CHAPTER 6: PLOWMASTER

Many of the desired maintenance vehicle functions identified by the focus groups, as well as many of the desired improvements in maintenance management practices identified by the participating states, rely on the collection, delivery, and management of data about the maintenance vehicle's immediate environment, roadway conditions, and onboard systems. Rockwell International's PlowMaster mobile computer system (PlowMaster) is the centerpiece of the prototype maintenance vehicles, performing data integration and formatting functions critical to successful realization of the advanced-technology vehicle concept. Rockwell developed the PlowMaster from its own mobile computer system for transit applications. Installed onboard the vehicles, the PlowMaster collects data transmitted from vehicle sensors and other technologies, formats data in a common format, displays data in user-friendly formats for the operator in the cab, and stores data on a removable Personal Computer Memory Card International Association (PCMCIA) card for off-board data delivery. The PlowMaster has cellular and radio communications capabilities; the study team plans that, in future phases, the PlowMaster will perform off-board data communications via cellular, and perhaps eventually, radio communications.

The relationship between the PlowMaster and other technologies installed on the prototype maintenance vehicles for this study is shown in Figure 6-1. The primary components of the PlowMaster are a smart Mobile Data Terminal (MDT) and a Flexible Interface Adapter (FIA), shown in Figure 6-2.

This chapter discusses the main features of the PlowMaster, as well as installation, operations, and performance results during Phase II. See Appendix C for Rockwell's complete guide to the PlowMaster mobile computer system.

OBJECTIVE

Conduct proof of concept regarding incorporating a central, onboard, computerized data collection and management system on winter maintenance vehicles.

MEASUREMENT

The PlowMaster MDT and FIA are successfully installed on the prototype vehicles, and they operate as expected. Expected performance includes the following: Data from the subsystems (friction meter measurements, air/pavement temperatures, global positioning system (GPS) location and time, snow plow positions, power booster information, etc.) are collected by the onboard computer, formatted for user-friendly display on the in-cab terminal and for use in management systems, and stored on a removable PCMCIA card for off-board delivery. Data from the PCMCIA cards are found to be complete and formatted so that they can be manipulated for use in decision making and management processes. Equipment operators give a favorable report of information provided by, and the user friendliness of, the PlowMaster in-cab display.

DISCUSSION

The following sections discuss the components, installation and operations, and performance of the PlowMaster on the prototype winter maintenance vehicles.

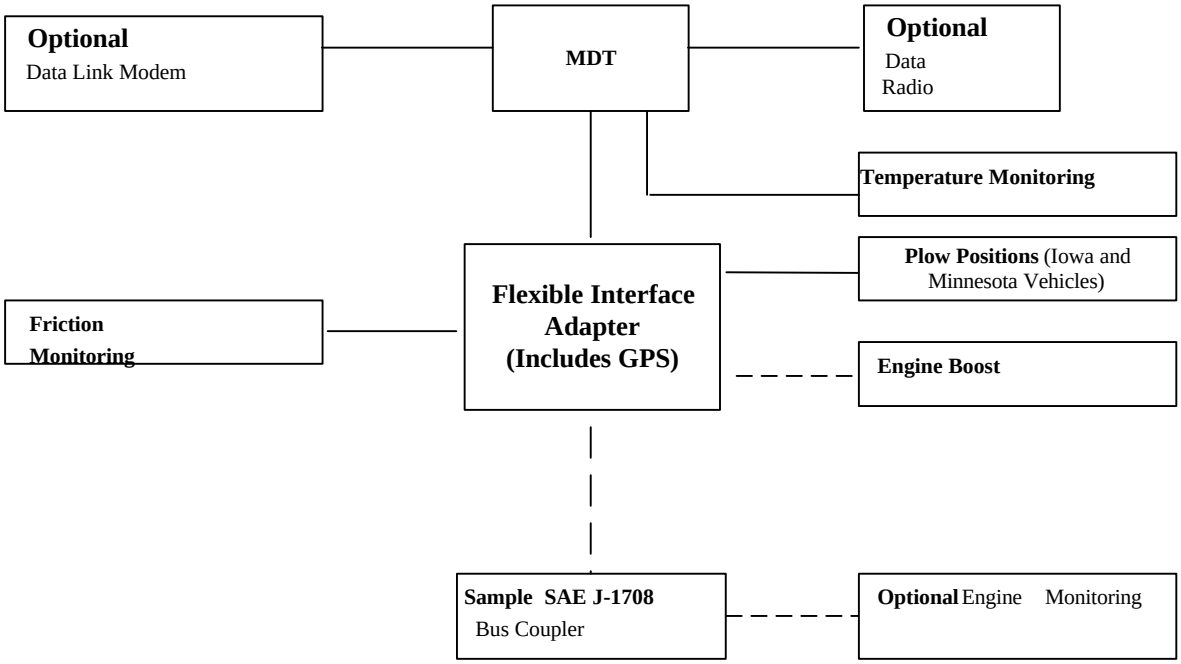

Figure 6-1 Interfaces between PlowMaster and other add-on technologies

PlowMaster Components and Installation

Table 6-1 lists PlowMaster components.

