintenance of the truck (19 respondents, 65.5 percent), and an auger or belt replacement (18 respondents, 62 percent).

It is noteworthy that only five respondents would recalibrate after the delivery of new material, and only nine would recalibrate when switching to a different material (salt to sand, for example). The Blackburn and Associates calibration guide mentioned previously offers suggestions in this area. On page 27, the guide includes the following recommendations:

Spreader/controller systems should be calibrated/recalibrated under the following conditions:

- When the spreader/controller unit is first put into service.
- Annually, before snow and ice control operations begin.
- After major maintenance of the spreader truck is performed and after truck hydraulic fluid and filters are replaced.
- After the controller unit is repaired or when the speed (truck or belt/auger) sensors are replaced.
- After new snow and ice control material is delivered to the maintenance garage location.

Recalibrating after delivery of new material or when switching to another material is an important step to take to ensure calibration accuracy, according to both the Blackburn and Associates research report and the shorter calibration guide. All solids are not alike: salt differs in grain size and moisture content, both greatly influencing how it flows; sand differs considerably from salt. The calibration guide indicates that it is as important to recalibrate for these material variations as it is to recalibrate after major maintenance.

Who Performs Calibration

Respondents reported that calibration is generally performed by mechanics, operators and supervisors. Some agencies have specialized experts who calibrate: New Hampshire has a Winter Maintenance Program Specialist; New York State has Equipment Operator Instructors; Utah has a Maintenance Trainer. Idaho’s respondent reported that some districts designate one person to perform all calibrations so there is consistency within the district. Illinois’s respondent noted that calibration is checked by the operator, but can only be changed by the mechanic. The MnDOT–Statewide respondent noted that calibration is performed by various mechanics, operators, and supervisors across the agency. Wisconsin’s winter highway maintenance is directed at the county level: who calibrates varies from county to county. The respondents from Massachusetts and Ontario reported that the equipment vendor performs calibration.

Table 2.5 enumerates who calibrates equipment at the survey respondents’ agencies. Respondents were directed to choose as many options as applied.

Table 2.5 Who Performs Equipment Calibration
(Asterisks indicate comments, discussed above.)

Who Performs Calibration	State/Other Respondent	Total Respondents
Mechanic	Arizona, Delaware, Idaho, Indiana, Iowa, Kansas, Maryland, MnDOT–District 7*, Montana, Nebraska, New Hampshire, North Dakota, Ohio, Oregon, Pennsylvania, South Dakota, Washington State, Vermont, West Virginia, Wisconsin*, Wyoming	21
Operator	Colorado, Idaho, Illinois, Iowa, Kansas, Maryland, MnDOT–District 7, MnDOT–Statewide, Montana, North Dakota, Ohio, Oregon, Utah, Washington State, West Virginia, Wisconsin, WVB Partners, Wyoming	18
Supervisor/Manager	Colorado, Delaware, Denmark, Illinois, Indiana, MnDOT–District 7, New Hampshire, Ohio, Pennsylvania, Washington State, West Virginia, Wisconsin, WVB Partners	13
Vendor	Massachusetts, Ontario (Canada)*	2
Other	New Hampshire (Winter Maintenance Specialist), New York State (Equipment Operator Instructors), Vermont (Technician)	3

How Calibration is Performed

A free response survey question asked respondents how their agency performs calibration on its equipment. Nine respondents (30 percent) reported that they followed the manufacturer’s recommended procedures. Thirteen respondents (43.3 percent) briefly described their process or noted that they followed their own agency’s guidelines. Six respondents also sent documents describing aspects of their own procedures. (See [Appendices B through G](#).) Eight survey participants (26.6 percent) did not respond to this question. Table 2.6 provides a breakdown of the respondents’ methods into two categories. Table 2.7 presents comments from seventeen respondents on their calibration procedures.

Table 2.6 How Calibration Is Performed
(Asterisk indicates respondent sent information.)

How Calibration Is Performed	State/Other Respondent	Total Respondents
Follow manufacturer’s protocols	Colorado, Delaware, Illinois, Nebraska, New York State, South Dakota*, Vermont, West Virginia, WVB Partners	9
Follow agency protocols or other methods	Arizona, Idaho, Iowa*, Maryland, MnDOT–District 7, Montana*, North Dakota, New Hampshire*, Ohio, Ontario (Canada), Oregon*, Utah*, Wisconsin	13
Did not respond	Denmark, Indiana, Kansas, Massachusetts, MnDOT–Statewide, Pennsylvania, Washington State, Wyoming	8

Table 2.7 Respondents’ Comments on Calibration Procedures
(Comments have been edited for length and clarity.)

State/Other Respondent	Comments on How Calibration Is Performed
Colorado	It depends on the specific controller that is being used: Colorado uses Force America, Certified Cirrus, Dickey-John and more. These calibration documents are on the manufacturer websites.
Delaware	We use an electronic scale system attached to a skid steer and perform calibration procedure according to manufacturer. Calibration is verified with a test speed simulated dump.
Idaho	For granular materials, the controller is set to calibration mode, material is then off loaded/distributed. All off-loaded material is weighed and input back into the controller, completing the calibration process. The weighing of the material is accomplished by using a calibration catch box.
Illinois	Calibration is done per manufacturer's recommendation for speed-controlled units and per our policy for manual controls.
Iowa	Spreader is put into calibration mode and a set amount dispensed into a loader-mounted scale, usually a few hundred pounds. The spreader is tweaked and the process repeated until “accurate.” Process is also repeated for sand and sand mix; every material drags the auger differently per pound.

State/Other Respondent	Comments on How Calibration Is Performed
Maryland	It is done at the maintenance facility by subject matter experts.
Montana	Calibration is by drop tests.
Nebraska	Calibration is done per manufacturer's instructions. Five-gallon bucket and scale.
New York State	Calibration is performed in salt barn following manufacturers manual. [Application] rates entered based on NYSDOT guidelines.
North Dakota	Set the minimums and maximums for the hydraulic function. Enter in the max RPM value. Set the ground speed by a mile course. Use a scale to discharge approximately 300 lb. of material; the system counts the shaft revolutions. Liquids calibration uses a flow meter, which counts the revolutions. Enter the value when a five-gallon pail is full.
Oregon	Mechanics or operators are provided direction in the ODOT Calibration Guide.
South Dakota	Manufacturer recommendations. For solid material we use a calibrated dump scale and for liquid pre-wet we use five-gallon water buckets.
Utah	Salt is offloaded onto a scale in a specific time frame.
Vermont	Calibration is done according to manufacturer specifications.
West Virginia	Follow vendor's recommended procedure. Also utilize an agricultural hopper type grain scale to capture material and weigh.
Wisconsin	Not the same everywhere. Different shops have different methods.
WVB Partners	Following Force America's documentation on spreader control calibration procedures.

2.4 Confidence in Calibration Accuracy

This section of the survey posed five related questions about calibration accuracy:

- **Confidence in calibration accuracy**
- **Reason for inaccuracy: equipment**
- **Reasons for inaccuracy: materials and other**
- **Maintaining gate height**
- **Salt moisture content**

Confidence in Calibration Accuracy

After addressing many questions about their agency’s calibration routines and techniques, respondents were asked to assess their own level of confidence in the accuracy of their equipment’s calibration. Thirteen respondents (43.3 percent) described themselves as “Very Confident” in their equipment’s calibration accuracy. Another eleven respondents (36.7 percent) described themselves as “Somewhat Confident,” while six respondents were “Not Confident” or knew that the settings did not correspond to actual applied amounts.

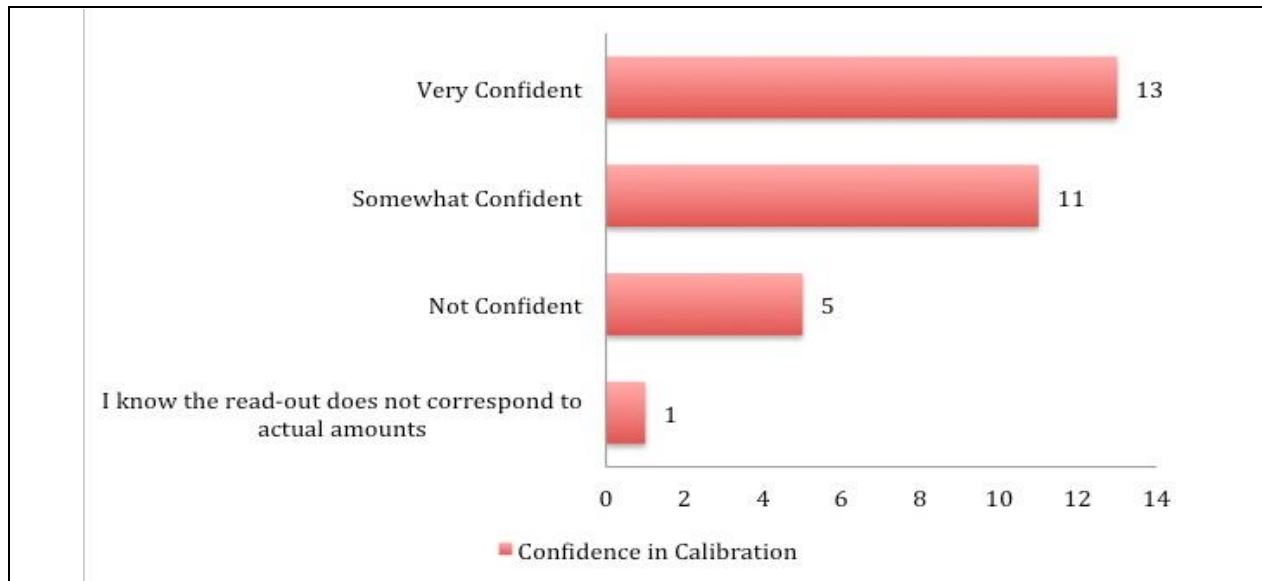
Comments from respondents indicated a range of perceptions underlying stated confidence levels within agencies. Iowa and Pennsylvania’s respondents noted that calibration should probably be performed more frequently throughout the season. The respondent from Kansas reported that newer equipment was better than old and augers were better than slat conveyers. The MnDOT–Statewide respondent reported that there was accuracy variation across the state because workers in some areas took calibration seriously while those in other areas did not take calibration “as seriously.” Nebraska’s respondent reported that self-assessments gathered from across the state indicated that most people reported they were “very” or “somewhat” confident. Calibration was as close as possible with available equipment, wrote North Dakota’s respondent, but “there will always be discrepancies . . . from chunks to moisture content of material used.” Oregon’s respondent reported having to rely on hard copy logs and end-of-season accounting of materials remaining to determine accuracy: “no formal evaluation of calibration accuracy have ever taken place.” Table 2.8 lists the respondents and their level of confidence in their equipment’s accuracy.

Table 2.8 Confidence Levels in Calibration Accuracy
(Asterisks indicate comments, discussed above.)

Confidence in Calibration	State/Other Respondent	Total Respondents
Very Confident	Idaho, Maryland, Massachusetts, MnDOT–Statewide, Montana, New York State, North Dakota*, Pennsylvania*, South Dakota, Vermont, Washington State, West Virginia, WVB Partners	13
Somewhat Confident	Arizona, Colorado*, Delaware, Illinois, Iowa*, Kansas*, MnDOT–District 7*, Nebraska*, Ontario (Canada), Oregon, Utah	11
Not Confident	Indiana, New Hampshire*, Ohio, Wisconsin, Wyoming	5
I know that settings do not correspond to actual applied amounts	Denmark	1

Figure 2.5 illustrates respondents’ confidence levels graphically. While the number of variables each agency must address to reach equipment calibration accuracy is large, the data suggest that equipment accuracy is attainable and maintainable.

Figure 2.5 Confidence in Calibration Accuracy



Reasons for Inaccuracy: Equipment

There are many factors that can contribute to equipment losing its calibration accuracy. Survey respondents were asked to consider two lists of possible reasons for such a loss: the first list focused on possible equipment problems, the second on issues with material and other reasons. Respondents were asked to select as many factors as they thought applied to their agency.

The most likely reason for loss of accuracy stemming from equipment function was considered by most respondents (63.3 percent) to be related to age and wear of the equipment. The next two most likely reasons were calibration issues: either the calibration procedure was not followed completely (43.3 percent) or the machine was not calibrated frequently enough (36.7 percent). Thirty percent of respondents noted “belt drive problems,” while “user unfriendliness” and an inability of the equipment to function at a certain rate and speed were each noted by seven respondents (23.3 percent). “Other problems” was selected by 40 percent of respondents, and the range of “other” is wide and varied. Comments are included below.

The most salient points of the data gathered from respondents answering this question are the prominence of first, equipment age, and second, frequency and effectiveness of calibration as factors contributing to equipment inaccuracy. Table 2.9 displays the possible reasons and respondents’ choices.

Table 2.9 Possible Reasons for Calibration Inaccuracy: Equipment
(Asterisks indicate respondents included comments.)

Reason	State/Other Respondent	Total Respondents
Equipment not calibrated often enough	Colorado, Illinois, Indiana, Oregon, MnDOT–District 7, Montana, Nebraska*, Pennsylvania, Ohio, Washington State	11
Calibration procedures not followed completely	Arizona, Colorado, Delaware, Idaho, Indiana*, Kansas, Oregon, Maryland, Massachusetts, MnDOT–Statewide, Pennsylvania, Ohio, Wyoming	13

Reason	State/Other Respondent	Total Respondents
Equipment/procedures not user-friendly	Illinois, Oregon, Montana, Pennsylvania	4
Loss of calibration coding	Kansas, Nebraska*, New York State, Pennsylvania, South Dakota, Utah, West Virginia	7
Belt drive problems	Colorado, Montana, Nebraska*, New Hampshire, New York State, North Dakota, Pennsylvania, Ontario (Canada), Vermont, Washington State	10
Age/wear of equipment	Arizona, Colorado, Illinois, Iowa, Kansas, Maryland, MnDOT–District 7, MnDOT–Statewide, Montana, Nebraska*, New Hampshire, New York State, Pennsylvania, Ohio, Ontario (Canada), Utah, Vermont, Washington State, West Virginia	19
Equipment not capable of applying at high rate/speed	Arizona, MnDOT–District 7, Nebraska*, New Hampshire, Pennsylvania, Utah, Washington State	7
Other equipment problems	Delaware*, Denmark*, Idaho*, Montana*, New York State*, Pennsylvania*, Ontario (Canada)*, South Dakota*, Vermont*, Washington State*, Wisconsin*, WVB Partners*	12
Other Factors	Iowa*, Nebraska*, North Dakota*, Ohio*, MnDOT–District 7*	5

Figure 2.6 presents the same data in graphic form.

Figure 2.6 Calibration Inaccuracy: Equipment

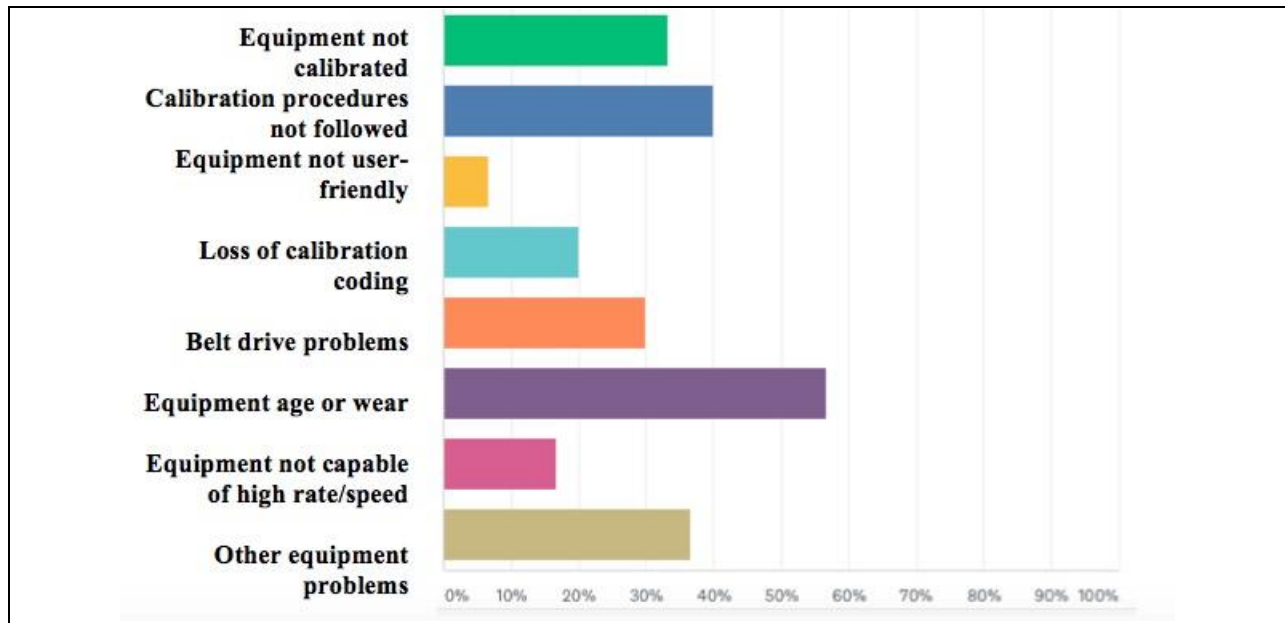


Table 2.10 presents comments of 17 respondents who discussed how various equipment inconsistencies could contribute to calibration inaccuracy.

Table 2.10 Comments on Equipment Problems and Calibration Inaccuracy

State/Other Respondent	Comments on Equipment Problems and Calibration Inaccuracy
Delaware	Operators have adjusted the gate on the spreader systems.
Denmark	Equipment measures how much liquid used. Next it calculates how much should have been used. Finally if there was too little spread, the equipment spreads more, and so on. Totally the result is +-3%, but on the road standard deviation is 40%.
Idaho	Primary cause is sensor failure.
Indiana	Mainly a training issue.
Iowa	Different size texture of salt that is delivered now vs. what was in the pile before; it doesn't flow into the auger the same way or is more or less dense.
MnDOT– District 7	Salt with more moisture than usual may cause clumps and get stuck; it can bridge and doesn't come out of the auger. The auger rate sensor gets dirty at times and the wires can get corroded. The auger rate or speed sensor fails and the sander controller doesn't record the material totals as it should.
Montana	Sensor failure, gate height does not match selected program, inconsistent moisture content of material and bridging of material.
Nebraska	Gate setting on RDS trucks is not set correctly.
New York State	Rate sensor failure, speed sensor failure, improperly inflated tires, and control valves sticking.
North Dakota	The hydraulic motor sensor fails or loss of speed signal. Hydraulic motor or hydraulic pump fails are rare. Valve section compensator fails are rare. Hydraulic relief stuck open is rare.
Ohio	Material bridging and moisture content is a concern.
Ontario, Canada	Driver misuse, faulty sensors, material sensors removed or invalidated.
South Dakota	The majority of our inconsistency is due to the drivers not setting the gates correctly, therefore, letting too little or too much salt out.
Vermont	Rate sensor failures.
Washington State	Drop gate may have been altered or bound up material.

State/Other Respondent	Comments on Equipment Problems and Calibration Inaccuracy
Wisconsin	Not certain whether it is easy to recognize equipment that is “out of calibration.” Not sure if operator can recognize a discrepancy.
WVB Partners	The wrong slide-in was put in the wrong truck.

Reasons for Inaccuracy: Materials and Other

The quality of salt/deicing material and its movement through the system, as well as other factors were addressed in the second question concerning possible reasons for the loss of calibration accuracy. This question presented eight problematic scenarios involving material moving in the equipment, salt/deicer quality, and other factors.

The two most frequently selected choices possibly contributing to inaccuracy were “the flight on the auger is not full” (16 respondents, 53.3 percent) and a lack of skill in the person calibrating the equipment (15 respondents, 50 percent). “Material sticking to the bed” and “moisture in the salt” were selected by equal numbers (13 respondents, 43.3 percent). Eleven respondents (36.7 percent) selected “inconsistencies in material measure—volume versus weight” as a possible reason for calibration inaccuracy.

Fewer respondents selected differences in salt grain size (seven) and the accuracy of on-board (four) or in-ground (three) scales as sources of equipment calibration inaccuracy. While these problems may not be widespread among Clear Roads and other agencies, they are still areas that warrant close attention and consideration as possible sources of calibration inaccuracy.

It is worth noting that incorrectly performed calibration was chosen by a majority of respondents as a likely source of equipment inaccuracy in this set of choices, as it was in the previous set.

Table 2.11 presents the possible reasons for inaccuracy and the respondents who selected those reasons.

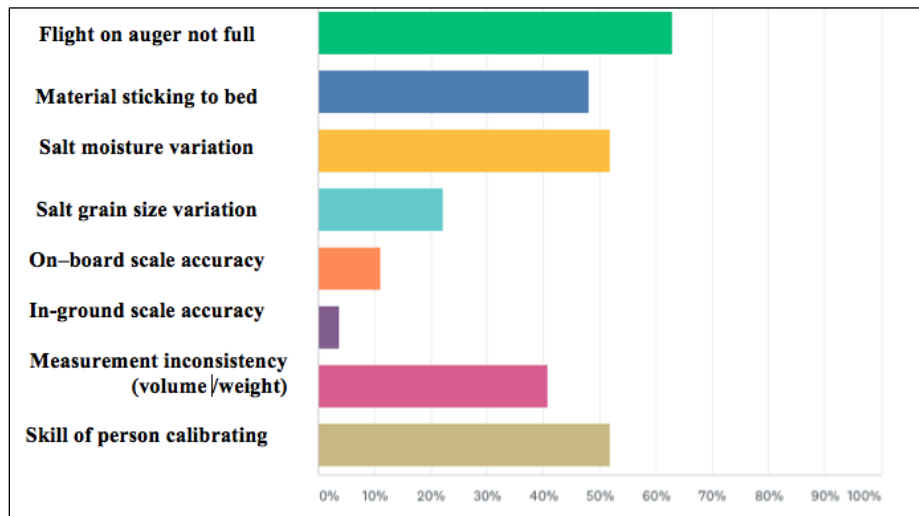
Table 2.11 Possible Reasons for Calibration Inaccuracy: Materials and Other

Reason	State/Other Respondent	Total Respondents
Flight on auger not full	Arizona, Delaware, Illinois, Indiana, Iowa, Kansas, Oregon, Maryland, Massachusetts, MnDOT–District 7, Montana, Nebraska, New York State, Ohio, Vermont, Washington State	16
Material sticking to bed	Colorado, Illinois, Kansas, Oregon, Massachusetts, MnDOT–District 7, Montana, Nebraska, New York State, Ohio, Vermont, Washington State, Wisconsin	13
Variation in salt moisture	Colorado, Illinois, Iowa, Oregon, Massachusetts, MnDOT–District 7, Nebraska, New Hampshire, New York State, Pennsylvania, Ohio, Washington State, Wisconsin	13
Variation in salt grain size	Colorado, Iowa, Massachusetts, Pennsylvania, Ohio, South Dakota, Washington State	7

Reason	State/Other Respondent	Total Respondents
Accuracy of on-board material scales	Arizona, Massachusetts, Ontario (Canada), Utah	4
Accuracy of in-ground scales	Delaware, Massachusetts, Montana,	3
Inconsistencies (volume vs. weight) in material measures	Illinois, Maryland, Massachusetts, Montana, Nebraska, New York State, Ohio, South Dakota, Washington State, West Virginia, Wyoming	11
Skill of person calibrating	Colorado, Illinois, Indiana, Kansas, Oregon, Maryland, Massachusetts, MnDOT–District 7, MnDOT–Statewide, Montana, North Dakota, Ohio, Ontario (Canada), Wisconsin, Wyoming	15
Other comments*	Arizona, MnDOT–District 7, Montana, North Dakota, Utah, Wisconsin, WVB Partners	7

Figure 2.7 also presents this data, illustrating the portion of respondents who chose each reason in a graphic bar chart.

Figure 2.7 Calibration Inaccuracy: Material Quality and Other



Maintaining Gate Height

The gate height, which allows a certain amount of material to pass through, is a point on the spreader system that is vulnerable to inappropriate adjustment or accidental change. If the gate height that was used in calibrating a system is later inadvertently changed, the calibration will no longer be accurate.

The survey asked respondents how their agency ensures that the correct gate height is maintained throughout operations. While a few agencies do not have the gate height problem due to design differences in their equipment, many respondents reported methods their agencies use to fasten or otherwise ensure that the gate height remains in the correct position. Newer technology is one remedy: Arizona monitors gate position via its AVL system; Vermont also has gate height sensors.

Because the range of solutions is wide and varied, some respondents' answers may be instructive for those agencies that have not yet solved the problem or that seek a better solution than they currently use. All respondents' contributions are included in Table 2.12 below.

Table 2.12 Maintaining Correct Gate Height

State/Other Respondent	How to Ensure Correct Gate Height Is Maintained
Arizona	Gate position is monitored by the AVL system and reported if gate settings are changed.
Delaware	Drilled holes and installed bolt to prevent easy manipulation.
Idaho	Still working on that one.
Illinois	Only two available opening widths are available and they are chosen based on severity of event and whether we will be applying material low volume or high volume.
Indiana	Supervisors are to inspect gates prior to operation.
Kansas	Through training. We use different gate setting for different materials so there is a concern that the gate does not get lowered when needed. Auger trucks do not have a gate, so this eliminates this problem.
Maryland	Most of our trucks use horizontal spreader boxes where the tailgate swings open and allows material to fall from the bottom so no gate is present. The slide-in boxes we have all have painted marks on them that let the driver know where to keep the gates open to.
Massachusetts	We make the calibration vendor mark the proper gate height with tape on the spreader body. This way someone driving behind the spreader can see whether the door is at its proper calibrated height (normally 2.5").
Montana	We measure the gate opening and/or have built gauges to match heights.
Nebraska	Set to 4" and hope they don't change it. Place a bolt in the gate opening adjustment.
New Hampshire	We mark the gate height and check them throughout the storm.
New York State	All trucks are purchased with dual auger system and there is only one size opening for material. This has proven to be the most effective in gate issues because there is no adjustment.
North Dakota	Gate height is very important. As is an operator who knows how far a load can go. If the material in the truck runs out, the spreader is still spinning and counting the totals.

State/Other Respondent	How to Ensure Correct Gate Height Is Maintained
Ohio	We tighten them and told the crews not to touch the adjustments.
Ontario, Canada	Generally only two options for gate height—one for sand one for salt. Visual checks can be made. Some units now adding gate height sensors.
Oregon	The gate is marked to indicate the appropriate settings for salt and abrasives. We are interested including gate sensors in the future.
Pennsylvania	PennDOT chains their tailgate, also place spacers between tailgate and bed.
South Dakota	We will use a tape measure and paint a line on the sander to show the proper height for that setting.
Utah	We don't have fixed gates or a gate sensor, so our calibration is dependent on a 4-inch gate height, if that is changed the calibration is off and the computer cannot sense that.
Vermont	Gate height sensors.
Washington State	We have the gates marked for typical applications and when the rate needs to be drastically increased we have a gate setting for that setting.
West Virginia	Visual checks by the supervisor.
Wisconsin	We do not have any means to ensure that the gates are being calibrated or if they need to be adjusted or calibrated.
WVB Partners	No need to adjust the gate height. We leave it alone after calibration.
Wyoming	Depend on Supervisor to monitor the gates.

Salt Moisture Content

The moisture level in salt affects how it flows (or clumps or sticks) against itself and through equipment, how it spreads on the roads, and how much it weighs. Excessive moisture levels in salt and salt/deicer mixtures can adversely affect calibration accuracy, which is based upon a consistent flow of material. The survey asked respondents the typical moisture content of their salt supplies. The respondent from Wisconsin noted that their salt suppliers are penalized if they deliver salt with a moisture content above 2 percent. Salt moisture content is just one of many controllable variables that may advance or hinder an agency’s attainment of calibration accuracy.

Table 2.13 provides the salt moisture content of typical salt supplies reported by respondents’ agencies. Thirty percent of respondents did not know the moisture content of their material, while another 26.6 percent—eight respondents—reported moisture content above 2 percent. Forty percent of respondents use salt with a moisture content of 2 percent or below.

Table 2.13 Moisture Content of Salt

Salt Moisture Content	State/Other Respondent	Total Respondents
0 to 0.5%	South Dakota	1
0.6 to 1.0%	Maryland, MnDOT–Statewide, Vermont, West Virginia, Wisconsin	5
1.1 to 2.0%	Illinois, Indiana, Massachusetts, MnDOT–District 7, Ohio, Pennsylvania	6
2.1 to 3.0%	Wyoming	1
3.1 to 5.0%	Arizona, Colorado, Montana, New Hampshire, Oregon, Washington State	6
Over 5.0%	WVB Partners	1
Don't know	Delaware, Idaho, Iowa, Kansas, Nebraska, New York State, North Dakota, Ontario (Canada), Utah	9

Overall Calibration Experience: Free Response

The final question in this section was a free response opportunity. Participants were asked to describe their overall experience with equipment calibration. Five respondents recounted success and or/offered advice. Twelve respondents described their agencies’ prevailing challenges.

Respondents from Idaho, Montana, Ontario, South Dakota, and WVB East End Partners described aspects of their successful operations and/or offered advice:

- The respondent from **Idaho** wrote: “Experience has been good. Confident in our process. Once we went statewide, material management has improved.” Idaho has AVL/MDC on all trucks.
- **Montana**’s respondent reported, “Calibration is very important to MDOT. Our operators are trained to monitor their daily storm totals on their truck computers to ensure they match estimated loaded amounts.”
- **Ontario**’s respondent noted that “proper calibration is imperative and should have daily checks to ensure we are getting what we think we are putting out on the road.”
- **South Dakota**’s respondent reported: “Overall we are pretty happy with our salt consumption and calibrations. Since we started using AVL/MDC in a portion of our fleet we have seen a huge savings.”
- The respondent from **WVB East End Partners**, a private highway maintenance contractor, offered advice: “You have to calibrate each material separately. You need to train your operators on what expectations are, levels of service, cycle times, how and why your materials perform and the limitations of them. You also need to train on the budget implications and environment issues of over-salting. In two years of operation we have had tremendous success in our winter operations. Knock on wood.”

Twelve respondents described challenges they know they must face and overcome, many including mention of training deficiencies and other problems arising from human error, the necessity of careful, thoroughly performed calibration, and more frequent calibration. Examples of responses follow:

- **Oregon**’s respondent noted the of “lack of training/understanding and experience with respect to initial calibration procedures and on-going calibration verification.”
- A comment from **Ohio** noted a “lack of willingness to consistently calibrate.”

- **Utah**'s respondent recounted a story that may resonate with others: the first, older controllers used in the state were not calibrated correctly and operators learned not to trust them. Now, years later, trust has still not been earned back. Many operators "put the controller in manual mode and control how much they put out with gate height."

Beyond calibration challenges, respondents also mentioned sensor failures, salt bridging and failing to flow out, augers and chains not consistently full of material, operators driving too fast or using too-fast spinner speeds and spinner direction, the agency's lack of a scale to verify amounts, and insufficient supervision of operators.

Respondents' comments are presented in Tables 2.14 and 2.15.

Table 2.14 Calibration Experience: Success/Advice
(Responses edited for length and clarity.)

State/Other Respondent	Overall Experience of Equipment Calibration: Success/Advice
Idaho	Experience has been good. Confident in our process. Once we went statewide, material management has improved.
Montana	Calibration is very important to MDT. Our operators are trained to monitor their daily storm totals on their truck computers to ensure they match estimated loaded amounts.
Ontario, Canada	Proper calibration is imperative and should have daily checks to ensure we are getting what we think we are putting out on the road.
South Dakota	Overall we are pretty happy with our salt consumption and calibrations. Since we started using AVL/MDC in a portion of our fleet we have seen a huge savings.
WVB Partners	You have to calibrate each material separately. You need to train your operators on what expectations are, levels of service, cycle times, how and why your materials perform and the limitations of them. You also need to train on the budget implications and environment issues of over-salting. In two years of operation we have had tremendous success in our winter operations. Knock on wood.

Table 2.15 Calibration Experience: Problems
(Responses edited for length and clarity.)

State/Other Respondent	Overall Experience of Equipment Calibration: Problems
Delaware	A problem is operators and mechanics altering the equipment setup.
Denmark	Spreading accuracy on the road is most significant [problem]. Next factor when using liquid is dosage variation, and third is turbulence.

State/Other Respondent	Overall Experience of Equipment Calibration: Problems
Indiana	Moisture content is required to be under 2%; however, sometimes materials with higher moisture content is delivered.
Massachusetts	User error with closed loop controllers; improper gate door height; insufficient supervision of spreader operators.
MnDOT– District 7	Material spreader controller calibration should be performed more often. Each shift operator needs to pay attention to how much they load and how much they use and to check if it is what the material spreader shows was used.
Nebraska	Sensor failures are a problem.
New York State	Problems: Speed of the truck while spreading. Spinner speed too high (fast). Spinner direction (material being place in wrong section of road). Rate sensor failures.
North Dakota	Human error: the system is only as good as the operator running it and person calibrating the equipment. Chunks often are stuck in the end gate. Running out of material. Hydraulic motor sensor failure.
Ohio	Material bridging, augers, and drag chains not being consistently full of material and lack of willingness to consistently calibrate.
Oregon	Most of the equipment in ODOT's fleet is not standard, and there is a lack of training/understanding and experience with initial calibration procedures and on-going calibration verification.
Utah	Initially, when operators had electronic controllers, they were not calibrated correctly, so operators learned not to trust them. UDOT spent many years trying to regain their trust, but there are still many operators who put the controllers in manual mode and control how much they put out with the gate height.
Washington State	A problem is lack of a scale to measure the amount of actual weight of material loaded into the truck.
Wisconsin	In Wisconsin, counties plow all the state highways, and they do the calibration. There is a policy and instructions on how to calibrate, but no enforcement or penalty for those that don't follow policy. There is little to no DOT staff to assist or check on this.

2.5 Identifying Solutions

This section included survey questions examining the following areas:

- **Verifying accuracy of calibration**
- **Methods of verifying accuracy of application rates**
- **Equipment recommendations**
- **Scale calibration and models**
- **Training of in-house calibration personnel**

Verifying Accuracy of Calibration

Verifying the accuracy of equipment calibration is an essential step agencies must take if they are to determine whether discrepancies in application amounts arise from inherent equipment inadequacies or, conversely, from any of the many controllable variables that influence calibration accuracy.

In this section, respondents were queried about their agency’s means of verifying calibration accuracy.

More than half (53.3 percent) of respondents use a scale to verify calibration, while the remainder do not. Table 2.16 shows which respondents reported using scales for calibration verification and which did not.

Table 2.16 Calibration Verification by Scale or Similar Means

Calibration Verified by Scale or Similar?	State/Other Respondent	Total Respondents
Yes	Arizona, Colorado, Indiana, Iowa, Kansas, Maryland, Massachusetts, MnDOT–District 7, MnDOT–Statewide, Montana, New York State, North Dakota, Pennsylvania, Ohio, Ontario (Canada), Vermont	16
No	Delaware, Denmark, Idaho, Illinois, Oregon, Massachusetts, Nebraska, New Hampshire, North Dakota, Pennsylvania, South Dakota, Utah, Washington State, West Virginia, Wisconsin, Wyoming, WVB Partners	14

Table 2.17 shows the range of scale-based methods that sixteen respondents used to verify their equipment’s calibration.

Table 2.17 Verification of Calibration by Scales

Type of Scale or Measurement	State/Other Respondents	Total Respondents
Loader Scale	Colorado, Indiana, Iowa, Kansas, Maryland, Massachusetts, MnDOT–District 7, MnDOT–Statewide, Montana, New York State, North Dakota, Ohio, Ontario (Canada)	13
In-ground Scale	Colorado, Indiana, Ohio, Vermont	4
On-board Scale	Arizona	1
Bucket counts	Massachusetts, Montana, New York State	3
Other	Pennsylvania (noted “Freedom Spreader Controller”)	1

Several agencies used more than one method to verify calibration, such as loader and in-ground scales (Colorado, Indiana, Ohio) and or a scale and bucket counts (Massachusetts, Montana, New York State). The MnDOT–Statewide respondent reported using loader scales, but also noted that they were able to use GPS/AVL units to compare data to totals from the trucks. In the case of a large discrepancy, calibration verification or full calibration is performed.