Table 6-1 Equipment supplied

Equipment Name	Vendor	Part No.
Mobile Data Terminal (MDT)	Rockwell Collins, Inc.	822-0972-004
Flexible Interface Adapter (FIA)	Rockwell Collins, Inc.	822-1125-002
FIA Terminal Adapter	Rockwell Collins, Inc.	988-5946-001
GPS Antenna (optional)	Rockwell Collins, Inc.	MA/COM pn AMP-C-114

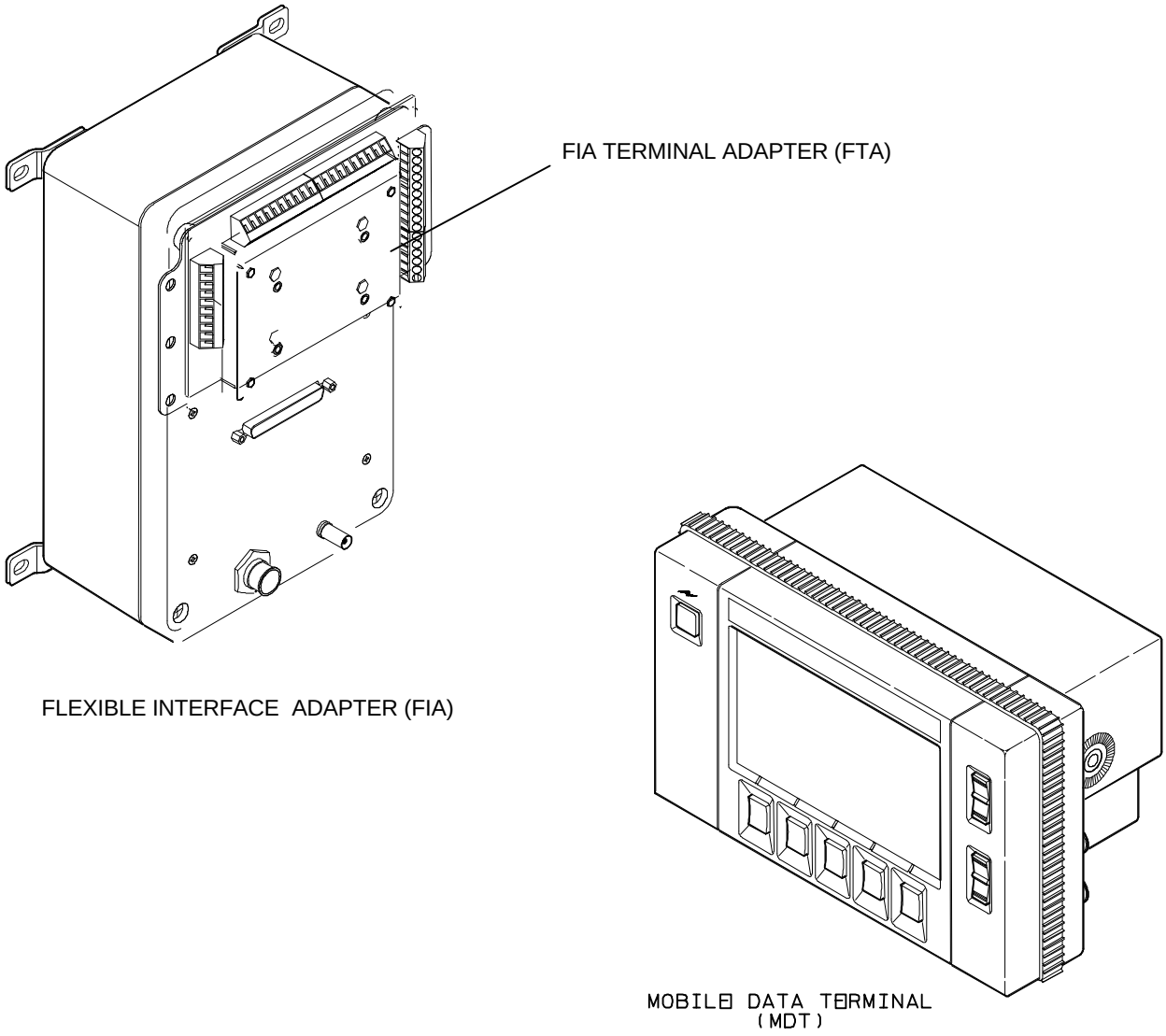

Figure 6-2 PlowMaster equipment

Flexible Interface Adapter

The FIA is the heart of the PlowMaster system**.** The FIA is a single, integrated unit containing an electrical interface to the MDT and other vehicle subsystems, a radio interface, and integral GPS receiver (engine). As shown in Figure 6-2, the FIA provides switching and control for numerous optional inputs and outputs. The GPS receiver within the FIA locates vehicles geographically as the vehicle travels on the roadway and then stamps, or codes, data collected from other systems with GPS location and time information. (The GPS antenna and receiver are discussed in detail as a separate technology in Chapter 7.)

Mobile Data Terminal

The MDT provides the human-machine interface and display in one rugged, compact package. The MDT connects to the FIA to provide all vehicle functions for the PlowMaster system. The MDT is mounted on a swivel base in the vehicle cab and is designed for maximum reliability and minimum operator workload. After experimenting with various locations for the MDT in the cab, each state installed its MDT in slightly different positions. Iowa constructed a wrap-around dash extension for the display, and Minnesota modified the swivel post mounting to a console-type mounting. The purpose of the modifications was to free as much space in the cab as possible. (See each state's in-cab configurations described in Chapter 5.)

The operator interface consists of a three-inch by six-inch, graphics-capable (128 x 240 pixel) monochromatic liquid crystal display (LCD) and 10 backlit switches for operator interaction with the system. The screen is readable in direct sunlight and is backlit for night operation. Controls are provided to vary the contrast and brightness of backlighting. The switches are used to access information by paging through information displayed on the screen.

The PlowMaster employs Intel® personal computer (PC)-based processor architecture and uses a real-time kernel to provide multitasking features. Access to vehicle systems outside of the MDT is provided by eight hardware interfaces. These interfaces include a portable PCMCIA interface, for downloading data, and an interface to the FIA. The MDT includes a Type II PC card. The PC card provides FLASH memory for the MDT and uses a 68-pin edge connector for electrical connection to the MDT. The PC card includes the PlowMaster software information. All information is stored on each PC card. This allows any vehicle to drive any route without changing the PC card.

GPS Antenna

Rockwell's optional GPS antenna was installed above the cab on the prototype vehicles during Phase II. (See a full discussion of GPS technology, including installation and performance, in Chapter 7.)

Operations: Data Collection, Formatting, and Storage

The PlowMaster collected data, or outputs, transmitted from other add-on technologies (GPS, friction meter, air/pavement temperature sensors, etc.), translated the data into a common format, and stored them on a removable PCMCIA card. These functions are illustrated in Figure 6-3. Translation was necessary because each technology had its own data format and reporting time sequence, and the formats were generally not compatible. The diagram in Figure 6-4 shows the data output of each add-on technology collected by the PlowMaster, along with the reformatted data output. Table 6-2 provides a brief definition of each data element.

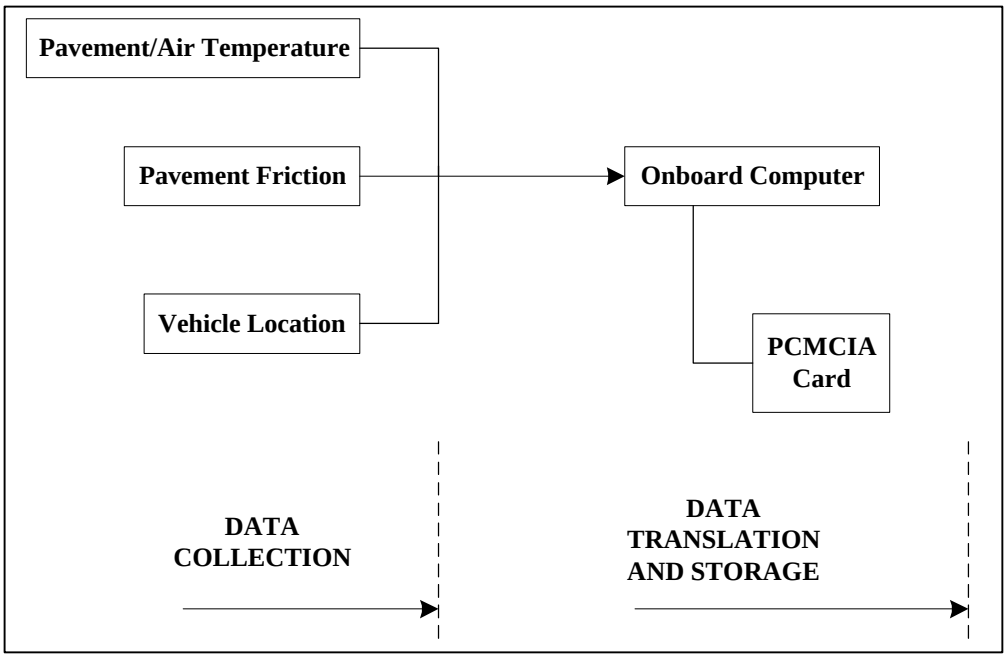

Figure 6-3 PlowMaster functions

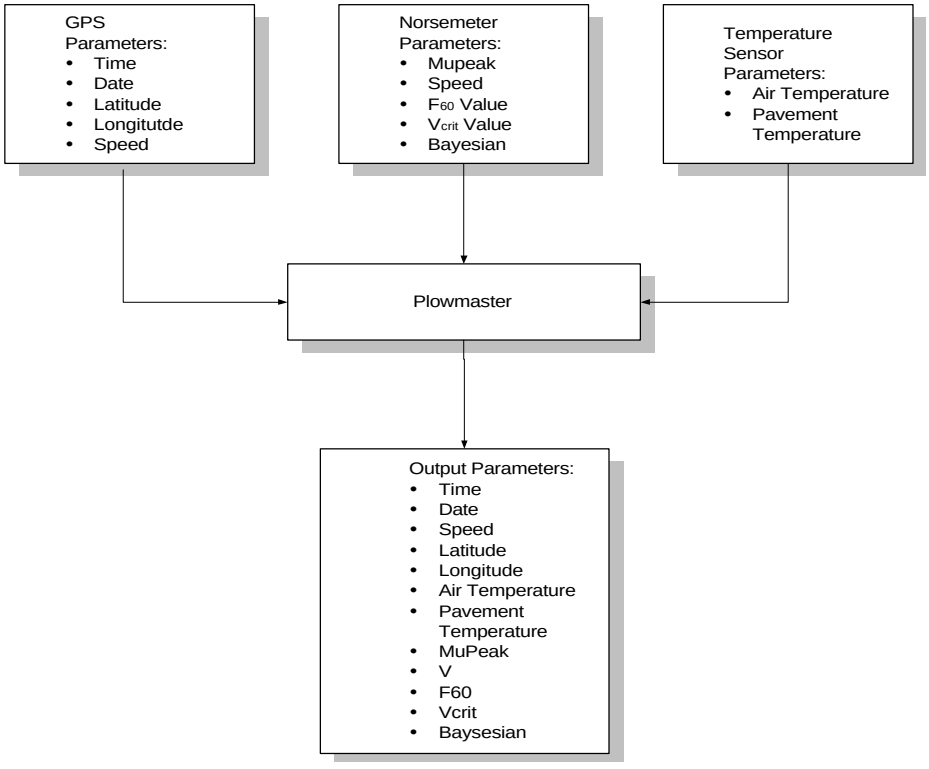

Figure 6-4 PlowMaster input/output parameters

Table 6-2 Sensor outputs

Parameter	Description
Time	Uniform Time Conversion (UTC)
Date	Date data was recorded
Latitude	GPS latitude location
Longitude	GPS longitude location
Speed	GPS speed of the vehicle in Km/h
Air Temperature	Temperature outside of the vehicle in degrees Fahrenheit
Pavement Temperature	Temperature of pavement in degrees Fahrenheit
μ_{peak}	Direct measured peak friction value
V	Slip speed, difference between the vehicle travelling speed and the tire rolling speed
C^2	Shape factor related to constant speed.
F_{60}	Measured peak friction value adjusted to a speed of 60 km/h
V_{crit}	Critical speed of vehicle at which slippage occurs
Bayesian	Statistically smoothed value for friction (averaged from several readings over a short period of time)