While 14 respondents indicated that they did not use scales to specifically verify calibration, many joined the majority of respondents (25 total) in answering the next free-response question about their agency’s method of verifying application rates.

Methods of Verifying Accuracy of Application Rates

The range of methods respondents reported their agencies using to verify the accuracy of application rates was wide, from rough visual inspections (Ohio) to AVL/MDC systems on each truck to monitor application rates (Idaho).

Twenty-five respondents provided descriptions of their verification procedures; their methods are diverse. Delaware, Idaho, and Iowa use **AVL systems**. Wisconsin uses GPS/AVL to a minimal degree. Massachusetts, New Hampshire, New York State, South Dakota, Vermont, and Wyoming reported using **drop tests or bucket counts**. **Paper logs** are used by Oregon, Pennsylvania, and Ontario to some extent. Oregon expects to move toward full AVL/Telematics on trucks 2009 and newer. Ontario, West Virginia, and WVB Partners **assess stockpiles** after storms or at the end of the season. Kansas, the MnDOT–Statewide respondent, Nebraska, and North Dakota **check the amount of material used and miles driven with controller settings**. Ohio and Utah reported that verification was done **visually** by judgment or by “**past experience**.” Montana reported doing **regular calibration, monitoring, and cross-checking loads with daily totals**.

Five respondents (Arizona, Colorado, Denmark, Maryland, and MnDOT–District 7) chose not to contribute their methods. Table 2.18 below presents respondents’ descriptions of their verification methods.

Table 2.18 Verification of Application Rates
(Responses edited for length and clarity.)

State/Other Respondent	Verification of Application Rates
Delaware	We verify material applications with AVL systems that now record application rates.
Idaho	AVL/MDC on each truck is used to monitor application rates.
Illinois	Separate material tracking system that watches delivered amounts and input the totals that spreaders show were applied. If salt stockpile remains when the amount we had ordered should be gone based on usage, we know the spreaders are not accurately capturing the real material usage.
Indiana	Driver will note that rates are off and request inspection or new calibration.

State/Other Respondent	Verification of Application Rates
Iowa	AVL data will verify what it was set to for managers to review in real time or later—to ascertain whether it was set to the supervisor's direction vs. whether the operator did something different.
Kansas	We use a load scale. During a storm, we determine how many miles and at what rate the operator spread and when he ran out of material.
Massachusetts	Bucket counts and pre- and post-storm salt shed volume surveys are used.
MnDOT– District 7	Our verification process is in our own Material Spreader Calibration Guides. Sometimes we take the number of tons reported applied during a shift and divide by the number of miles, multiply by 2,000 to find the average rate in lbs./lane-mile the controller should have been set at. If this average lbs./lane-mile rate matches the average rates the operator set their controller to during the shift, we have confidence the controller is still calibrated. If the average rate doesn't match, we do a verification or a full calibration of the Material Spreader Controller.
Montana	Regular calibration, monitoring and cross checking loads with daily storm totals.
Nebraska	Comparing "storm total" on spreader controller with what was put in the truck.
New Hampshire	We use a drop test.
New York State	Most keep track of buckets loaded and end of shift application rates for each truck.
North Dakota	Manually checking the estimated pounds of material against the number of miles driven.
Ohio	Basically, the operator visually looks at the salt coming out and makes a judgment call as if they feel it is the correct amount. Inventory assessments in storage facilities are made using a visual estimate.
Ontario, Canada	Written and visual methods; we now measure our stockpiles using an independent third party.
Oregon	Currently, we use hard copy logs. We will be implementing full AVL/Telematics on most trucks, 2009 and newer.
Pennsylvania	Fill out paper taper log and compare to data for spreader controller.
South Dakota	We use a dump scale and measure the drop to verify it is within tolerance.
Utah	Uncertain. They may measure it by feel or past experience.

State/Other Respondent	Verification of Application Rates
Vermont	We use a drop test.
Washington State	Distance and width of application.
West Virginia	Post season material audits.
Wisconsin	AVL-GPS to a minimal degree. We generally allow the counties to be self-policing.
WVB Partners	Stockpile assessments after the storm.
Wyoming	Bucket loads converted to tons and input into Agile Assets work orders.

Equipment Recommendations

Two survey questions asked respondents if they had experiences with spreader systems that proved reliably accurate over time or those that proved unreliable. Some respondents recommended designs that other respondents reported to be problematic, which suggests that there are other controllable variables at play affecting some equipment reliability. Table 2.19 lists respondents' general design recommendations.

Table 2.19 Equipment Designs: Reliability Perceptions

Types of Equipment	Perceived as Reliably Accurate	Perceived as Unreliable
Solid Material Spreaders	Augers are better than conveyor chains. V-box sanders	V-box because of gate height variations. Live bottom, tailgate auger. V-box with flight chain.
Liquid Systems	Hydraulic pumps. Pre-wet and direct application tank systems.	Spray nozzle at gate.
Other Systems and Components	Slide-in sanders because they can be removed for repairs.	Tailgate sanders seem to put out lots of material quickly and bridging can be a problem; unreliable at slow speeds and low usage per revolution. AVL systems are still newer technology and finicky to troubleshoot.

Scale Calibration and Models

Those respondents who reported agency use of scales to verify calibration accuracy were asked how often their scales were calibrated, as well as the scale brand and model, if it functioned well. Six respondents (Arizona, Delaware, Maryland, Ohio, Ontario, and Vermont) indicated that they calibrated their scales **annually**. Colorado reported scale calibration performed **every two to three months**. South Dakota’s respondent noted that the scales were calibrated “when we notice the drop scale not measuring correctly.” The scales in Montana are calibrated using a “handheld portable scale,” but the frequency was not provided.

Only the respondent from South Dakota provided the name and model of the scale system the agency uses: Scale Tec drop scale PN 7300114-Kit-IV-Steel Calibrator with GT400. The respondent noted the average cost of the system (approximately \$3500).

Employee Training for In-House Equipment Calibration

Respondents were asked how calibration skills were taught in those agencies performing calibration tasks in-house (that is, not using a vendor or other third party to calibrate). More than half of respondents’ agencies (16, 53.3 percent) provide in-house training in equipment calibration. Some take advantage of training from the vendor and also have their own training courses. New York State uses its own instructors to calibrate the equipment.

Table 2.20 summarizes the training methods of the respondents. Respondents’ comments about their agency training methods follow in Table 2.21.

Table 2.20 Agency Calibration Training Methods

Training Method	State/Other Respondent	Total Respondents
Manufacturer/Vendor Training	Arizona, Delaware, Iowa, Nebraska, North Dakota, Ohio, South Dakota, Vermont, West Virginia, Wisconsin, Wyoming, WVB Partners	12
Training Classes	Colorado, Idaho, Illinois, Indiana, Iowa, Oregon, Maryland, MnDOT–District 7, Montana, New Hampshire, Ohio, Vermont, Washington State, Wisconsin, Wyoming, WVB Partners	16
Use the Manufacturer Manual	Kansas, Nebraska	2
Other Methods	Maryland (experts teach others), New York State (instructors calibrate equipment)	2

Table 2.21 In-House Calibration Training: Comments

State/Other Respondent	In-House Calibration Training Comments
Arizona	Initially, all our technicians were trained by the vendor.
Colorado	This is a part of winter operations training for new employees and also a part of the winter operations refresher courses for veteran employees.
Delaware	Trained by ground speed controller vendor.

State/Other Respondent	In-House Calibration Training Comments
Idaho	Individuals with the desire and interest in the computerized componentry typically step forward and show an interest. They are then trained on the process and typically take enough interest to train others who show an interest.
Illinois	Four-hour in-person training to higher level staff at maintenance yards, ideally performed annually and for any new staff.
Indiana	Each district currently has their own process or Standard Operating Procedure, uniformity across the state has not been established.
Iowa	All equipment operators receive on-site instruction from their districts
Kansas	Manufacturer’s manual.
Maryland	We do not have an official in house training. Our methods are passed down by our experts at each facility.
MnDOT– District 7	Our agency conducts calibration in-house and we have an extensive training program. We have several training documents and some YouTube videos that show a step-by-step process on how to calibrate each Material Spreader Controller in our agency.
Montana	Operators and mechanics are trained by maintenance and equipment reviewers either in the field or at our maintenance academy.
Nebraska	Follow instructions on controller. Use the controller operator’s manual. Also use a sales representative for Force America.
New Hampshire	We have about ten trainers. We have a manual that they use and training is done each year starting next year
New York State	Instructors perform most calibrations to keep control of rates. Employees were able to be certified by the instructors but that no longer is the case due to employees getting into the computer heads and manipulating the system.
North Dakota	Trained by the equipment sales representative. Read the calibration guide. Trial and error: calibrate system, run simulated speeds, catch material, and measure.
Ohio	Our employees are trained by the vendors, mechanic and supervisors.
Oregon	ODOT recently developed a calibration guide, and the importance of calibration is covered during the introductory winter maintenance training course.
Pennsylvania	PennDOT Mechanics are trained by vendor. PennDOT Mechanics perform calibration.
South Dakota	Our mechanics are trained by the manufacturer and their recommendations.

State/Other Respondent	In-House Calibration Training Comments
Utah	They are trained by Force America personnel
Vermont	Training by vendors of spreader controls and our CG mechanics
Washington State	We have about 50 dedicated employees that regularly calibrate. Calibration training is available to all techs once a year.
West Virginia	Vendor, train the trainer
Wisconsin	On the job training—from those with experience and training videos.
WVB Partners	Vendor rep. training through Force America, and we do classroom and hands on training.

2.6 Specifications and Documentation

Respondents were asked to send documentation their agencies use for calibration. Many noted that they use the manufacturer’s manuals for their equipment models and included company links. Six state DOT respondents—Iowa, Montana, New Hampshire, Oregon, South Dakota, and Utah—sent documents specific to their agency’s calibration. Their documents are included as [Appendices B through G](#).

Respondents’ Closing Comments

Respondents were given an opportunity to offer closing comments at the end of the survey. The contributions of nine respondents—brief comments and advice—are presented in Table 2.22.

Table 2.22 Respondents’ Closing Comments
(Responses edited for length and clarity.)

State/Other Respondent	Closing Comments
Indiana	INDOT has not established a statewide standard for calibration and training. However, we are working to implement uniform training and maintenance SOPs for next year.
Maryland	We would be interested in seeing the documents or practices that other states have in place for possible future implementation.
Massachusetts	Closed loop ground speed control is effective. AVL material tracking systems are still "young" technology with which we struggle to get data wirelessly transmitted to us. We are interested in examining auger-based slurry spreaders as an alternative to conveyer-based systems because pre-wetting is better (more saturation) in the auger-based systems

State/Other Respondent	Closing Comments
MnDOT– District 7	If you have a GPS/AVL system and are using it to capture your material spreader controller data, make sure you know the limitations of the controller. Many material spreader controller companies do not allow you to get all the data from the spreader and only allow you to poll [the controller] every so often. Make sure you have at least one person or a team dedicated to ensuring you are getting quality data, as this will be the difference in success or failure in data quality and any reports you plan to utilize based of the data.
Nebraska	Responses were collected from several districts and put together for this survey. Some responses contradicted others. The consolidated response comprises the variety of different individuals.
New Hampshire	We calibrate to within 5 percent accuracy or greater, but when the trucks are running and putting out material the accuracy goes out the window and some units are up to 75 percent off.
New York State	As a quality control, drop tests are performed periodically throughout the winter. If unacceptable discrepancy found then full calibration is performed.
Ohio	I believe the true issue with calibration and accurate material dispensing involves the material moisture and consistency.
Washington State	Most of our equipment is calibrated using portable scales that get shared around the state prior to the winter season. This year we have resurrected our Snow and Ice Academy that will begin to dive into more in-depth training on calibration for our folks in the field.

3 Literature Search

3.1 Overview

A literature search supplemented the survey findings in five topic areas:

- Recent research
- Research and manuals addressing calibration accuracy
- Training that addresses calibration accuracy
- Representative state practices
- Technology from agriculture

3.2 Recent Research

Quantitative Assessment of Snow Plow Sensor Failure Impacts on Winter Maintenance Operations, William A. Holik, William H. Schneider IV and Christopher Miller, Transportation Research Board, 95th Annual Meeting, 2016.

<http://amonline.trb.org/trb60693-2016-1.2807374/t017-1.2819856/418-1.2820073/16-1916-1.2813763/16-1916-1.2985400>

Description: Implementing GPS/AVL systems and combining other remote sensing data allows transportation agencies to better monitor equipment and materials. However, these sensors function in a harsh environment, exposed to cold temperatures, moisture and corrosive materials. As a result, sensors on trucks may fail or require recalibration to be able to record accurate data essential for effective materials application. Researchers collected data over three winters to analyze sensor function on snowplow trucks deployed by the Ohio Department of Transportation.

- On page 5, researchers described the sensor inaccuracy problem:
Output sensors are extremely important to a GPS/AVL system, since they are typically used to monitor material usage. Application rates recorded from hydraulic controllers of plow trucks are known to be unreliable. As a result, bed scale sensors may be implemented to track the weight of material contained in the bed of a plow truck. When these sensors are implemented as a part of a GPS/AVL system, material application rates may be determined using the distance traveled and the difference in weight of material in the bed at the start and end point of the maintenance route. This approach eliminates any issues with hydraulic controllers reporting incorrect application rate data. Due to the importance of bed scale sensors in obtaining accurate material usage data, an in-depth evaluation of failures and calibration requirements for these sensors [was] conducted.
- On page 14, researchers noted, “it was found that the bed scale sensors utilized in this study recorded data 68% of the time. When data were being recorded, it [was] found that 34.4% of the readings consisted of erroneous data.”
- Page 15 reports how sensor inaccuracy may result from maintenance:
Maintenance performed on the truck may cause inaccurate data to be recorded by the sensor system. For example, if a hydraulic hose is damaged and replaced by a hose of a different size (this can occur if a hose of the same size is not available), the material application rates may be higher or lower than what is reported by the controller. This can

affect the data obtained from a sensor that records application rates directly from the controller. Bed scales are not impacted in this scenario, but this scenario emphasizes the importance of good communication with mechanics and the need for regular calibration of sensors.

- Page 18 reports that [t]he bed scale sensors were evaluated for accuracy and reported weight values within 2.2% of the ground truth weight values when correctly calibrated. When not calibrated, they reported weights within 8.4% of the ground truth weight values. The cost difference between trucks that have been calibrated and those that have not been calibrated ranges from \$150 to \$270 per truck per winter season. This is a large cost savings that may be realized by simply calibrating sensors.

Evaluation of the GPS/AVL Systems for Snow and Ice Operations Resource Management, William H. Schneider IV, John Lurtz, Alexander R. Maistros, Mallory Crow, William A. Holik, Zachary T. Gould, John M. Lurtz, Jr., Casey J. Bakula; Ohio Department of Transportation, September 2017.

<https://ntl.bts.gov/lib/62000/62400/62455/15417.pdf>

This comprehensive research project examined how Ohio DOT's snow and ice operations could be better served by GPS/AVL systems to monitor vehicles in the field and consumable material resources to increase overall levels of service. *From the abstract:*

Phase One of the project, was to implement 22 trucks with systems that work with the hydraulic system on the truck. During this phase, the research team was able to implement one system that works with both primary hydraulic systems in the ODOT fleet. With success in Phase One, Phase Two was developed to scale-up the fleet from 22 to 187 trucks throughout the state.

GPS/AVL and material usage data were closely monitored and stringently tested. Calibration inaccuracy and means to remedy it were addressed in multiple places.

- From page 48 (pg. 56 in the PDF) on calibration inaccuracies:
Throughout the use of a hydraulic system, it is possible that the system may need [to be] calibrated or checked for calibration needs. This means that the auger is on a certain setting that had a predetermined application rate, but the system is applying more or less than the assumed value. **This may lead to the driver anticipating an empty bed while there is still salt, or the opposite where they could anticipate there is salt in the bed when in fact they have none left** [*emphasis added*]. To alleviate this issue, calibrations are required on the hydraulic system. Multiple checks and calibrations were conducted on a series of trucks at the Summit County Boston Heights Garage located in District 4.
- Figure 4.5 on page 45 (pg. 57 in the PDF) illustrates the common problem: difference between auger settings (“theoretical weight”) and actual weight of material discharged. On setting 2 of one test system, for example, the theoretical weight was 100 lbs./lane mile, while the actual weight varied from 175 to 250 lbs./lane mile. Setting 4 of 250 lbs./lane mile actually discharged 125 lbs./lane mile. Recalibration of application systems brought the actual amounts discharged close to the theoretical (auger setting) amounts.
- The researchers suggested the use of a third party to monitor salt usage per truck on page 47 (pg. 59 in the PDF):
With the amount of money ODOT spends annually on salt, it is vital to operations and

budgeting to monitor salt usage. To calculate the amount of salt that is used throughout a shift, month, or even winter season, there are various different types of technology capable of calculating this information. This third party entity may aid ODOT in monitoring salt usage down to the truck level allowing them to see the amount of salt every truck within their fleet applied if implemented in all trucks.

3.3 Research and Manuals Addressing Calibration Accuracy

Calibration Accuracy of Manual and Ground Speed Controller Salters. Robert R. Blackburn, Edward Fleege and Duane Amsler, Clear Roads, 2008.

http://clearroads.org/wp-content/uploads/dlm_uploads/05-02_WisDOT-0092-06-21_Calibration-Final-Report.pdf

Calibration Guide for Ground-Speed-Controlled and Manually Controlled Material Spreaders.