Tables 6-3, 6-4, and 6-5 are excerpts from data files, or sensor outputs, downloaded from the PlowMaster onboard computers, one data file for each of the prototype vehicles. The first five columns (UTC time, Lat, Lon, Heading, and GPS Speed) are GPS sensor outputs, i.e., the "GPS stamp." The next two columns (AirTemp and RoadTem) are temperature sensor outputs. The final six columns (Mu Peak, V, C2, F60, Vcrit, and Bayesian) are outputs from the friction meter sensors. Friction values recorded as "–1" indicate the sensor for that technology was not reporting at the time these data were recorded, which was early in the process verification effort. Friction values were successfully recorded at a later period in the Phase II study. . Generally, μ_{peak} is a measure of friction with a range of zero to one; the reading for μ_{peak} should therefore never be negative or more than one. PlowMaster multiplies the recorded μ_{peak} by 1,000 (to avoid fractions), creating an acceptable range for μ_{peak} up to 1,000. To obtain the actual μ_{peak} values, however, one would multiply the value shown in the table by 0.001. For example in Table 6-3, the first μ_{peak} value shown is 731. If one multiplies 731 by 0.001, the actual value for μ_{peak} is 0.731, (which is between 0 and 1). Some μ_{peak} values, however, were recorded above 1,000, indicating that the ROAR friction meter was not operating correctly.

Table 6-3 Onboard computer data file A041801.xls, Iowa vehicle, January 4, 1998

UTCTime	Lat	Lon	Heading	GpsSpeed	AirTemp	RoadTemp	MuPeak	V	C2	F60	Vcrit	Baysian
65666	41.6643169	-93.5763388	347.728	37.424	33.63	24.00	731	6647	-5871797	474	56977	717
65667	41.6644641	-93.5763818	347.613	37.446	33.63	24.00	731	6647	-5871797	474	56977	717
65668	41.6646108	-93.5764253	347.499	37.536	33.75	24.00	731	6647	-5871797	474	56977	717
65669	41.6647580	-93.5764689	347.499	37.446	33.75	24.00	731	6647	-5871797	474	56977	717
65670	41.6649047	-93.5765130	347.270	37.491	33.75	23.88	540	4068	-5871797	428	59138	670
65671	41.6650514	-93.5765560	347.671	37.312	33.75	24.63	540	4068	-5871797	428	59138	670
65672	41.6651975	-93.5765978	347.957	37.178	33.75	23.25	540	4068	-5871797	428	59138	670

Table 6-4 Onboard computer data file A141801.xls Michigan vehicle, January 14, 1998

UTCTime	Lat	Lon	Heading	GpsSpeed	AirTemp	RoadTemp	MuPeak	V	C2	F60	Vcrit	Baysian
219765	44.0059180	-85.5030835	192.170	10.133	31.25	23.88	-1	-1	-1	-1	-1	-1
219766	45.0059180	-84.5030835	193.170	11.133	32.25	24.88	-1	-1	-1	-1	-1	-1
219767	46.0059180	-83.5030835	194.170	12.133	33.25	25.88	-1	-1	-1	-1	-1	-1
219768	47.0059180	-82.5030835	195.170	13.133	34.25	26.88	-1	-1	-1	-1	-1	-1
219769	48.0059180	-81.5030835	196.170	14.133	35.25	27.88	-1	-1	-1	-1	-1	-1
219770	49.0059180	-80.5030835	197.170	15.133	36.25	28.88	-1	-1	-1	-1	-1	-1
219771	50.0059180	-79.5030835	198.170	16.133	37.25	29.88	-1	-1	-1	-1	-1	-1

Table 6-5 Onboard computer data file A13b701.xls Minnesota vehicle, February 5, 1998

UTCTime	Lat	Lon	Heading	GpsSpeed	AirTemp	RoadTemp	MuPeak	V	C2	F60	Vcrit	Baysian
417826	44.6563648	-93.6771439	242.934	42.233	26.38	19.00	680	-63	0	0	100	458
417827	44.6562875	-93.6773564	242.877	42.345	26.25	17.88	680	-63	0	0	100	458
417828	44.6562101	-93.6775690	242.934	42.256	26.25	17.63	680	-63	0	0	100	458
417829	44.6561339	-93.6777827	243.335	42.300	26.38	18.63	680	-63	0	0	100	458
417830	44.6560577	-93.6779964	243.564	42.323	26.38	17.00	680	-63	0	0	100	458
417831	44.6559821	-93.6782102	243.564	42.233	26.38	17.38	680	-63	0	0	100	458

Operations: MDT Display

In addition to collecting, translating, and storing data from other add-on technologies, the PlowMaster displayed these data in understandable formats for the vehicle operators on the MDT in-cab displays. Location data provided by the GPS were not displayed on the in-cab display; however, loss of GPS signals and information was highlighted on the MDT as an alert.

Rockwell programmed the display screens, or pages, for road maintenance operations, and the consortium states agreed which display screens to implement.. Because raw data collected by the vehicles' add-on technologies were not helpful to vehicle operators, the MDT display pages were refined during Phase II to provide information in user-friendly formats as described in this chapter. CTRE staff worked closely with equipment operators and Rockwell to fine-tune the in-cab displays, concentrating on developing easy-to-read menus and screens that presented information in convenient formats. For example, operators did not want to see friction values; they wanted to know whether roadway traction conditions were good, fair, or poor.

MDT Screen Setup

Vehicle operators access PlowMaster functions using two rocker switches and five function switches on the top right side of the MDT display, bottom right of the display, and along the bottom of the display. The switches and display screen are clearly shown in Figure 6-2. The top rocker switch selects an item on a page, and the bottom rocker switch changes the value of the selected item. Function switches across the bottom of the MDT for the main screens typically provide the following:

F1 – Setup
F2 – Temperature
F3 – Spreader
F4 – Traction
F5 – Plow status

For example, from the PlowMaster main page, pressing the function switch under the word "Temperature" (F2) changes the screen to the temperature page.

Operator Log In

Generally, before each data capture trip, vehicle operators must log in to, or initialize, the PlowMaster using the MDT toggle switches. The typical log-in procedure associates the operator with the assigned route to be driven and ensures the operator is authorized to access the vehicle. When the vehicle is started, the MDT prompts the operator to enter a driver identification number and the assigned route identification. Once the correct data are entered, the system automatically moves to the main page. If power is removed from the MDT after the driver is logged in and later restored, the MDT will return to the main page and automatically log in the operator to the same assigned route. However, if the run switch is turned off while the driver is logged in, the MDT logs off automatically.

If the vehicle system detects the vehicle has moved more than 1,000 feet prior to log-in completion, the operator is prompted by the MDT to complete the log-in procedure. After real-time communications have been implemented, if a vehicle continues to move more than 2,000 feet prior to operator log-in, the dispatcher/base station will be advised of a possible theft. When another operator assumes control of the vehicle, the initial operator must log out of the system and the new operator must enter the proper driver ID. The MDT maintains the previously entered route identification numbers.

Main Page

Figure 6-6 shows the MDT's main page.

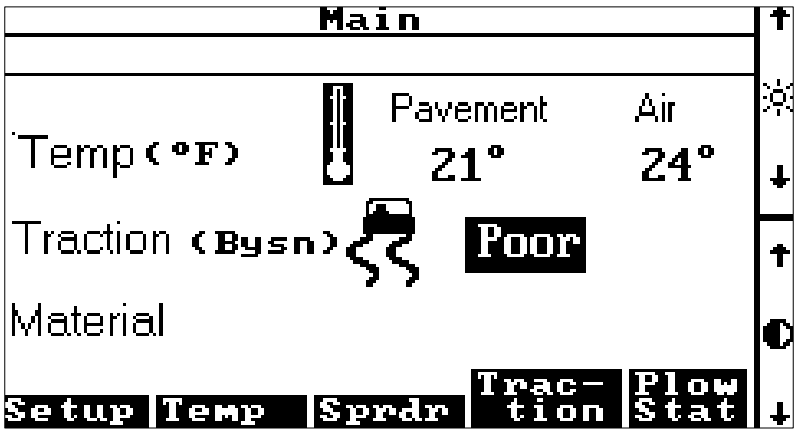

Figure 6-6 Typical main page

The main page of the PlowMaster displays current data collected through the operational sensors. When the light bulb and the half-blackened circle are displayed on the right side of the page, the top rocker switch on the right of the screen controls the brightness and the bottom rocker switch controls the contrast of the MDT display. The line under the title "Main" at the top of the page is called the advisory line. Advisories appearing on this line and the appropriate corresponding maintenance action are listed Table 6-6.

On the main page, both pavement and air temperatures are presented in degrees Fahrenheit. The thermometer icon to the left of the temperature indicators appears when a condition degrades to poor or falls below settings established by a supervisor as fair. The icon flashes to attract the attention of the vehicle operator and remains flashing for 45 seconds after first appearing.

The main page also displays road traction conditions. The conditions are calculated as friction coefficients, using data collected through the friction meter sensors. These coefficients are generally meaningless to operators, however, so Rockwell programmed the PlowMaster to translate the coefficients into good, fair, or poor, based on operator settings. When roadway surface traction conditions degrade to poor (i.e., fall below the setting established as fair), the slippery icon (Manual of Uniform Traffic Control Devices W8-5) to the left of the traction indicator, along with the word "Poor," appears on the screen. The icon flashes for 45 seconds.

The last row of data is reserved for identification of chemical materials used in road maintenance application. These data were not provided by the PlowMaster in Phase II.

Table 6-6 Maintenance advisory messages

Advisory	Maintenance Action Required
Log-in Required	None; operator must log in before beginning route
Insert Data Card	Ensure PCMCIA card is inserted into MDT
Data Card Full	Ensure empty PCMCIA card is inserted into MDT
Software Load Failed	MDT reprogramming was unsuccessful
Software Loaded, Resetting	None
Loading MDT Software	None
Check Receiver Connection	Check GPS receiver for secure connection
Check Diff Connection	Check GPS engine (receiver) for secure connection
Speed Too Slow for Logging	Increase vehicle speed
Check NorseMeter	Check Norsemeter for secure connection
Check RoadWatch Connection	Check Norsemeter for secure connection
Check Data Link	Check Norsemeter for secure connection
Data Card Load	None
Check GPS Antenna	Check GPS antenna for secure connection
Receiver Searching for Sats	None
Check Differential Source	None; suggest moving vehicle 400 feet
Poor Satellite Geometry	None; suggest moving vehicle 400 feet
Old Correction Data	None; suggest moving vehicle 400 feet
Receiver Position Degraded	None; suggest moving vehicle 400 feet
Receiver Position Obtained	None

Temperature Page

Pressing setup (F1) from the main page selects the maintenance page. This page was not intended to be operational during Phase II.

Pressing F2 from the main page accesses the temperature page. Refer to Figure 6-7.