Robert R. Blackburn, Edward Fleege and Duane Amsler, Clear Roads, Feb. 2009.

http://clearroads.org/wp-content/uploads/dlm_uploads/05-02_WisDOT-0092-06-21_Calibration-Final-Calibration-Guide.pdf

Through rigorous simulated field tests over two years, researchers closely examined the calibration accuracy of seven brands of salt/deicer applicator equipment commonly used in Clear Roads states. The “Calibration Guide” is the separate practical version of the comprehensive research report. These two projects lead to the publication of many more DOT calibration guides, as well as the establishment of training programs in the years after its publication. The research revealed calibration difficulties in many areas that are still prevalent:

- On page 49 of the study (pg. 60 in the PDF), Table 5-8 shows an applicator’s actual output compared to the desired output entered into the controller, summarized here:

The percent of difference for the solid discharge amounts are given in Table 5-8 and also in Table I-3. The percent of difference for the solid discharge ranges from -44.4% (under application) to +43.9% (over application).

- Appendix H of the study contains many tables that illustrate the wide variance of discharged material from the dialed-in settings on many machines. Page 187 (pg. 198 in the PDF) shows a table with an actual discharge variation from +13% to -23% of the dialed-in amount over several speeds. It is a typical example from the study.

Actual material discharge variation from controller settings in this range is still reported among operators today.

Manual of Environmental Best Practices for Snow and Ice Control. Laura Fay, Mehdi Honarvarnazari, Scott Jungwirth, Anburaj Muthumani, Na Cui, Xianming Shi; Western Transportation Institute, Montana State University; Dave Bergner of Monte Vista Associates, LLC and Marie Venner of Venner Consulting, Inc. Clear Roads and Minnesota Department of Transportation, June 2015.

http://clearroads.org/wp-content/uploads/dlm_uploads/Manual_ClearRoads_13-01_Final-Revised.pdf

This manual on environmental best management practices for snow and ice control was developed by a large group of experts using information acquired from a literature review, survey, and follow-up interviews. Relevant to this synthesis review is information on aspects of snow and ice control materials application techniques and equipment. These could improve practices, leading to material and cost savings while reducing impacts to the environment.

- Page 18 (pg. 36 in PDF) reports on the large number of training and certification programs that include teaching calibration skills.
- Pages 83–85 (pgs. 101–103 in the PDF) discuss equipment calibration, referring to previous studies, including Blackburn et al., 2009 (listed above). Frequent calibration is emphasized as a means to maintain accuracy in application. This is the concluding statement from that section:
Mixed results were reported on whether contractors calibrate their equipment each season. When agencies were asked if they had made any efforts to improve calibration of solid or liquid application equipment, 58% responded yes, but 39% said no. **For this reason we recommend increased or improved equipment calibration as an area for transportation agencies and their contractors to reduce the impacts of snow and ice control operations on the environment.** [emphasis in original]
- Appendix D, page D4 (pg. 236 in PDF) reports on Rhode Island DOT’s successful use of closed-loop spreaders, mentioning the need to gain staff acceptance of the technology and its purpose. If operators understand the benefits of the system, more calibration will be accepted as a necessary task.

Manual of Best Management Practices for Road Salt in Winter Maintenance. Wilfrid Nixon and R. Mark De Vries, Clear Roads, November 2015.

http://clearroads.org/wp-content/uploads/dlm_uploads/0537_2015-Clear-Roads-Best-Practice-Guide-WEB.pdf

A product of previous comprehensive research study on road salt management and information needs in the field, this manual is an accessible road salt management handbook for snowplow operators and supervisors. It covers procurement, storage, application, and emergency management. A discussion on equipment calibration includes this caveat on page 29:

Anecdotal evidence suggests that poorly or improperly calibrated (or in some cases, totally uncalibrated) dispensing systems may actually be applying twice as much material as intended. So, by implementing a regular and thorough calibration process, an agency can save as much as 50% of their total material applications.

3.4 Training That Addresses Calibration Accuracy

Training and Certification of Maintenance Workers: A Synthesis of Highway Practice. NCHRP Synthesis 483. Nancy Laffey and Kathryn A. Zimmerman, Applied Pavement Technology, Inc., Urbana, Illinois, NCHRP, 2015. <http://nap.edu/23458>

This synthesis documents front-line maintenance worker training and certification practices for highway transportation agencies in the United States and Canada. The information presented includes training and certification subject areas, the training delivery methods, the instruction sources, and whether relationships to share materials are promoted to foster access to training.

Clear Roads training programs are mentioned in this study, including the recently completed “Snow Plow Operator and Supervisor Training” (see http://clearroads.org/wp-content/uploads/dlm_uploads/FR_CR.12-04.pdf). See page 28 (pg. 41 of the PDF):

As part of a current research project, Clear Roads is creating [22] instructor-led training modules of varying lengths for state workforce crews on snowplow operations. The instructor-

led training modules are designed for different experience levels. The resulting instructor-led training products will be available to all 36 Clear Roads member agencies.

Calibration is also covered in operator training programs provided by some DOTs and Local Technical Assistance Programs. One example:

MnDOT Maintenance Training

<http://www.dot.state.mn.us/maintenance/training.html>

3.5 Representative Agency Practices

Clear Roads member agencies have calibration guides of varying complexity for their snowplow operators and supervisors. Many resemble the short version offered in Vermont (below). Most snow state DOT sites include links to the comprehensive guides offered by Clear Roads and other organizations. A new development is evident in Massachusetts' 2017–2018 contract for snowplow contractors: third-party certification of calibration.

Spreader Calibration Procedure, Vermont Local Technical Assistance Program (LTAP) Center
<http://localroads.vermont.gov/sites/localroads/files/files/resources/materials/Spreader-Calibration-Procedure.pdf>

This is a one-page calibration check, representative of calibration guides from DOTs across states maintaining snowplow fleets.

Contract for snowplow operators, 2017–2018, Massachusetts DOT

Massachusetts now requires snowplow contractors to supply proof of third-party certified calibration of open-loop systems to specified discharge rates. This exhibits a clear concern about calibration accuracy. See Attachment E of the Massachusetts document.

https://www.massdot.state.ma.us/Portals/8/docs/SnowAndIce/ControlAgreement2017_2018withAttachments.pdf

3.6 Technology from Agriculture

Clear Roads: Developing a Totally Automated Spreader System Guides #1, #2, #3.

Thompson Engineering Company, Clear Roads, February 2014.

http://clearroads.org/wp-content/uploads/dlm_uploads/11-03-Totally-Automated-Spreader-Guides_1_23.pdf

Page 38 of Guide #3 reports on agricultural applicators, their extreme precision, and the hurdles salt/deicing equipment designers must clear to approach that degree of precision. Agricultural spreaders function at very slow speeds (14 mph is considered extremely fast) in an environment very different from that of snowplows and deicing equipment:

Probably the most studied and challenging metric in the quest to automate the spreader functions of the agricultural (and winter maintenance) spreaders is accuracy coupled with speed of the vehicle. . . . Though still below the salt spreading speeds, the agricultural industry claims to have achieved (Trimble-Straight talks of 14 mph (too slow for salt) with accuracy of one inch (too much for salt)).

Appendix A

Survey Questions

The following survey was distributed to the primary winter maintenance contacts of the 36 Clear Roads member agencies and to the Snow and Ice ListServ to gather information for this synthesis report.

Question 1 requests the respondent's name, title, agency, email address, and telephone number.

Equipment

2. What types of material application systems does your agency use to apply SALT/SOLID deicer materials? Select all that apply.

- Manual
- Open-loop ground speed control
- Closed-loop ground speed control
- Other (please specify)

3. What types of material application systems does your agency use to apply LIQUID materials? Select all that apply.

- Manual
- Open-loop ground speed control
- Closed-loop ground speed control
- Other (please specify)

4. Does your agency use GPS/AVL (global positioning systems/automatic vehicle locators) to determine the location of vehicles and spreaders?

5. Does your GPS/AVL (global positioning systems/automatic vehicle locators) system record data from bed scale sensors or other information sources on the vehicle?

Calibration

6. How often does your agency normally calibrate its equipment?

- Annually, at the beginning of each winter season
- Every 3–4 months
- Every 1–2 months
- When it needs it
- Don't know
- Other

7. How close does the controller's read-out need to be to the actual amounts of material applied for your agency to consider the equipment "calibrated"?

- +/- 1 to 3 percent of actual material applied
- +/- 4 to 6 percent of actual material applied
- +/- 7 to 9 percent of actual material applied
- +/- 10 percent

Appendix A

Survey Questions

- Greater than 10% difference between controller read-out and actual application
- Equipment calibration never gets closer than within 10% of actual material applied
- Don't know

8. What events trigger a calibration of your equipment? Select all that apply.

- When the spreader/controller unit is first put into service
- After major maintenance of the spreader truck
- After hydraulic motor, hydraulic fluid and/or filters are changed
- After the auger or belt is replaced
- After the controller unit is repaired or the speed sensors (truck or belt/auger) are replaced
- After new salt/deicing material is delivered
- When switching to a different type of material (salt vs. sand, etc.)
- When the operator notices a difference between controller data and actual amounts applied

9. Who performs the calibration of material application equipment for your agency? Select all that apply.

- Mechanic Operator
- Supervisor/ Manager
- Vendor
- Other

10. How is calibration performed?

Confidence in Calibration Accuracy

11. What level of confidence do you have that your agency's calibrated material application equipment applies the amount of material that the controller indicates?

- Very confident
- Somewhat
- Not confident
- I know the settings do not correspond to actual applied amount

12. When calibrated equipment has failed to apply the amount indicated by the controller, which of the following equipment problems do you think may contribute to the discrepancy? Select all that apply.

- Equipment not calibrated often enough
- Calibration procedures not followed completely
- Equipment and/or calibration procedures are not user-friendly
- Loss of calibration coding
- Problems with belt drives
- Equipment age/wear
- Equipment isn't capable of delivering material at high rate/speed combinations
- Other equipment problems (please describe in comment box)

Appendix A

Survey Questions

13. When calibrated equipment has failed to apply the amount indicated by the controller, which of the following material qualities or other possible problems do you think may have contributed to the discrepancy? Select all that apply.

- Flight on the auger not full of material
- Material sticking to bed
- Variation in moisture content of salt
- Variation in size of salt grains
- Accuracy of on-board material scales
- Accuracy of in-ground scale
- Inconsistencies in material measurements (volume vs. weight)
- Skill/experience/training level of person conducting calibration

14. The gate height is considered by some to be particularly vulnerable to accidental changes and other human error. How does your agency ensure that the gate height is correct throughout operation?

15. What is the typical moisture content of the salt your agency uses for winter maintenance?

- moisture 0 to 0.5 percent
- moisture 0.6 to 1 percent
- moisture 1.1 to 2 percent
- moisture 2.1 to 3 percent
- moisture 3.1 to 5 percent
- moisture over 5 percent
- Don't know

16. Please describe your overall experience. Which contributing factors seem most significant?

Identifying Solutions

17. Does your agency verify the accuracy of calibrated material application equipment by using other means of measurement to determine how much material has been applied? (For example, on-board truck scales, in-ground scales, loader scales, or particle scanners.)

18. What method does your agency use to verify application rates?

19. If you verify application rate accuracy as described above, have you found any spreader systems that maintain accurate application rates over a reasonable amount of time? Please provide details (make, model, year, and details such as auger type, V-box, etc.) for any systems that you would recommend as especially accurate.

- Solid material spreaders
- Systems for applying liquids
- Controller units
- Other systems/components

Appendix A

Survey Questions

20. Have you found any spreader systems that fail to maintain accurate application rates over a reasonable length of time? Please provide details (make, model, year, and details such as auger type, V-box, etc.) about systems that have proven to be problematic.

- Solid material spreaders
- Systems for applying liquids
- Controller units
- Other systems/components

21. If you verify application rates using scales (on-board or in-ground), how often do you calibrate the scales?

22. If your scales maintain accurate calibration for a reasonable amount of time, please list make, model, year, and other details if available.

23. If your agency conducts calibration in-house, how are employees trained to calibrate equipment? Please describe.

Specifications and Documentation

24. Does your agency have any specifications, formal or informal policies, or other documentation related to the processes discussed above (calibration procedures, other means of measuring spreader output, etc.)?

25. Please use this space to provide any comments or additional information about your answers.

Appendix B Iowa DOT

Calibration using Electronic Scales

Calibration of spreader controllers is very important to make sure the right amount of material is being spread from the back of the truck. A spreader that is off by 10% can result in a loss of 23 tons of salt each year. The cost of that many tons is nearly \$1,500 a year per truck. With 900 trucks in the Iowa DOT fleet if all spreaders were over applying by 10% it would cost the state \$1,275,000 a year in materials.

Spreaders should be calibrated at least once a year, before the start of the winter season. If any work has been done on the auger, spreader, coil, hydraulics or other part of the spreader system, it should also be recalibrated. Calibration of liquid systems (prewet and anti-icing) should also be done at the same time to make sure the right amount of liquids is being applied.

The following is a step-by-step procedure for calibrating a spreader controller using an electronic scale:



Figure 1. Electronic scale used for calibration

Appendix B Iowa DOT

1. Make sure the salt you are using for the calibration is similar to the type used on the roadway and is free of clumps and debris
2. Make sure to keep your hands away from any moving parts while calibrating equipment
3. Make sure all connections between the readout display and the battery are secure and tight
4. Make sure the battery is secured to the scale. The best battery to use for this application is a gel type battery
5. Power-on the unit by pressing the On button
6. Clear the display by pressing the Net/Gross and zero buttons (the display should now show, "0" on the display screen)



Figure 2. Press the Zero and Net/Gross button to reset the scale

7. If you have an object in the garage that has a known weight, place it in the scale to see if the scale has the accurate weight. If the scale is off by more than a pound contact the scale manufacturer for how to initiate repairs

Appendix B Iowa DOT

8. Remove the spinner from the truck
9. Place the electronic scale under the spreader discharge, but make sure the scale does not touch the truck or any other object. (Leaning on the scale or allowing it to touch the truck will add weight to the scale and give false readings).



Figure 3. Raising the dump body but make sure the truck or anything else touches the scale

10. Raise the dump body to charge the spreader
11. Run a little material into the spreader to make sure the material is flowing freely and the auger is full

Appendix B Iowa DOT



Figure 4. Run material through the system to make sure material is flowing freely and the auger is full

12. Reset the scale again by pressing the Net/Gross button followed by the zero button. This should reset the unit to zero (you do not need to empty the scales after each material run, just reset the display)

Appendix B Iowa DOT



Figure 5. Truck calibration

13. Run the spreader until the scale reads a certain number (the higher the number the more accurate the calibration. 500 pounds is a suggested amount but a range between 250-500 should be adequate to get a good calibration)

Appendix B Iowa DOT



Figure 6. Take the reading from the scale



Figure 7. Calibration in progress

Appendix B Iowa DOT

14. Stop the operation and press the Stop button on the display
15. Refer to the spreader control system manual now to determine how to set the spreader control system to match the output from the electronic scale



Figure 8. This is the SpreadSmart method to enter data- Check the spreader controller manual on how to enter the calibration number

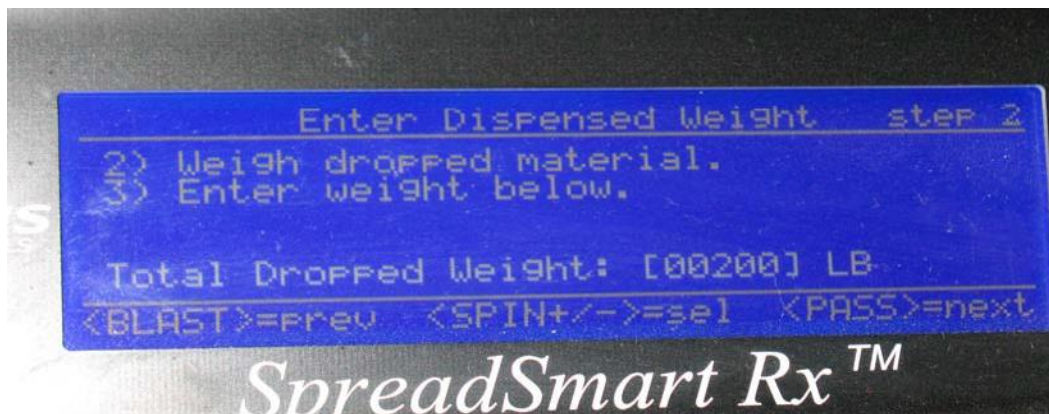


Figure 9. Enter the reading from the scale display into the spreader control.

16. The test should be repeated at least two times for each truck but preferably three times to make sure the readings are reasonably consistent and repeatable.
17. Once the calibration is completed a calibration form should be completed on each truck and filed until the next calibration. A copy of the calibration should be kept in the truck and in the garage.

Appendix B Iowa DOT

18. Some garages maintain historical records of truck calibrations to better understand when a system is becoming erratic and need further repairs
19. Make sure the electronic scale is turned off and secured to the end-loader with chains. Move the scales away from the truck to dump the salt back into the salt pile (If the scale is equipped with standard 12-volt battery, make sure to remove the battery before dumping the salt back into the pile. If a sealed gel-cell battery is used, it does not need to be removed before dumping the salt back into the pile).



Figure 10. Make sure the scale is turned off and secured to the end loader before dumping the salt back into the pile

Appendix B Iowa DOT



Figure 11. Make sure the battery is properly secured before dumping the salt back into the pile



Figure 12. Salt returned to the pile and ready for cleaning

Appendix B Iowa DOT

20. After calibrating all trucks, wash the scales thoroughly to remove any salt that might be left behind. If cleaned properly the scales should last for many years.



Figure 13. Make sure to wash the scale before putting it away

Using the electronic scale should reduce the amount of time required to calibrate trucks and also improve the accuracy of the spreader output.

If you have any problems with the electronic scale, please contact Scale-Tec at 319-462-2344.