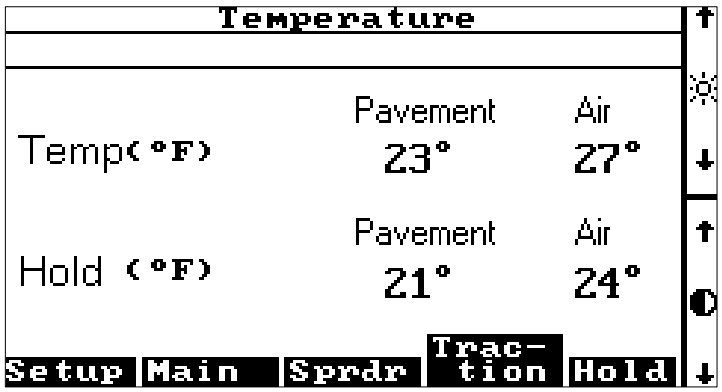

Figure 6-7 Temperature page

On the temperature page, notice the F2 switch now selects the main page. Pressing F2 from the temperature page returns the operator to the previous page, or main page.

The temperature page contains an advisory line (the line is blank in Figure 6-7) directly under the title of the page. For a listing of advisories, refer to Table 6-6.

Pavement and air temperatures are displayed in the top half of the screen. Had a trend been established from these changing values, an up or down pointing arrow indicator (↑) or (↓) would have appeared adjacent to the temperature readings indicating the direction of the trend. Temperature trends are established through the temperature setup display; see the next section.

The bottom half of the screen indicates the pavement and air temperatures when the operator pressed the Hold (F5) switch. The purpose of the hold function is to save a record of temperature readings at a specific time and location. At a later time or during a return run, the operator can compare current temperatures against temperatures held in hold.

From this screen, the operator may access the temperature setup page (F1), return to the main screen (F2), continue to the spreader page (F3) or traction page (F4), or press F5 to hold another set of pavement and air temperatures.

Temperature Setup Page

Pressing F1 from the temperature page accesses the temperature setup page. Refer to Figure 6-8.

The temperature setup page contains an advisory line directly under the title of the page, which is currently blank. For a listing of advisories, refer to Table 6-6.

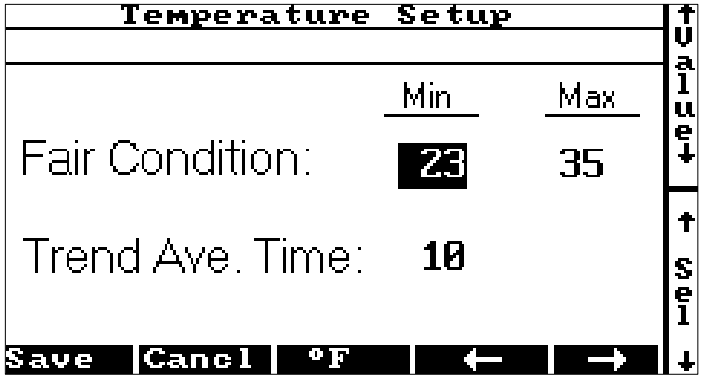

Figure 6-8 Temperature setup page

The top portion of the temperature setup page displays minimum and maximum temperature settings that define fair temperature conditions. The study team set the value for the fair condition during the June 24, 1997 meeting held in Cedar Rapids, at the Rockwell complex. Generally, the range for fair is from 32° F (below 32° F, the condition is poor) to 35° F; however, a 35° F temperature that is dropping quickly also changes to a poor temperature condition.

The bottom portion of the page displays the length of time, in seconds, for which PlowMaster will average temperatures to define trends. Pressing the bottom rocker switch moves the cursor between these two sections of the setup page. Pressing the top rocker switch increases or decreases the value selected. Switches F4 and F5 move the cursor left or right across the screen.

PlowMaster averages the temperatures recorded over the time set on this screen and compares the average with the previous average, then displays the arrow trend indicator on the temperature page to show if temperatures are generally rising or falling. When the temperature drops below the maximum fair condition, the advisory icon thermometer appears on the main page, indicating a fair to poor condition exists. When temperatures rise above the maximum fair condition, the advisory icon disappears, indicating a good condition exists.

Pressing F1 saves the information selected on this page and returns to the temperature page.

Pressing F2 cancels the information selected, reverting the system to previous information selected on this screen, and automatically returns to the temperature page.

Pressing F3 toggles between degrees Fahrenheit and Celsius.

Spreader Page

Pressing F3 from the main page accesses the spreader page. See Figure 6-9.

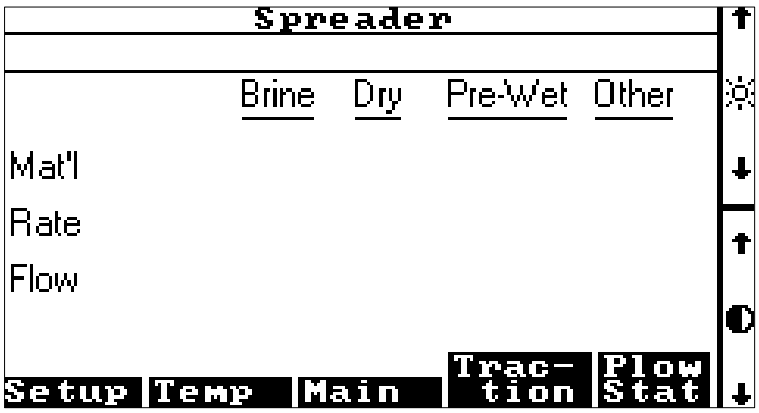

Figure 6-9 Spreader page

Although it was not implemented in Phase II, the spreader page can provide information about ice and snow control materials, their dispersal rate, and flow preparedness. These materials might include salt brine, dry and pre-wet chemicals, and a category designated for other agents used in road maintenance. Pages available from the spreader page are the spreader setup page (F1), temperature (F2), main (F3), traction (F4), and plow position status (F5).

Friction Monitor Page

Pressing F4 from the main page accesses the friction monitor page. Refer to Figure 6-10.