Appendix C
Montana DOT

CIRUS CONTROLLER CALIBRATION CHEATSHEET

Checking Calibration – Field staff

- Go to Automatic mode
 - Check that material setting matches gate setting (example; Sand 6 is 6" gate)
 - Shut off spinner
 - Shut off all liquid (pre-wet and anti-ice)
 - Confirm target rate (recommend 400-600 lbs.)
- Push menu button to get back into home screen
- Spinner down to no speed mode
 - Pass or pause to select
 - MPH is in lower left of screen (20 mph is generally the default)
 - Auger up to 30 MPH
 - At 30 MPH it takes 120 seconds to go a mile. This is the basis for calculating rate
 - Run the material until the auger chute is full to the adjusted height and the spinner head is loaded with material
 - Place a tarp under the sander chute to catch all the material
- Raise RPM to operating speed (typically 1600-1700)
 - Have the Timer near the rear of the truck
 - When all are ready start the sander
 - Have the Timer watch the auger, timing starts when the auger begins moving
 - Stop at 10 seconds
- Weigh the material
 - Be sure to allow for bucket weight (typically about 2.3 lbs.)
- Multiply the material by 12 to get the per mile weight (weighed for 10 seconds and it takes 120 seconds to go a mile @ 30 mph.)
 - May be adjusted to weigh 20 seconds multiply by 6 or weigh 30 seconds and multiply by 4 etc....
 - Total of the time multiplied by the number must equal 120
- The multiplied weight should be close to the target weight.

Appendix C Montana DOT

- A repeat of the test may be done to confirm the weight
 - Taking such a small weight may cause minor changes running a couple of tests helps to confirm calibration
- If the truck is out of calibration (typically more than 10%, example 60lbs off for a 600 lb. target) a mechanic will be needed to change the calibration.

CIRUS CONTROLLER CALIBRATION CHEATSHEET

Changing Calibration / Calculating pulses method Mechanics only

- Perform regular calibration to determine target weight and actual weight.
- From the main menu - hold Auger and Pre-wet down to get to password screen.
- Spinner +/- to adjust number.
- Pass or pause to go to next number.
- Pass to enter password.
 - This will take you to the configuration page.
- Spinner +/- to scroll down to materials.
 - Pass or pause to enter materials.
- Pass or pause to enter granular.
- Spinner +/- to proper material.
 - Example; enter sand 6 if calibrating sand 6.
 - Pass or pause to enter correct material setting.
- Spinner +/- on granular page to scroll to pulses.
 - Second page
- Check to see what current pulses are.
- Multiply the target weight by current pulses.
 - Divide that number by the actual calculated weight dropped, this will give you what the pulses should be.
 - We have had better luck when add 1 – 2 pulses to this number.
- Change pulses to calculated number with **Anti-Ice +/-**

Appendix C

Montana DOT

- If you use something other than anti-ice it will take you to another menu (such as the drop test) and you will need to start over
- Blast to setup page
- Blast to get out of material setup
- Blast to get out of setup wizard
 - Should see “saving configurations” this will then take you to the main menu.
- Run the truck for a few seconds to allow it to adjust and then re-test the calibration

Appendix D
New Hampshire DOT



Calibration Test Plan

Prepared for: State of New Hampshire Department of Transportation

Contract #: Automated Vehicle Location (AVL) System RFP 2016-016

Version 3.0

Date: March 9th, 2017

Appendix D New Hampshire DOT

Revision History

Version	Date	Document Author(s)	Nature of Change
1.0	2016-11-27	Krista Schmidt	Original Release
2.0	2016-12-04	Krista Schmidt	Added Liquid Calibration & Catch Test
3.0	2017-03-09	Mark Gillingham	Updated with procedures to improve accuracy
4.0	2017-12-03	Mark Gillingham	Updated to optimize calibration process

Appendix D New Hampshire DOT

Guide for Calibrating Compu-Spread 440 and 550 Spreaders

1	Power up the controller. This may require turning on a toggle switch somewhere on the dash that may or may not be labeled "Spreader".
2	Confirm that the system is operating in closed loop by confirming there is an "A" in the upper left hand side of the monitor. If there is an "O" or an "M" the system cannot be calibrated.
3	Confirm that the gate setting is at @ at the bottom of the monitor.
4	Enter the meter reading of the truck onto the spreader calibration sheet.
5	Insert the programming key and turn it clockwise about one quarter of a turn.
6	With the arrow on "System Set Up", press enter.
7	With arrow on Name-ID, press enter.
8	Confirm region is shed abbreviation (NASM, MCKM, HKTM, HPTM, DVRM). If it is not, with arrow on incorrect name, press enter and use the up/down, left/right buttons to enter the correct region. To delete a character simply scroll to the blank space after Z and before 0. Press enter when done.
9	Confirm that the correct truck is displayed under the Truck ID. Correct if it is not.
10	Enter OK in the Truck ID box on the calibration sheet.
11	Press ESC to Exit.
12	Scroll down to Operation Setting and press Enter.
13	Date and Time and press Enter.
14	Confirm date and time is accurate and correct if not. Check OK in Date Time box on calibration sheet.
15	Press ESC twice to get back to Setting page.
16	Scroll down to Sensors and Valves and press Enter.
17	Scroll down to Conveyor Setup and press Enter.
18	With arrow next to Conveyor Sensor, press Enter.
19	Confirm pulses/revolution and enter it onto the calibration sheet. This number is usually 16, but it depends on what type of conveyor motor is on the unit.
20	Press ESC to exit 3 times to get back to Settings.
21	Scroll down to Material Set UP and press Enter.
22	Confirm that "SALT" is selected next to Solid 1.
23	With arrow next to Solid 1, press Enter.
24	Confirm the weight per revolution and enter it onto the calibration sheet.
25	Press ESC twice to get back to the Settings page.
26	Load the spreader hopper with one (1) bucket of salt (approx. 1 ton).
27	Discharge enough salt to fill the spinner disc. Ensure the starting point has an even "cake" of salt at the gate exit and brush away any excess salt before starting the calibration test.
28	Measure the thickness of the salt layer on the conveyor from the floor of the hopper (not on top of one of the conveyor tines), to insure that there is 2" of salt. Adjust gate if necessary and ensure it is properly marked and easily visible from where the operator adjusts the gate.

Appendix D New Hampshire DOT

29	Place portable scale in a location to collect salt (leave the salt on the spinner disc). - Note: Upon completion of the catch test ensure that any salt which fell outside of the portable scale is collected and placed in the bin before the final weight is recorded.
30	With programming key installed, and arrow next to MATERIAL SET UP press Enter.
31	Select SALT.
32	Use the down navigation button to move the cursor to CALIBRATION and press the Enter button.
33	Operate the truck at between 1200 and 1500 RPM to ensure good hydraulic flow (use the cruise control if possible).
34	Scroll down to START and press the enter button.
35	Set the conveyor to 3.
36	Allow the system to run for several minutes until the scale hopper is fairly full.
37	Press the Enter button to stop the calibration process.
38	Weigh the discharged material.
39	Press the Enter button and using right/left navigation arrows move the cursor under the number to be changed.
40	Using the UP/DOWN navigation arrows, enter the weight of the material.
41	Once the proper weight has been entered, press the Enter button.
42	Using the DOWN navigation arrow, move the cursor to ACCEPT VALUE.
43	Press the Enter button again to confirm acceptance of the weight value.
44	Enter the spreader inventory number on the calibration sheet.
45	Enter any other comments such as how many saddle tanks and what size, type of spreader controller, etc.

Catch Test Procedure

	IMPORTANT: Before conducting the Catch Test Procedure ensure that items 26, 27, 28, & 29 from the previous section are complete.
1	No key is necessary.
2	Confirm there is an "A" in the upper left hand corner indicating the system is in Closed Loop.
3	Turn PTO on.
4	Press and hold the enter button and press the ESC button and release them at the same time.
5	Press the ESC button. The screen should change to Trip Summary screen.
6	Press the "UP" arrow once or twice.
7	The screen should change to "Status". If it doesn't, press ESC and start again. Sometimes this takes a couple of tries.
8	Once on the STATUS screen, change the ground speed to 20 MPH by using the up arrows. Each button press results in 5 MPH change.
9	Select 300 LBS/MI application rate (should be the number 2 setting). Confirm by looking at

Appendix D New Hampshire DOT

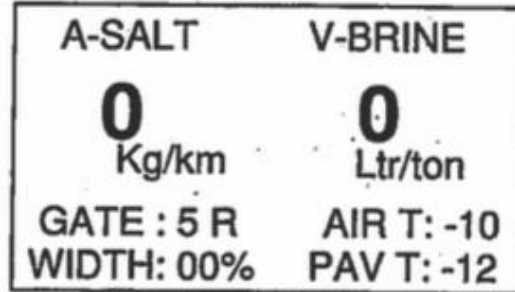
	the App Rate on the monitor.
10	Run the simulation test for 180 seconds (3 minutes) and then shut off the conveyor by either turning the conveyor knob to 0 or by pausing the system (pressing both the spinner and conveyor knobs at the same time). Note, when running the "Catch Test" on the CS550 the conveyor will automatically stop at the end of the entered time period. (See Page 12 of the CS550 Calibration document for detailed instructions on how to run the Catch Test function)
11	At ground speed of 20 MPH, for 3 minutes, and an application rate of 300 pounds per mile, should produce approximately 300 lbs of salt in the bin of the portable scale.
12	<p>Acceptance Test Criteria and Calculation:</p> <ul style="list-style-type: none"> - Retrieve the total weight dispersed from the controller and record this number (i.e. Controller #). - Record the actual weight of dispersed salt into the bin on the portable scale (i.e. Actual #). - Compare the Controller # with the Actual # to ensure the numbers are within +/- 5% of each other for an acceptable (pass) test. - Calculation: Divide the smaller of the numbers by the larger number and the result should be ≥ 0.95 (95%) which is within the 5% variance. <p>IF the test DOES NOT meet the "acceptable test" criteria move to item #13. IF the test meets the "acceptable test" criteria move to item #14.</p>
13	<p>NOTE: If the Controller Weight and the Actual Weight are NOT within the acceptable 5% variance than the controller must be "recalibrated" with a new "WT/REV #".</p> <ul style="list-style-type: none"> - CS440: Perform the following calculation <ul style="list-style-type: none"> o $\text{Controller \#/Actual \#} = \text{Result}$ o $\text{Result} \times \text{WT/REV \#} = \text{New WT/REV \#}$ o Update the "WT/REV #" with the "New WT/REV #". o Note: See page 28 of the CS440 Calibration document for instructions on how to update the WT/REV #. - CS550: Enter the "Actual Weight" from the scale in the field provided on the controller once the catch test has been completed. Use this number to recalibrate the WT/REV # in the controller. Note that the weight per revolution number will be calculated automatically and displayed in the bottom right of the screen. <p>Repeat steps 9 to 12</p>
14	<p>OPTIONAL: Repeat the Catch Test with the following values:</p> <ul style="list-style-type: none"> - Simulated Ground Speed = 20 MPH - Set Rate = 150 LBS/MI - Time = 180 seconds (3 mins) <p>Note: This test should produce approximately 150 lbs of salt in the bin of the portable scale. Proceed to item #15 once the test meets the "acceptance test" criteria.</p>
15	Press ESC to exit and then power off the box to get out of ground speed simulation mode.
16	Repeat the test for every solid material ie: sand.

Appendix D New Hampshire DOT

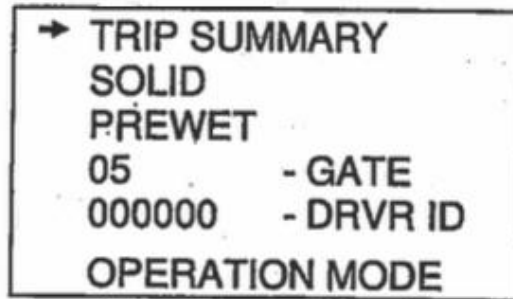
Simulated Ground Speed

1. Simulated Ground Speed Activation in Operation Mode (without a key)

- Make sure that the vehicle is stationary (ground speed = 0) and display is on main OPERATION SCREEN as shown below:



- Hold ENTER button down, press ESC button, and let go both buttons at the same time.
- Press ESC to switch to OPERATOR SCREEN as shown below:



- Press UP and DOWN buttons to adjust simulated ground speed as shown in the following screen.

Bosch Rexroth Canada Corp. * 490 Prince Charles Dr * Welland, On * L3B 5X7 * www.boschrexroth.ca

Compu-Spread 550 Ground Speed Simulation Procedure

1	Tap the speed button (upper left hand side).
2	Up and down arrows will appear.
3	Hold the up arrow for 10 seconds and let go.
4	Tap the up arrow again to desired speed.

Appendix D New Hampshire DOT

Material Calibration



1	Select the Value Symbol to enter into the material calibration screen.
2	Place an adequate catch container under the spreader discharge chute.
3	Make sure that sufficient material in the Hopper and the system is safe to run.
4	Set Gate Position

MANUAL: CHANGE CAL GATE TO MATCH THE ACTUAL GATE POSITION

READBACK: ADJUST ACTUAL GATE POSITION

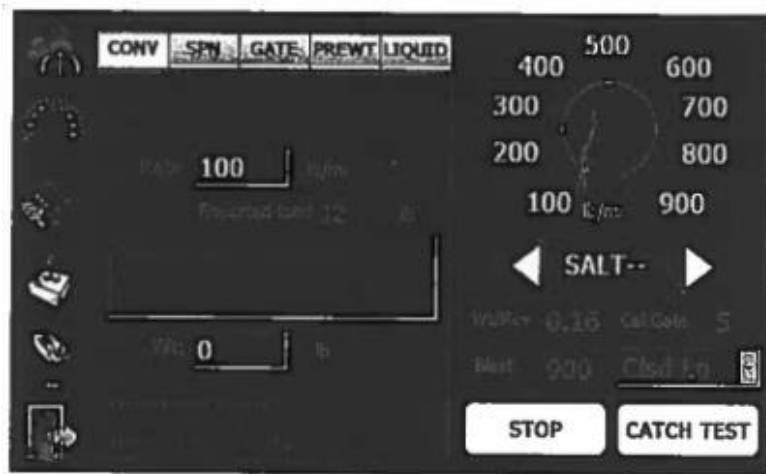
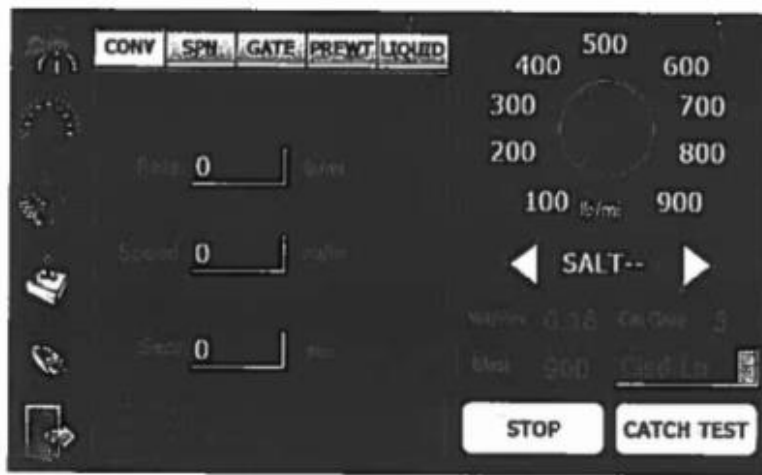
CLOSED LOOP: SET TO A DESIRED GATE POSITION

5	Turn conv knob and or SPN knob to run.
6	Stop when desired amount is reached.
7	Measure the material and enter it.
8	Press calibrate button to complete.

NOTE: Press STOP button to stop the process anytime during the calibration.

Appendix D New Hampshire DOT

Material Catch Test



1	Select the Value Symbol to enter into the material calibration screen.
2	Place an adequate catch container under the spreader discharge chute.
3	Enter the desired rate, speed and duration of the catch test using on-screen keypad.
4	Press "Catch Test" to begin material dispensing (hydraulics must be active).
5	When test is complete, weigh the material and enter the value.
6	An appropriate weight per revolution will be calculated and displayed on the right side of the screen.
7	Repeat this procedure for all solid materials (use the green arrows to select material types).
8	The individual rates can be adjusted by tapping the rate # and editing the value with the keypad.
9	These same procedures apply to pre-wet and liquid.

Appendix D New Hampshire DOT

NOTE: The material names can be changed by selecting the text "SALT- -" and using the keypad to edit.

Liquid Material Calibration (Prewet or Anti-Icing)

1	Tap on the symbol and PREWET/NORM tab to enter into Liquid Calibration
2	Place an adequate catch container under the liquid spray nozzle.
3	Make sure that sufficient liquid in the tank and they system is safe to run.
4	Press "CALIBRATION" button to proceed.
5	Turn PREWET knob to run.
6	Stop when desired amount is reached.
7	Measure the liquid volume and enter the value.
8	Press "CALIBRATION" button to complete.

Liquid Material Catch Test

Follow the same steps as conducting catch test for solids, setting the controller as follows:

Rate: 10 sec per ton
Speed - 20 mi/hr
Sec: 90 sec

The expected result is to collect 5 gallons of liquid at the end of the test within +/- 4% accuracy, therefore acceptable range for a pass is 4.8 to 5.2 gallons.

Appendix E
Oregon DOT

**Guideline on Calibration of Central Hydraulic
Systems for Dump Trucks**

Office of Equipment Management
May 28, 2003

The following guidelines give a step-by-step method for calibrating a Pengwyn Series or Force America Series Central Hydraulic system. The Office of Equipment Management has set the following time frames for calibrating these systems.

1. All systems should be calibrated at least once a year, in the fall, prior to or during the County's Dry-Run.
2. If the Control Box is exchanged with another Control Box, a complete re-calibration must be performed.
3. The Auger Fault section should be re-calibrated every 2 months during the winter season.
4. If the Auger motor is replaced with a new motor of the same type and size, the Auger Fault section must be re-calibrated.
5. If the Auger motor is replaced with a new motor of a different type or size, both the Auger Fault and Auger Rate sections must be re-calibrated.
6. If the Auger is replaced with a new Auger, both the Auger Fault and Auger Rate sections must be re-calibrated.

Calibrations may be saved to a laptop to facilitate the re-calibration of Control Boxes. However, Auger Rate values saved to a laptop computer may no longer be valid values if the auger motor is replaced. Furthermore, with the constant wear of the Auger Motor, it is recommended that Auger Fault calibrations always be re-calibrated and not uploaded from the laptop.