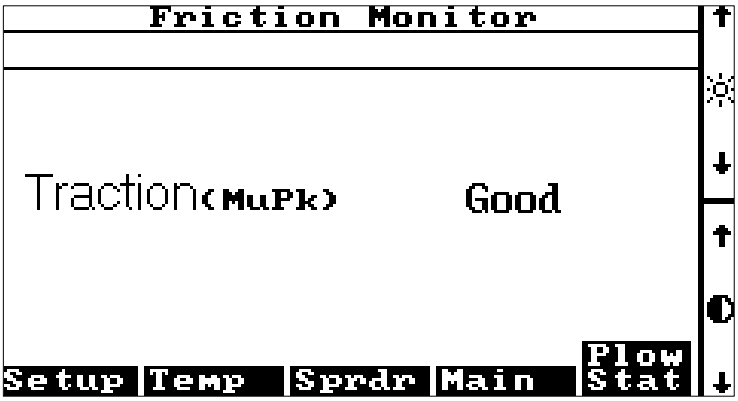

Figure 6-10 Friction monitor page

The friction monitor page contains an advisory line directly under the title of the page, currently blank. For a listing of advisories, refer to Table 6-6.

The friction monitor page displays road condition information based on the amount of traction the vehicle wheels have on the pavement. Traction is evaluated using a friction coefficient of μ_{peak}, F60, or Bayesian, which is selected from the friction meter setup page (F1); see the next section. The condition is evaluated in terms of good, fair, or poor. When the traction drops below the minimum fair condition, an advisory icon (Manual on Uniform Traffic Control Devices W8-5, "slippery when wet") appears on the main page, indicating a poor condition exists. When traction rises above the minimum fair condition, the advisory icon disappears indicating a fair condition exists and the friction monitor page displays a fair condition. Pages available from the friction monitor page are the friction meter setup (F1), temperature (F2), spreader (F3), main (F4), and plow position status (F5).

Friction Meter Setup Page

Pressing F1 from the friction monitor page accesses the friction meter setup page. Refer to Figure 6-11.

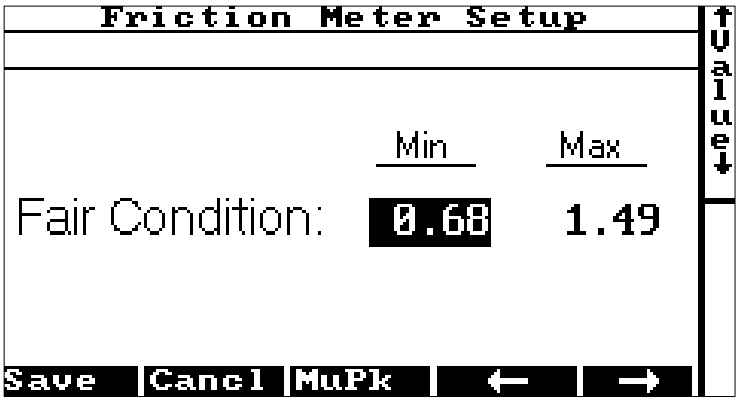

Figure 6-11 Friction meter setup page

The friction meter setup page contains an advisory line directly under the title of the page, currently blank. For a listing of the advisories, refer to Table 6-6.

Using data collected by the friction meter, PlowMaster stores friction conditions as a Bayesian, μ_{peak}, or F60 coefficient. μ_{peak} is the standard coefficient for friction. F60 is the result of the μ_{peak} coefficient at 60 kilometers per hour. The Bayesian coefficient is the calculation for friction based on a composite of averages represented as a nonlinear function. The friction setup page contains minimum and maximum coefficients of friction selected by the study team to define a fair traction condition.

At the June 24, 1997 meeting at Rockwell in Cedar Rapids, Iowa, the study team reviewed criteria used by traffic engineers to determine when wet pavement sections are slick enough to require posting special signs. The team set the default average μ_{peak} range for a fair traction

condition at 0.26 – 0.35. If average μ_{peak} falls below .26, the display shows poor traction conditions; if average μ_{peak} is above .35, the display shows good traction conditions. It should be noted that this range of values for fair traction conditions applies to wet pavements, not to ice- or snow-covered pavements. During Phase III, the study team will consult the Federal Highway Administration's *Test and Evaluation Project No. 28: Anti-icing Technology, Field Evaluation Report* and other ongoing research across the country regarding winter roadway traction conditions and, based on their findings, will adjust the default fair traction range to reflect winter roadway conditions.

Pressing the top rocker switch increases or decreases the "fair" values selected. Switches F4 and F5 move the cursor left or right across the screen. Pressing F1 saves the information selected on this screen and returns to the friction monitor page. Pressing F2 cancels the information selected, reverting the system to previous information selected on this screen, and returns to the friction monitor page. Pressing F3 toggles between μ-peak, F60, or Baysian friction coefficients.

Plow Status Page

Pressing F5 from the main page accesses the plow status page. Refer to Figure 6-12.

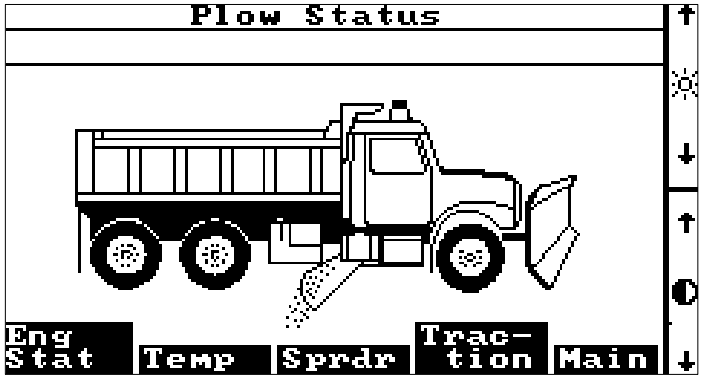

Figure 6-12 Plow status page

The plow status page contains an advisory line directly under the title of the page, currently blank. For a listing of advisories, refer to Table 6-6.