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Pengwyn Calibration

The following pages are a step by step method on calibrating M and Z series Pengwyn Hydraulic systems. The goal is to place a person in each station, as listed below, where one person will calibrate that section of the Pengwyn calibration for every truck. Each station should have 1 or 2 people working that station. The trucks will be moved from station to station by an Operator. Stations may involve mathematics, time keeping or driving, so each person at each station should be capable of using a calculator and/or stop watch and should have a CDL.

Stations:

- A. Spreader Fault
- B. Spreader Rate
- C. Speedometer Setting
- D. Drag, Jam, Spread Rates, Date, etc.

Items Needed:

Measuring Wheel, Spray Paint, Calculator, Pencil, Stop Watch, Pengwyn Calibration Key.

First:

Using a measure wheel, mark a 500ft straight line distance where possible. Spray paint a start and finish line.

All trucks should have Spreader (Hoppers, Spreader gates, or Under Tailgate Spreaders) mounted and in working condition.

Set Pengwyn Manual Key Switch to 'ON'

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Station A: Spreader Fault

Pengwyn 221, 222 and S-Series systems don't not have a spreader fault calibration. If the system is a 221, 222 or S-Series system, skip this section.

All other systems, complete the following:

1. Place Pengwyn Calibration Key into the Operate/Calibration/Maintenance lock.
2. Turn key to Maintenance.
3. Set engine to 1500 rpm.
4. Verify that temperature is at least 80 degrees.
 - a. If temperature is below 80 degrees, hold plow up until temperature reaches 80 degrees.
5. Turn spreader control switch to Automatic.
6. The system will run through settings 1 to 15. Settings should start out low and progressively get bigger.
7. After step 15 is completed, turn spreader control switch off and turn key back to operate.
8. Remove the Calibration Key.
9. Return the truck to Idle.
10. Truck spreader fault is calibrated.

Station B: Spreader Rate

If truck is a Super Hopper, go to 17 and use the value 85 as Auger Rate.

11. Place Pengwyn Calibration Key into the Operate/Calibration/Maintenance lock.
12. Turn the Calibration Key to Operate.
13. Set engine to 1500 rpm.
14. Turn Pengwyn to mode 2.
15. Turn Pengwyn Auger Setting to 2.
16. Turn Spreader Control Switch to Manual.
17. Go to the rear of the truck and count the number of times the auger rotates in one minute. *If the system has a drag chain, count the number of flights in one minute.*
18. Record Number of Revolutions/*flights* on the truck's Calibration Sheet for Auger Setting 2.
19. Turn Pengwyn Auger Setting to 1.
20. Turn Spreader Control Switch to Manual.
21. Go to the rear of the truck and count the number of times the auger rotates in one minute. *If the system has a drag chain, count the number of flights in one minute.*
22. Record Number of Revolutions/*flights* on the truck's Calibration Sheet for Auger Setting 1.
23. Turn Spreader Control Switch to OFF
24. Return the truck to Idle.
25. Subtract the number of revolutions/*flights* for Auger Setting 1 from Auger Setting 2.
26. Record this value on truck's Calibration Sheet.

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27. Using the table on the worksheet, select the spreader that is on the truck. Write the Spreader Value for that spreader in the space labeled **Spreader Value**.
28. Multiple the value from step 16 by the **Spreader Value**.
19. Record this value on the truck's Calibration Sheet. This is your **Auger Rate** setting in **lbs/gal/min**.
20. Turn the Calibration Key to Calibrate.
21. Turn Pengwyn to mode 2.
22. Turn Pengwyn Auger Setting to 0.
23. Using the bed up/down switch to increase or decrease, set this value to your new **Auger Rate Value**.
24. Turn the Calibration Key to Operate.
25. Remove the Calibration Key.
26. The **Auger Rate** is now calibrated.

Station C: Speedometer Setting

If the Pengwyn is an S-Series Manifold, the truck must be calibrated in the traditional ways. See Below**

1. Drive truck to the Start Line of the 500ft measured distance.
2. Line truck mirror up with the start line.
3. Turn Pengwyn Calibration Key to Operate.
4. Set Pengwyn mode switch to 4, Distance Measuring in feet.
5. Push the blast button, once, to start the distance measuring.
6. Drive the truck to the stop line, line the mirror up with the stop line, just as you did with the start line.
7. Record the distance shown on the Pengwyn as the **Pengwyn Measured Distance** on the truck's Calibration Sheet..
8. Push blast to stop the distance measuring.
9. Record the distance measured by the measuring wheel as the **Actual Distance** on the truck's Calibration Sheet..
10. Divided the **Pengwyn Measured Distance** by the **Actual Distance**.
11. Record this value (**Total:**) on the truck's Calibration Sheet.. This is your **Percentage Value**.
12. Turn the Pengwyn Calibration Key to Calibrate.
13. Set Pengwyn mode switch to 4.
14. Record the **Pengwyn Pulse/Mile** reading on the truck's Calibration Sheet.
15. Multiple Pulse/Mile reading by your **Percentage Value**. This is your new **Pulse/Mile** value. Record this value on the truck's Calibration Sheet.
16. Using the Bed up/down switch increase/decrease the Pulse/Mile value in the Pengwyn to this new reading.
17. Turn the Pengwyn Calibration Key back to operate.
18. Remove the Pengwyn Calibration Key.
19. The Speedometer Constant is now calibrated.

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** S-Series Calibration:

1. Place the Pengwyn Calibration Key in calibration lock. Turn the key to calibrate.
2. Set Pengwyn mode switch to 1.
3. Either drive the truck at 30 mph or jack the rear end up and run the truck at 30 mph.
4. While the truck is running at 30 mph, verify whether the Pengwyn speed matches the truck's speedometer.
 - A. If the speeds are within a mile of each other, the calibration is ok. Turn the Pengwyn Calibration Key back to its original setting and return the truck back for the next calibration step.
 - B. If the speeds do not match. Use the toggle switch underneath the Pengwyn control box to vary the speed on Pengwyn display until it matches the truck's speedometer. Then turn the Pengwyn Calibration Key back to its original setting and return the truck back for the next calibration step.

Station D: Miscellaneous Settings

If the Pengwyn is an S-Series System, skip to line 6.
All values are increase/decreased using the bed up/down button.

On all Pengwyns

1. Turn Pengwyn Calibration Key to Calibrate.
2. Set Pengwyn mode to 2.
3. To set **Spreader Drag** setting, Push the plow angle button to the left and hold. Using the bed up/down button, set Drag to 50 psi.
4. To set **Spreader Jam** setting, Push the plow angle button to the right and hold. Using the bed up/down button, set Jam to 2500 psi.
5. To set Minimum Value, Push the plow up button to the up position and hold. Using the bed up/down button, set Value to 1 for spreadergates and 2 for hoppers.
6. To set Auger Spread Rates:
 - A. Turn to Auger Setting 1
 - B. Using the bed up/down button, set at 50 lbs per mile.
 - C. Turn to Auger Setting 2
 - D. Using the bed up/down button, set at 100 lbs per mile
 - E. Repeat for Augers Settings 3 through 12, setting each step from 150 to 600 lbs/ mile.
 - F. Auger Settings 13, 14, and 15 should be set to 600 lbs/mile.
7. Set Pengwyn mode to 3.
8. To set Day and Time:
 - A. To set Day, push bed up/down button to cycle through the days.
 - B. To set Hours, Push the plow angle button to the left and hold. Using the bed up/down button, set the Hours.
 - C. To set Minutes, Push the plow angle button to the right and hold. Using the bed up/down button, set the Minutes.

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For Trucks with Z97, M-Series, or Z - Series

1. To set the Spinner Minimum,
 - A. Turn Pengwyn Calibration Key to Calibration.
 - B. Turn Pengwyn Mode to 1.
 - A. Push Plow Down and hold.
 - B. Using the bed up/down, set value to 0 for standard spreaders and 5 for zero velocities.
2. To set the Wetting calibration:
 - A. Turn Pengwyn key to Calibration.
 - B. Turn Pengwyn Mode to 7.
 - C. Using the plow up/down/left/right buttons, find the pump value and hold.
 1. If Wetting pump is a 7000 Oberdorfer, using the bed up/down, set wetting constant to .78
 2. If Wetting pump is a 3000 Oberdorfer, using the bed up/down, set wetting constant to .32
 - D. Using the plow up/down/left/right buttons, find the Wetting Max and hold.
 1. Using the bed up/down, Wetting Max should be set to 10 gal/ton.

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Calibration Sheet

Truck Number: _____

Date: _____

Truck License Plate: _____

Pengwyn Series: _____

Spreader Fault Calibration: __

Spreader Rate Calibration: **(if Super Hopper use 85 lbs/gal/min)**

Number of Revolutions at Spreader Rate 2: _____

Number of Revolutions at Spreader Rate 1: _____

Spreader	Spreader Value
OPI Spreader gate	5.5
Flink Tailgate Spreader	5.5
Swenson Hopper	11
Warren Hopper	5.5
Hi-Way Drag Chain Bed	4.9
Henderson Drag-Chain Bed	4.2

Difference: _____ X _____ = _____ lbs/gal/min rate

Spreader Value

Speedometer Setting:

Pengwyn Measured Distance: _____
divide by

Actual Distance: _____

Total: _____ X _____
= _____

pulse/mile value

(Pengwyn Pulse/Mile)

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Auger Drag: __ (50 psi)

Auger Jam: __ (2500 psi)

Minimum Value: __

Auger Spread Rates (1 to 15): __

Day and Time: __

Spinner Minimum: __

Wetting Constant: __

Wetting Max: __

Appendix F South Dakota DOT

Prewet Settings

Prewet Motor - This will be either Electric or Hydraulic

Prewet Mode - closed

Enable Prewet Manual - NO

Prewet Pulses/Rev - 012

Prewet Min. - (If you have Electric pump this will be set to 0)

(If you have hyd. pump we set this to where the pump will no longer turn then, (physically look) then turn it down 3 more numbers, example – if the pump quits turning at the setting 320 ma then we set the minimum at 290 ma)

Prewet Max. - (If you have Electric pump this will be set to 100)

(If you have Hyd. pump we find the max by watching the RPM reading of flow meter (number in upper right corner of display). This is done with liquid in tank and running through nozzle. Adjust power until you have the highest RPM reading on the display then bump the number up 3 more. Example if you get the max reading at 620 ma then we set the max to 650 ma.

Prewet Max RPM - Enter RPM number seen in setting Prewet Max

Closed Loop Gain - 250

Enable Prewet Unload - YES

Prewet oz/rev - (Depends on Flow meter)

White flow meter with 1/4" pipe thread ports, came on systems with electric pumps– 0.38

White flow meter with 3/8" pipe thread ports, came on systems with hyd driven pumps – 0.85

Micro-Trak FM500 (1/2") flowmeter – 2.0

Micro-Trak FM750 (3/4") flowmeter – 22.0

Select # Rates - 6

20, 30, 40, 50, 60, 70 Rates

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South Dakota DOT rate calculator gallon/mile-2

STRAIGHT SALT - Prewet Settings											
Electric Prewet Pumps - Rates in red will not work											
Hydraulic Prewet Pumps - Rates in red and orange will not work											
Material Lbs / Mile	Prewet Rate Setting	Gal. Per Mile	MPH	MPH	MPH	Material Lbs / Mile	Prewet Rate Setting	Gal. Per Mile	MPH	MPH	MPH
50	20	0.5	30	25	20	50	50	1.3	30	25	20
100	20	1.0	30	25	20	100	50	2.5	30	25	20
150	20	1.5	30	25	20	150	50	3.8	30	25	20
200	20	2.0	30	25	20	200	50	5.0	30	25	20
250	20	2.5	30	25	20	250	50	6.3	30	25	20
300	20	3.0	30	25	20	300	50	7.5	30	25	20
350	20	3.5	30	25	20	350	50	8.8	30	25	20
400	20	4.0	30	25	20	400	50	10.0	30	25	20
450	20	4.5	30	25	20	450	50	11.3	30	25	20
500	20	5.0	30	25	20	500	50	12.5	30	25	20
50	30	0.8	30	25	20	50	60	1.5	30	25	20
100	30	1.5	30	25	20	100	60	3.0	30	25	20
150	30	2.3	30	25	20	150	60	4.5	30	25	20
200	30	3.0	30	25	20	200	60	6.0	30	25	20
250	30	3.8	30	25	20	250	60	7.5	30	25	20
300	30	4.5	30	25	20	300	60	9.0	30	25	20
350	30	5.3	30	25	20	350	60	10.5	30	25	20
400	30	6.0	30	25	20	400	60	12.0	30	25	20
450	30	6.8	30	25	20	450	60	13.5	30	25	20
500	30	7.5	30	25	20	500	60	15.0	30	25	20
50	40	1.0	30	25	20	50	70	1.8	30	25	20
100	40	2.0	30	25	20	100	70	3.5	30	25	20
150	40	3.0	30	25	20	150	70	5.3	30	25	20
200	40	4.0	30	25	20	200	70	7.0	30	25	20
250	40	5.0	30	25	20	250	70	8.8	30	25	20
300	40	6.0	30	25	20	300	70	10.5	30	25	20
350	40	7.0	30	25	20	350	70	12.3	30	25	20
400	40	8.0	30	25	20	400	70	14.0	30	25	20
450	40	9.0	30	25	20	450	70	15.8	30	25	20
500	40	10.0	30	25	20	500	70	17.5	30	25	20

Appendix G Utah DOT

These pages represent Utah DOT's detailed specifications for the purchase of material spreaders.

Scope:

The function of this scope is to outline the following minimum requirements, but is not limited to additional features furnished by the manufacturer, for the material spreaders; including discount from price list for OEM parts. The spreaders are to be new units of current model and to have all standard features. The bid price MUST include delivery of each unit.

DETAILED SPECIFICATIONS

1. Construction:

- 1.1. Construction of the spreader shall be high-grade 201 stainless steel.
- 1.2. The body and sides shall be 10 gauge stainless steel.
- 1.3. The body longitudinal shall be manufactured of 7-gauge stainless steel and shall extend 24" beyond hopper to support spinner.
- 1.4. All bolts shall include a locknut and two washers made of stainless steel.
- 1.5. All bolts are to be long enough to go completely through locknut when assembled.
- 1.6. All welding shall be done with stainless welding wire or rod.
- 1.7. Hopper shall be continuously welded. Longitudinal shall be slotted out to the rear for easier gearbox and shaft removal

2. Dimensions:

- 2.1. Capacity- 7.5 cu. Yd. Struck (minimum).
- 2.2. Length inside -approximately 13 ft.
- 2.3. Length outside front to latch bar - 13 ft. 6 in.
- 2.4. Height overall- approximately 50 in.
- 2.5. Width inside- approximately 78 in.
- 2.6. Width overall (including spill guards) - 96 in. approximately.

3. Body:

- 3.1. "V" type hopper body with sides sloped approximately 45-degrees.
- 3.2. Body supported by 6 (minimum) triangle braces extending full height.
- 3.3. Body to have two braces between sides and top.

4. Hopper Screens:

- 4.1. The hopper screens will be constructed of (3/8") diameter steel rod inter-laced through screen (1/4" x 1 1/2") flat bar forming an open grating size approximately (2-1/2" x 2-1/2")

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- 4.2. The mesh will be reinforced by using 2" x 3/8" angle iron with the edge supports reinforced with 3/8" x 1" flat bar.
- 4.3. Minimum of three hinges will be paced over the 6" #9 "H" beam center support in order that the screens may be opened fully vertical from either side.
- 4.4. One (1) four-foot screen plus three (3) 3-foot screen per side.
- 4.5. Each screen shall have a positive lock to retain the screen to the "H" beam.
- 4.6. Each screen shall have pitch design with an 18" height above hopper top, with adequate supports. To be discussed at the paper pilot.

5. Spill guards:

- 5.1. Shall have 10 gauge 201 stainless steel vertical spill guard at rear bolted to hopper extending 19" in. above and full width of spreader.
- 5.2. Rear spill guard to have the stainless steel angle iron braces extending 1 ft. down on the hopper.
- 5.3. Rear spill guard to have integral full width stainless air deflector for light bar with mounting plate for LED light bar "rotobeam".
- 5.4. To have 201 stainless steel spill guard at front sloped forward 30-degrees from horizontal to 19 in. above hopper with triangular braces on each side.
- 5.5. To have taper cut side spill guards starting at side rails and sloping down 45-degrees to total outside width of 96 in.
- 5.6. To be supported by six (6) flanged gussets on each side all 10 gauge 201 stainless steel.
- 5.7. Outside flanges shall have 45-degree downward bend to reinforce free edge.

6. Discharge Gate:

- 6.1. The discharge gate shall be made of 10 gauge 201 stainless steel and ruler shall be provided at the rear of hopper.
- 6.2. The screw type jack with grease zerks installed and an extended handle with Polyethylene U-joint for easy cranking.

7. Tie Downs:

- 7.1. To have (2) tie downs for dump installation. To be 4" wide x 6' long nylon straps with "D" ring attached to one end.
- 7.2. Two burned 3/4" stainless steel J-hooks to be welded to sides of spreader.
- 7.3. Brackets to be stainless steel located 2' back from front on each side of hopper.

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- 7.4. Brackets to be positioned to pull at state specified angle. To be discussed at paper pilot.
- 7.5. To have 3" x 3"x 78" long 10ga stainless steel tube to be welded to inside of the hopper sides in line with the "J" hooks.

8. Mounting Bar:

- 8.1. To have 4"x 4"x ½" stainless steel angle iron bar at the rear with 1-1/4" round pins to engage tailgate latches.
- 8.2. Round pins to be stainless steel material and field welded to fit each individual truck for a precision fit.
- 8.3. Mounting bar shall be bolted and braced to spreader frame.
- 8.4. Mounting bar must be below truck bed floor so that spillage can be washed from bed.
- 8.5. Mounting bar must be 86" wide to prevent sander from shifting.

9. Front Alignment:

- 9.1. Front alignment body guide bar 82.5" wide manufactured from stainless steel angle 2"x 2" x ¼" angle. Two pieces welded together forming a 2" square tubing
- 9.2. Must include a 5" grease able caster wheel to load into dump body.
- 9.3. Wheels must be adjustable to accommodate varying dump body dimensions.

10. Guide Skid:

- 10.1. To have 6" piece of inverted 7 gauge formed stainless steel channel welded to each end of bottom frame channel.

11. Lifting Eyes:

- 11.1. To have four (4) ¾" stainless steel D-ring lifting eyes and one (1) center lifting eye.
- 11.2. Center lifting eye shall be in the fixed upright position. To be discussed at paper pilot.
- 11.3. Manufacture to locate center eye to pick-up spreader level with all components attached.
- 11.4. Hopper screens must fully open with center lifting eye installed.

12. Conveyor:

- 12.1. Shall be a minimum of 24" wide.
- 12.2. To have 7 gauge one piece 201 stainless steel floor.

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- 12.3. Conveyor to have 3/8" x 1-1/2" flights at 4" spacing, welded top and bottom to pintle chains.
- 12.4. Chains to be Allied Lock AL667X or equal.
- 12.5. Chains to have full length formed 7 gauge guards so that only flights are exposed to material in hopper.
- 12.6. Sprockets are to be eight (8) tooth on 2" shaft.
- 12.7. Shall have two (2) 2-ply rubber belting wipers to be provided for cleaning both sides of conveyor chain.
- 12.8. A front seal strip is to be provided.

13. Bearings:

- 13.1. Are to be self-aligning 2" take-up style bearings (Dodge #131177 or equal) in a stainless steel frame.
- 13.2. Bearings to have grease leads ran to manifold at rear.
- 13.3. Spring-loaded screw type adjusting rods must be clear of pre-wet tanks and be able to be easily adjusted from the rear.
- 13.4. Shall have 3" minimum travel. To be discussed at paper pilot.

14. Grease manifold:

- 14.1. A greasing manifold shall be supplied to adequately lubricate the front idler bearings and the feed gate jack assembly at the rear of the hopper.
- 14.2. These three (3) grease points shall have separate grease lines rated at 2,500 psi burst that shall meet at a centralized point at the rear of the hopper.
- 14.3. Tubing shall be secured to prevent chaffing.
- 14.4. This location shall be the grease point for the entire system.
- 14.5. Each 1/8" grease line shall have an adequate pressure rating to allow the system to be greased with a commercial grease gun.
- 14.6. Tubing to be filled prior to delivery.

15. Conveyor Drive:

- 15.1. To be cast iron hollow bore shaft mounted gearbox 50:1 gear reduction, 2" output shaft, oil bath, with antifriction bearings on input and output shafts and direct-coupled motor.
- 15.2. Guard to be installed over input shaft.

16. Hydraulic Drive Motor:

- 16.1. The motor shall be Char-Lynn 101-1027 or equal

17. Spinner & Chute:

- 17.1. Entire spinner to be 10 gauge 201 stainless steel, minimum 20" diameter.

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- 17.2. Shall include six (6) radial, stainless steel replaceable fins.
- 17.3. Hydraulic spinner motor to be located above disk in UDOT approved manner. To be discussed at paper pilot.
- 17.4. Spinner chute to have three adjustable and one front fixed deflectors. Rear deflector to overlap side deflectors in all positions. Deflector shall be easily adjusted and removed without use of tools.
- 17.5. Spinner chute shall include two (2) adjustable internal baffles.
- 17.6. Spinner disk shall be 32" below truck bed floor. Spinner disk to be attached to motor shaft by a 3/8" grade 8 bolt and locknut.
- 17.7. Spinner to be supplied with parker brand hydraulic disconnects, and 90 degree elbows at the spinner motor.
- 17.8. The entire spinner assembly shall be pinned to hopper for easy removal or tip up.
- 17.9. The spinner chute shall be a dump over model that allows hopper to be unloaded without dumping material on the spinner disk with the chute in the lowered position.

18. Hoses:

- 18.1. Hydraulic pressure hose to be Parker 431 with crimped fittings.
- 18.2. Hydraulic return hose to be Parker 431 with crimp fittings.
- 18.3. Hoses are to be run from motors to bulkhead fittings at one location on lower right of spreader.
- 18.4. Hoses are to be clamped to a stainless steel bracket to prevent chaffing and accumulation of ice.
- 18.5. Hoses of sufficient length will be connected to the bulkhead fittings and have Parker brand hydraulic quick couplers as follows.
 - 18.5.1.1. Conveyor pressure: Parker 1B7511 with #08 hose + mating coupling 1B7521
 - 18.5.1.2. Spinner pressure: Parker 1B7521 with #08 hose + mating coupling 1B7511
 - 18.5.1.3. Combined return: Parker 1B101 with #12 hose + mating coupling 1B10021
 - 18.5.1.4. No galvanized or black pipe fittings is acceptable

19. Air Foil:

- 19.1. Full length airfoil mounted on top of rear spill guard approximately 4" high.

20. Lights:

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- 20.1. To have stainless steel light bar with three (3) light ID. Cluster shielded, four (4) 4" stop, turn tail lights shielded, two (2) red clearance lights shielded and four (4) red reflectors.
- 20.2. Truck-lite stop and tail lights shall be super 44 LED 4" sealed
- 20.3. Part#44030RS grommet kit.
- 20.4. Marker and clearance Truck-lite part # 10050R grommet kit LED 2-1/2".
- 20.5. Shall have amber LED light bar.
- 20.6. "Highlighter" LED 15" SAE J845, CLASS 1 LIGHT BAR . P/N 454101HL-02
- 20.7. Light bar to mounted near center at rear of spreader with protective cover over light bar. Must be able to service and repair without removing light bar.
- 20.8. To have white "LED" work light located to illuminate spreader discharge on left side. Light to have 12 gauge cylindrical shield held in place by pivot bolt.
- 20.9. Shield to extend 3" Below light. Light shield assembly to have mounting that provides adjustment in two directions.

21. Wiring:

- 21.1. Wiring from work and strobe lights to junction box in the light bar.
- 21.2. Wiring to be clamped to prevent chaffing, with no sharp bends, with moisture proof connections.
- 21.3. All wiring must be jacketed cable, individual wires ran through tubing is unacceptable. No splices in wires.
- 21.4. Two(2) 10', seven conductor, 14 gauge, (minimum) corrosion resistant molded type cable with molded plug to be "bob-tail" product. Phone (403)272-0318 to be supplied
 - 21.4.1.1. One cable will run from the work and light bar junction box to the truck chassis and will be colored red.
 - 21.4.1.2. The second cable will run from the STT marker light junction box to the truck chassis and will be colored black.

22. Painting:

- 22.1. All stainless steel metal shall be left unpainted. Carbon steel components shall be powder coated.
- 22.2. All stainless steel edges shall be buffed to eliminate all sharp edges.

23. Identification:

- 23.1. Each unit shall have a stainless steel metal tag permanently attached to upper left rear. Below the spill guard, with the following information:
 - 23.1.1.1. Manufacturer's name
 - 23.1.1.2. Year of manufacture

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- 23.1.1.3. Model number and serial number.
- 23.1.1.4. Each unit shall have the UDOT (6) digit unit number.
(Example: 13-1023) in 2" high number located below rear light bar.
- 23.1.1.5. The unit numbers will be specified on purchase order when issued.

24. Hydraulic pre-wetting de-icing system:

- 24.1. Hydraulic pre-wetting de-icing system, to be pre-wetting capable of maintaining a consistent ratio of liquid salt brine or max chloride to a pre-determined granular deicing material output.
- 24.2. The control box must contain a liquid pump capable of delivering 10.5 GPM and an approved flow meter compatible with ground speed of the control box.
- 24.3. The de-icing system tanks are to be mounted on the v-box spreader so as not to interfere with the loading or unloading of the spreader on the trucks.
- 24.4. The hydraulic system housing is mounted to be easily accessible during operation, and is connected to the truck hydraulic system via two (2) hoses.
- 24.5. All mounting brackets for the spray system components are to be 201 stainless steel.
- 24.6. The chemical pump outlet is connected to the variable orifice spray nozzles by nylon reinforced PVC hose, to allow the proportional calcium chloride adjustment.
- 24.7. To have two (2) 200- gallon minimum saddle tanks, constructed of (LLOPE) Polyethylene and UV stabilized.
- 24.8. The tanks to have anti-slosh baffles and properly vented.
- 24.9. To have two (2) variable orifice nozzles in the chute, designed to spray throughout the system's chemical flow rate.
- 24.10. Shall have an easy removable filter on the system.
- 24.11. Controller to have a low-level indicator inside of cab. And an automatic pump shutoff to prevent pump failure when out of fluid.
- 24.12. Tanks to be capable of being filled through a 5" cap at the top or from the bottom of the tanks through the drain valve. Plumbing to withstand a 50 G.P.M. Pump.
- 24.13. A single 2" quick coupler for easy hookup and disconnect. Shall be capable of filling each tank separately or both at the same time. The crossover pipe shall be large enough to fill both tanks approximately at the same time when filling.

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- 24.14. Junction box shall be Stahlin's "J" series HPL water tight, submersible, corrosion resistant enclosure. Enclosure shall have 10 gauge mounting plate on rear of enclosure for mounting and on the bottom of enclosure for reinforcement.
- 24.15. Hoses enter and exit boxes using sealed grommets or bulkheads.

Option 1. ROTATING SPINNER & CHUTE:

- 1.1 The spreader shall have a rotating spinner system and shall be capable of being adjusted electronically in the cab using a manufacture's control console and harness to spread from 1 lane left, center, or right; or up to 3 lanes at one time.
- 1.2 The rotating spinner shall utilize a traditional chute weldment with four (4) - position height adjustment. The material will then enter the focus which is constructed of 201 stainless steel.
- 1.3 The focusing chute shall allow the spinner assembly to rotate left to right.
- 1.4 The pivoting of the spinner shall be achieved through a single double acting cylinder.
- 1.5 The pivoting cylinder shall have the capability to accept a linear transducer which will provide feedback to the in-cab controller on current position.
- 1.6 The pivoting cylinder and transducer shall be designed so the transducer can be replaced without the need to replace the pivoting cylinder.
- 1.7 The rotating spinner disc shall be driven by a 4-bolt 2.8 CR hydraulic motor. Spinner motor shall have an integral sensor capable of providing spinner disc feedback to the in-cab console.
- 1.8 The spinner disc shall be constructed of stainless steel with formed fins. Fins shall be in a counter clockwise rotation. Diameter of disc shall be a minimum of 22"
- 1.9 The rotating spinner system must have been out in the market successfully and proven workings for at least one (1) full year.

Option 2. STAINLESS STEEL STORAGE STAND SYSTEM:

- 2.1 Stainless steel storage stand system designed to load and unload spreader from dump body and designed to hold the weight necessary for storage.
- 2.2 The forward legs shall be designed to fold up as vehicle is backed under the stand.

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- 2.3 shall include caster wheels to roll into vehicle.
 - 2.4 rear legs shall be self-storing telescopic design and legs shall extend beyond the spinner assembly. Shipped loose
- Option 3. MILD STEEL STORAGE STAND SYSTEM:
- 3.1 mild steel storage stand system designed to load and unload spreader from dump body and designed to hold the weight necessary for storage.
 - 3.2 The forward legs shall be designed to fold up as vehicle is backed under the stand.
 - 3.3 Shall include caster wheels to roll into vehicle.
 - 3.4 Rear legs shall be self-storing telescopic design and legs shall extend beyond the spinner assembly. Shipped loose
- Option 4. TWIN AUGER SLURRY MIXING SYSTEM:
- 4.1 Slurry mix shall be completed through a stainless steel ported injector extending 6" into the hopper.
 - 4.2 Injector bar shall evenly distribute liquid to both sides of the dual auger conveyor system to create consistent slurry prior to chute area.
 - 4.3 Injector bar shall be securely mounted inside hopper under inverted "V" for protection.
 - 4.4 Dual 7" diameter variable pitch auger conveying system.
 - 4.5 The augers must be counter rotating toward center of hopper to assist prevention of bridging, break down clumps of material, and provide consistent discharge for an even spread pattern and eliminate streaking.
 - 4.6 Auger pipe shall be 3 ½" diameter, schedule 80, with ½" thick flighting.
 - 4.7 Each auger is individually driven at the rear by 24.7 CIR hydraulic motor directly coupled to the end of the auger shaft.
 - 4.8 Auger shafts utilize a polyurethane bushing at rear end of auger to eliminate seizing and ensure ease of maintenance.
 - 4.9 Auger shafts are supported at the front with 2" two (2)-bolt flange, grease able bearings.
 - 4.10 All bearings shall be equipped with grease zerks.
 - 4.11 The front bearings shall have a 304 stainless steel pipe extended to the rear of the unit for easy greasing.
 - 4.12 hydraulic inter-lock auger shut off system to shut auger down when the cover grates are opened. Interlock to be plumbed by the manufacturer.
- Option 5. 3-LANE ANT-ICE SYSTEM:

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- 5.1 The anti-ice system shall be capable of dispensing liquid De-icers at a rate of 60 gallons per lane mile at 60 MPH.
- 5.2 The liquid chemical pump must be a 210 GPM centrifugal pump with a 2" suction and 1 ½" pressure ports.
- 5.3 The hydraulic motor shall be integral with liquid pump. The hydraulic motor will require no more than 13 GPM @2100 psi, and must be capable of working on fixed gear pump systems or load sensing systems. (Proper valving must be supplied by installer)
- 5.4 The pump system shall include a replaceable screen line strainer.
- 5.5 An in-line turbine style liquid flow meter rated at 10-100 GPM shall be supplied for the anti-ice portion of the system.
- 5.6 A filter shall be installed after the pump to protect the flow meter, nozzles, and valves.
- 5.7 All hydraulic hoses and wiring shall be routed away from pinch points, sharp corners, and heat sources.
- 5.8 Check valves shall be installed at boom to minimize run-on and improve start up response.
- 5.9 Fittings connecting all major components shall be glass fill polypropylene, manifold style.
- 5.10 The spray boom system shall be 3-lane design and mount to the spreader stand legs.
- 5.11 The spray boom shall be adjustable in height.
- 5.12 The spray boom shall be constructed using stainless steel tubing with clamp on style spray nozzle assemblies.
- 5.13 The spray boom control valves shall be motorized 1-1/2" stainless steel trunnion style with poly housing. They shall be electronically controlled from the in-cab control system (control system not included). The valve motors shall be designed to be quick attaching as to provide the operator the ability to move the motor from one valve to the next in the event of a valve failure.
- 5.14 1-1/2" reinforced EPDM hose shall be provided for all liquid de-icer pressure lines.

Option 6. DEDUCT FOR NO PRE-WET

Option 7. MILD STEEL STORAGE STAND SYSTEM WITH STAINLESS STEEL REAR LEGS:

- 7.1 mild steel storage stand system designed to load and unload spreader from dump body and designed to hold the weight necessary for storage.
- 7.2 The forward legs shall be designed to fold up as vehicle is backed under the stand.

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- 7.3 Shall include caster wheels to roll into vehicle.
- 7.4 Rear legs shall be stainless steel self-storing telescopic design and legs shall extend beyond the spinner assembly. Shipped loose

Option 8.

Tip Up Spinner Chute:

- 8.1 Spinner chute shall be capable of being swung up and pinned in the up position to be out of the way for unloading hopper without the use of tools.
- 8.2 A winch with ¼" stainless steel cable shall be provided to facilitate easy raising of spinner chute.
- 8.3 Winch shall have an anti-back lash feature for operator safety.

UTAH DEPARTMENT OF TRANSPORTATION

Equipment Operations

Jeff Casper - Equipment Operations Manager

Specialized Combo with Hydraulics

PUBLICATION

State of Utah through the Utah Division of Purchasing and General Services is seeking the purchase of one 14- foot specialized combo pre-wet sander , that will be used to salt, sand and pre-wet roads. This specification is a product of the Utah Department of Transportation, hereinafter referred to as STATE. STATE does not assume nor accept any liability when this specification is used in the procurement process by any other entity.

PART I: GENERAL CLAUSES AND CONDITIONS

1. The equipment furnished under this specification shall be the latest improved model in current production, as offered to commercial trade, and shall be of quality workmanship and material. The supplier represents that all equipment offered under this specification is new at time of delivery. **DISCONTINUED, DEMONSTRATOR OR DEVELOPMENTAL MODELS ARE NOT ACCEPTABLE.**
2. Supplier shall submit, with the bid to BidSync (<http://www.bidsync.com>), the latest detailed specifications for the equipment offered. Supplier should submit the latest literature for informational purposes only. Should you need assistance from BidSync, contact support@bidsync.com or 801-765-9245.
3. Upon delivery, unit shall be completely assembled and adjusted. All equipment, including standard and supplement equipment, shall be installed, and the unit

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- shall be serviced and ready for continuous operations.
4. All parts not specifically mentioned, but are necessary for the unit to be complete for operation or are normally furnished as standard equipment, shall be furnished by the supplier. All parts shall conform in strength, quality, and workmanship to accepted standards of the industry.
 5. The unit provided shall meet or exceed all the Federal and State of Utah safety, health, lighting and noise regulations and standards in effect, and which are applicable to equipment furnished at the time of acceptance.
 6. It is the intent of the STATE to purchase goods, equipment, and services having the least adverse environmental impact within the constraints of statutory purchasing requirements, departmental need, availability, and sound economical considerations. Any suggested changes and environmental enhancements for possible inclusion in future revisions of this specification are encouraged.
 7. STATE, encourages all manufactures to comply, voluntarily, with the Society of Automotive Engineers (SAE) recommended practices.
 8. Required measurements standard will be given in English units or the industry's standard units.
 9. Failure to provide and comply with Part I of bidder submitted specifications will result in bid(s) being declared non-responsive.
 10. Requests for exception(s) to this bid must be submitted through questions and answers on BidSync. Any addenda will be issued through BidSync. **Exceptions shall not be granted to requests made after the question and answer deadline.**
 11. Successful bidder to include provisions for pre-build conference at UDOT headquarters (4501 South 2700 West, Salt Lake City, Utah 84119.)
 12. The equipment shall be warranted against all defects in material and workmanship for a period of not less than 24 months. If manufacturer's standard warranty period exceeds 24 months, then the standard warranty period shall be in effect. Warranty period shall start after equipment has been installed. UDOT shall provide the in-service date to the manufacturer. Basic warranty shall include agreement to allow all UDOT shops to be approved to complete in-house warranty repairs at UDOT maintenance shops. The warranty shall include nothing less than parts, labor reimbursement and repetitive problems, reasonable road travel cost reimbursement. If the manufacture's standard warranty includes any additional coverage not mentioned under these requirements, the standard warranty along with requirements shall be in effect.

State any exception and / or additions to the warranty here or state any attachment included.

PART II: GENERAL SPECIFICATIONS

1. SCOPE:

The intent of this bid is to define the minimum acceptable standards for a stainless steel 14- foot specialized pre-wet spreader, that will be used to salt, sand and pre-wet

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roads.

WARRANTY:

Bid to the state terms of warranty. All warranty periods shall start after auxiliary equipment has been installed and trucks are put into service. Basic warranty shall include agreement to allow all U.D.O.T. shops to be approved, to complete "In-house" warranty repairs, in U.D.O.T. shops. The warranty shall include parts, labor reimbursement and repetitive problems, reasonable towing and road travel cost reimbursement.

Bid response

Comply _____ *Exceptions* _____

Bid response *Basic Warranty*
period _____

Spreader warranty period.

Other warranty
period _____

(Attach copy if needed.)

Other _____

3. NOTICE TO BIDDERS:

Any example shown is listed to show type and class of equipment desired. Bidders are cautioned to read the specifications carefully, as there may be special requirements not commonly offered by the equipment manufacturer. Do not assume your standard equipment meets all detailed specifications merely because it is listed as an example. Bidders are cautioned that units delivered to the FOB points, which do not meet specifications in every aspect will be rejected. The combination of the characteristics of products cited shall be the minimum standard of quality for this bid. Products which meet the minimum standard and which are in other ways substantially equivalent to those designated will be considered for award.

PART III, DETAILED SPECIFICATIONS

1) Granular Hopper:

- 1.1) Inside length to be 14'
- 1.2) Capacity to be (8.0) yd minimum struck
- 1.3) Inside top width of V-Box to be 72"
- 1.4) Side slope to be 50 degree minimum
- 1.5) Hopper seams to be continuous welded on the inside and the outside of the body
- 1.6) Lift hooks on each corner are 1/4" x 2" formed 201 SS plate

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- 1.7) Sides and ends to be 10 gauge 201 SS
- 1.8) To include right and left spill shields and front spill shield from 201 stainless steel.

All miscellaneous hardware and mechanical fasteners shall be stainless steel

2) Conveyor System:

- 2.1) Dual auger trough to be 7 gauge 201 SS
- 2.2) Dual 7" diameter variable pitch auger conveying system.
- 2.3) The augers must be counter rotating toward center of hopper to help prevent bridging, break down clumps of material, and provide consistent discharge for an even spread pattern and to eliminate streaking.
- 2.4) Auger pipe shall be 3 ½" diameter, schedule 80, with ½" thick flighting.
- 2.5) Each auger is individually driven at the rear by 24.7 CIR hydraulic motor directly coupled to a 3.6:1 planetary gearbox, which is directly coupled to the end of the auger shaft
- 2.6) Auger shafts utilize a polyurethane bushing at both ends of each auger to eliminate seizing and ensure ease of maintenance.
- 2.7) Auger shafts are supported at the front with 2 inch, two bolt flange, grease able bearings.
- 2.8) All bearings shall be equipped with zerk fittings. The front bearings shall have a 201SS pipe extended to the rear of the unit for easy greasing.

3) Liquid Tank:

- 3.1) Reservoir shall provide 1400 gallons of liquid capacity.
- 3.2) Liquid reservoir is 10 gauge 201 stainless steel, full length of the body, 82" outside width, utilizes space under the spreader body to provide additional liquid capacity and shall be integral part of the spreader body with all seams continuously welded.
- 3.3) Liquid reservoir utilizes full baffling on 2 ft. centers to reduce liquid movement and provide structural integrity between internal and external sides of tank.
- 3.4) Agitator pipe is 1 ¼" dia. 201SS schedule 40 running full length of reservoir with holes 8" apart on both sides.
- 3.5) Tank feed shall be top and bottom fill. Any tanks without both will not be accepted.
- 3.6) Level gauge with an indicator and scale clearly marked by a decal showing tank level in gallon increments. The scale shall be of sufficient size and located in order to be clearly visible from the ground at the rear of the unit.
- 3.7) Reservoir shall have integral sump to utilize full capacity of tank. The feed to the pump shall be through this sump.

4) Rear Cabinet Enclosure:

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- 4.1) The unit shall include a full width 201 stainless steel cabinet built into the rear of the body that houses the liquid pumps, flow meters, and all valving.
- 4.2) The cabinet shall contain 3 access doors, right, left, center.

5) Liquid Pumps

- 5.1) The direct liquid anti-ice product pump shall be a hydraulic motor driven stainless steel centrifugal pump rated up to 210 GPM flow with a maximum pressure of 140 PSI.
- 5.2) A minimum 2-inch inlet and minimum of 1-1 /2-inch outlet.
- 5.3) The system shall have the capacity to maintain a minimum of 30 gallons per lane mile for three (3) lanes 12 feet each at 5 miles per hour up to 50 gallons per lane mile for three (3) lanes 12 feet each at 50 miles per hour.
- 5.4) The low flow slurry/prewet pump shall be capable of producing liquid flow at a minimum of 9 GPM.

6) Flow meters

- 6.1) The high-flow direct liquid anti-ice flow meter shall be a turbine style constructed of polypropylene operating at a maximum flow of 198 GPM.
- 6.2) Flow meter shall have flange style connections. Flow meter shall provide accurate liquid flow information to the hydraulic control system for precise control and monitoring.
- 6.3) The low flow slurry/prewet flow meter shall be an in-line rotary style liquid flow meter with accuracy up to 15 GPM. It shall provide liquid flow information to the Hydraulic Control System for precise gal/ton metering.

7) Electric Valves:

- 7.1) The operating manifold valve shall be constructed of hardened polyethylene with replaceable double O-rings on each connection of the valve.
- 7.2) Electric trunion style valves will control the spray boom(s) independently.
- 7.3) The switching shall be done within the cab of the truck and with easy movement of the operator. The valves shall open within .8 of a second.
- 7.4) The valves shall have 1-1/4" full port outlet to the booms, quick detach motors (without the use of tools) and capable of being opened and closed manually.

8) Control Valve:

- 8.1) The hydraulic valve shall be of modular manifold design.
- 8.2) Each hydraulic function requires an individual manifold stacked together to form the manifold base.
- 8.3) The manifold base shall consist of an inlet section with SAE #16 inlet porting, SAE #20 outlet porting, and SAE #4 load sense porting.
- 8.4) There shall be a main system relief in the inlet section to protect the system from high pressure in case the pump compensators fail.
- 8.5) The hydraulic control valves shall be pulse-width modulated, proportionally controlled.

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- 8.6) Each hydraulic valve segment shall be individually mounted to the manifold base assembly and be serviceable without removing any hydraulic hoses or any other hydraulic valve segments.
- 8.7) Each hydraulic valve segment shall have individual pressure compensation to achieve independent simultaneous operations.
- 8.8) All segments shall have heavy-duty continuous duty coils and connections shall be with Din connectors.
- 8.9) All coils shall operate at 12 VDC and require a maximum of 1400 mille-amps.
- 8.10) Valve segments shall be Add-A-Fold® model or prior approved equal. The valve is to be arranged as follows:

- ❑ Spinner chute control, 4-way, 5 GPM cylinder spool.
- ❑ Auger, 2-way, 20 GPM motor spool.
- ❑ Direct, 2-way, 20 GPM motor spool.
- ❑ Spinner, 2-way, 7 GPM cartridge.
- ❑ Prewet/Slurry, 2-way, 7 GPM cartridge.

9) Liquid Distribution and Spray System:

- 9.1) Spray system shall be capable of self loading and unloading the liquid product from the truck.
- 9.2) The process shall be done through 2" quick disconnects mounted at the rear.
- 9.3) The connections shall have caps to close off the connections when not in use with chains to prevent loss of cap.

10) Direct Liquid Anti-icing Booms

- 10.1) Spray system shall be capable of a 12-foot wide path through a single boom, directly behind the vehicle.
- 10.2) The sprayer will have the ability to spray a path on either side of the truck at 50 mph.
- 10.3) The spray path shall be a minimum of 12' to each side of the truck.
- 10.4) The complete unit shall be able to cover 36' when traveling at 50 mph.
- 10.5) The adjustable height booms can be no higher than 18" off the ground.
- 10.6) Center lane shall consist of a 1-1/2" diameter 304 stainless steel boom with minimum of 8 stainless steel straight stream nozzles and double clip nozzle bodies.
- 10.7) Independent right and left lane shall consist of 1-1/2" diameter 304 stainless steel boom with a minimum of 4 stainless steel straight nozzles and adjustable double clip nozzle bodies.
- 10.8) Each boom assembly shall have 1-1/2" adjustable check valve attached to inlet and shall be coupled to boom valves with 1-1/2" ID minimum hose and cam-locks.

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11) Slurring Mixing System

- 11.1) Slurry mix shall be completed through a stainless steel ported injector extending 6 ft into hopper.
- 11.2) Injector bar shall evenly distribute liquid to both sides of the dual auger conveyor system to create a consistent slurry prior to chute area.
- 11.3) Injector bar shall be securely mounted inside hopper area under inverted vee for protection.

12) Granular/Slurry Applicator & Placement Dispenser Control

- 12.1) Applicator chute shall be constructed of 10 ga 304 Stainless Steel.
- 12.2) Applicator shall be controlled from inside the cab to precisely direct material to the right, left, or center lanes on the go to match changing road conditions and lane configurations.
- 12.3) The material placement dispenser controls the direction and width of the spread pattern of granular, pre-wetted granular and “slurry” materials.
- 12.4) The spread pattern widths shall be from 4’ to 40’.

13) Tie Downs:

- 13.1) To have (4) tie downs for dump installation.
- 13.2) To be 4” wide x 6” long nylon straps with “D” ring attached to one end.
- 13.3) Brackets to be stainless steel located 2ft back from front and back on each side of hopper.
- 13.4) Brackets to be positioned to pull at state specified angle. To be discusses at paper pilot.

14) Screens:

- 14.1) 3/8” rod running through 2” x 1/4” flat bar turned on edge to provide approximately 2 3/8” openings.
- 14.2) Screens shall be hinged to a 5” I-beam.
- 14.3) Hydraulic safety interlock auger shut-off system disables auger rotation when top screens are opened—interlock plumbed at factory

15.) Stands:

- 15.1) Stand is to be made of structural steel, designed to support the full weight of the spreader when removed from truck.
- 15.2) It is intended to store spreader with only small amounts of material remaining in the hopper and tank.
- 15.3) Stand is to be designed so that the truck’s dump body can be partially raised and then can slide under the main- frame rails of the stand.
- 15.4) Upon contact of the wheels with the dump body floor, the front legs of the stand will lift off the ground and can be unlocked.
- 15.5) Upon contact of the rear of the dump body, the front legs will fold up inside the main- frame rails.

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- 15.6) Once the unit is completely inside the dump body, the body can be lowered and the rear legs will clear the ground and can be raised and locked in position.
- 15.7) Both front and rear legs to be adjustable to adapt to various height dump body applications.

Options:

- 1) Price per foot for longer trucks, to include larger granular capacity and liquid capacity.

\$ _____

- 2) Entire spinner shall be 10 gauge 201 stainless steel, minimum 20 " diameter. Shall include six (6) radial, stainless steel replaceable fins.

Hydraulic spinner motor shall be located above disk in UDOT approved manner. Shall be discussed at paper pilot.

Spinner chute shall have three adjustable and one front fixed deflector. Rear deflector to overlap side deflectors in all positions. Deflector shall be easily adjusted and removed without use of tools.

Spinner chute shall include two (2) adjustable internal baffles.

Spinner disk shall be 32" below truck bed floor. Spinner disk shall be attached to motor shaft by a 3/8" grade 8 bolt and locknut.

Spinner shall be supplied with Parker brand hydraulic disconnect and 90 degree elbows at the spinner motor.

The entire spinner assembly shall be pinned to the hopper for easy removal or tip up.

The spinner chute shall be a dump over model that allows hopper to be unloaded without dumping material on the spinner disk with the chute in the lowered position.

\$ _____

PART IV -PRICING

1. Price guarantee:

1.1 All pricing must be guaranteed for one year including the purchase price, option prices and parts discount.

1.2 The state may accept any item or group of items or overall low bid.

2. Purchase Price:

Please list the purchase price for the following to include, the cost of travel, lodging, and meals (per-diem), (See Part I, Item 12).

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2.1 Specialized Combo Unit as described in the specifications \$ _____

2.2 The percentage discount off of published price for parts, consumables and wear items associated with the Specialized Combo Unit being offered:
_____ % discount.

State the name of the published price pages and effective date

NOTE: This bid will be awarded based on the lowest responsible bidder that meets the specifications with the option's listed above. The successful bidder can modify chassis to meet the needs of city and government agencies based on percentage of discount off retail price pages. (please note pricing and catalog data.)

PART V – PARTS

1. The Bidder and/or with the manufacturer of the equipment furnished shall have an authorized dealer within the state of Utah.
2. The authorized dealer shall have factory-trained personnel available for authorizing of warranty repairs.
3. The dealer shall also maintain an inventory of high-usage parts and a quick source for low-usage parts. Consideration will not be given to bidders unable to satisfy to the State as to the adequacy of their parts network for the availability of replacement parts.

PART VI: DELIVERY, PILOT REVIEW, DOCUMENTATION, ACCEPTANCE AND PAYMENT

1. PILOT REVIEW

1.1 Pilot model is to be available for inspection with-in 90 days after receipt of purchase order. Expenses for two U.D.O.T. representatives to review the pilot will be paid by the successful bidder or manufacturer.

2. DELIVERY REQUIREMENTS:

2.2 Delivery shall be at no additional charge for locations within a fifty (50) mile radius of the Utah State Capital building.

2.3 Delivery will be at the STATE headquarters 4501 South 2700 West in Salt Lake City, Utah.

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2.4 Any reference to the manufacturer terms and conditions, such as F.O.B. shipping point, minimum order amounts of quantity, or prices subject to changes, will not be part of any contract with the successful bidders and will be disregarded by the State

3. TRAINING

3.1 INSTRUCTION ON SAFETY, OPERATION AND MAINTENANCE: The vendor shall provide the services of a competent, factory-trained, technician thoroughly trained in the use and operation of the units offered to STATE.

3.2 To provide to included the following.

- Operating procedures per operating manual.
- Preventive maintenance.
- Equipment limitations.
- Operator maintenance.
- Before operations checks and lubrication.
- Safety.
- Welding on equipment.
- Transporting non-operational use.
- Controls.
- Equipment operation, Do's and Don't.
- Hazardous situations.

3.3 LESSON PLAN: The supplier shall furnish a copy of the manufacturer's approved lesson plan for the instructional training within 30 days after award of the purchase order. The lesson plan may be taken from the operator's manual, provided all necessary information is included.

4. DOCUMENTATION:

4.1 Delivery must include Supplier's Invoice, a Copy of Warranty(s) and an Operator's Manual for each unit.

4.2 Operators Manual shall include start up procedure, check list for data collection, shut down procedure.

4.3 Delivery must also include one complete set of parts lists and (shop) repair manuals for each unit (3) sets of shop (repair) manuals at no additional charge. CD's are acceptable for shop repair manuals. Manuals shall include blueprints on all wiring and hydraulic schematics.

5. ACCEPTANCE:

5.1 All equipment ordered with this request will be subject to acceptance inspection

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and performance testing upon receipt.

5.2 Acceptance inspection and performance testing will not take more than five working days, weather permitting.

5.3 The vendor will be notified within this time frame of any units that do not comply with the purchase order specifications.

5.4 If any units are canceled for non-acceptance, the needed equipment may be purchased elsewhere and the vendor may be charged full increase, if any, in cost and handling.

6. PAYMENT

6.1 Invoices will not be approved for payment until all of the required spare parts, documentation and manuals have been received and the equipment has been accepted.

7. PRICING

7.1 All pricing must be guaranteed for one (1) year. Following the guarantee period, any request for price adjustment must be for an equal guarantee period, and must be made at least 30 days prior to the effective date. Any such request shall include sufficient documentation using published information showing logical mathematical evidence supporting the request. Any adjustment or amendment to the contract will not be effective unless approved by the State Director of Purchasing. The State will be given the immediate benefit of any decrease in the market, or allowable discount.

8. INVOICING

8.1 Contractor shall submit invoices to State:

UDOT Equipment Operations
4501 S 2700 W Box 145730
Salt Lake City, Utah 84119

8.2 The Purchase Order or Contract number shall appear on all invoices and correspondence. Billings must be itemized identifying clearly all products or services purchased. Invoices shall be submitted in a timely manner.

8.3 In the event the State is entitled to a cash discount, the period of computation shall commence on the delivery date or the date of a correct invoice,

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whichever is later. If an adjustment in payment is necessary due to damage, the cash discount period shall commence on the date final approval is authorized. The State reserves the right to adjust incorrect invoices. State will remit payment by mail or electronic commerce.

9. NON-COMPETE CLAUSE

9.1 The Contractor represents its officers and employees are free to contract with State and are not subject to restrictions by the terms of their present or past employment, including, but not limited to an agreement not to compete for a period of time unless disclosure has been made. Contractor must disclose to the State any possible conflicts in writing, before the contract is signed, and the State will evaluate whether to continue with contract execution. State may elect to terminate a contract immediately with a Contractor who is subsequently determined to be subject to such restrictions without liability to the State. If the State elects to terminate a contract for this reason, the State will supersede paragraph # 12 in Attachment A – Standard Terms and Conditions and will not provide 90-day prior notice to the Contractor.



research for winter highway maintenance

Lead state:

Minnesota Department of Transportation

Research Services
395 John Ireland Blvd.
St. Paul, MN 55155