When visibility is poor, operators often cannot see if the plow blades are engaged. The plow status page gives the operator a quick graphical representation of the three plows (front, carriage, and wing) in service and activated. Active plows appear on the screen; unengaged plows do not appear on the screen. In Figure 6-12, the front and carriage plows are active. In Figure 6-13, all three plows are active (front, carriage, and wing). Pages available from the plow status page are the engine status page (F1), temperature (F2), spreader (F3), traction (F4), and main page (F5).

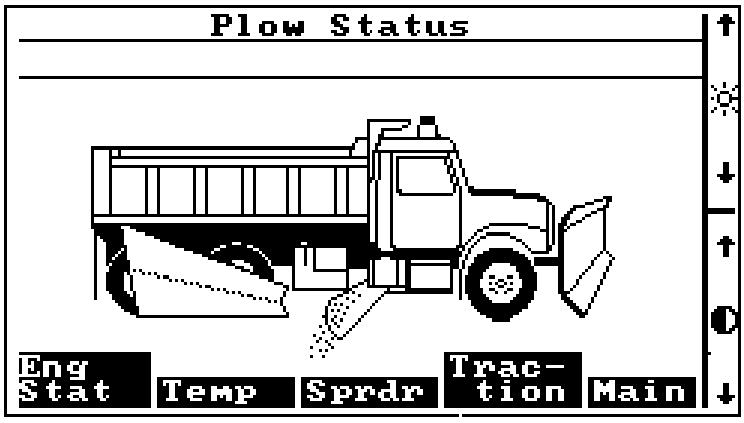

Figure 6-13 Full plow status page

Engine Status Page

Pressing F1 on the plow status page in Figures 6-9 or 6-10 accesses the engine status page. Refer to Figure 6-14.

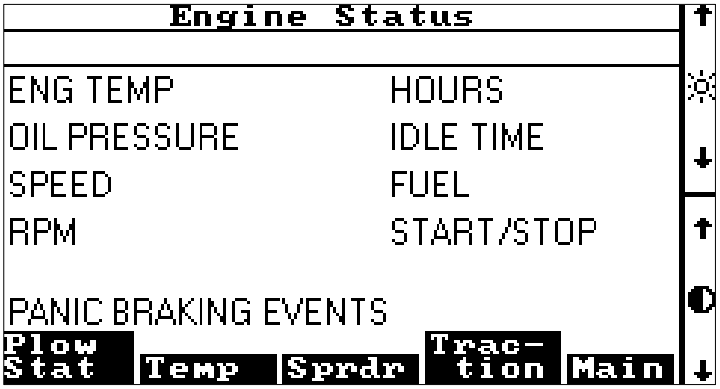

Figure 6-14 Engine status page

The engine status page, which was not implemented in Phase II, can provide information about engine maintenance and current data indicating engine performance: engine temperature, oil pressure, speed, revolutions per minute, hours of operation, idle time of operation, fuel level, and number of starts and stops. Engine status functionality, with software apparatus and sensor

interface, is currently under development. Pages available from the engine status page are the plow status page (F1), temperature (F2), spreader (F3), traction (F4), and main (F5).

Log-Out Procedures

At the end of the shift, the operator logs off the MDT. To log off, the operator repeatedly presses a function switch until F2 displays LOG OUT. The operator presses F2, and the screen returns to the log-in page. The values for driver ID, and route designation remain. A new driver on the route needs to change only the driver ID.

When the vehicle is shut off, the MDT remains on for a length of time determined by supervisor dispatch. This allows the operator to log off the MDT after the vehicle is shut off. It also prevents loss of MDT data in case of a temporary shutdown on the road and allows dispatch to communicate with the MDT after the end of a road maintenance run.

If the vehicle is off long enough while en route for the MDT to shut itself off, the route designation and driver ID, odometer readings, disabled mechanical alarms, etc., are lost. The driver ID and route must be reentered when the vehicle is started.

Performance

Based on data downloaded from the PlowMaster computers and collected at CTRE, the PlowMaster successfully collected outputs from other add-on technologies on the prototype vehicles, translated them into a common format, and stored them on PCMCIA cards. Missing or inaccurate data were generally traced to operator error or sensor malfunction rather than to problems with PlowMaster performance.

The PCMCIA card was generally an effective method for delivering data to CTRE. However, the only significant system malfunction traced to a PlowMaster computer program involved a failure to download data to the card. Data could not be downloaded because, during the data capture trip, the vehicle operator had shut down the system before logging out. Rockwell developed a software solution that allows the operator to log off the MDT after the vehicle has been shut down.

Because of the time lag between recording the sensor outputs on the Rockwell onboard computer and delivering data to CTRE, the PCMCIA card is not the most effective method of data transfer for supporting decision-making processes. In fact, lack of timely data after 1997-1998 winter storms made it impossible for CTRE to prove the concept that winter friction data can be collected by friction-measuring devices on a maintenance vehicle. See Chapter 8 for details. To be truly effective for roadway maintenance decision making, data must be analyzed in "real time," that is, as data are collected by the sensors. The study team is investigating the feasibility of using cellular data links and, eventually, existing DOT radio networks for real-time data communications in Phase III. PlowMaster will also provide the interface for real-time communications.

Based on feedback from vehicle operators, described more fully in Chapter 15, the in-cab displays, as modified by Rockwell for road maintenance operations, were easy to view and use

without distracting the operators from their driving and maintenance tasks. The information presented on the displays was user friendly.

OBSERVATIONS

Proof of concept was successful; the Plowmaster supplied by Rockwell was successfully installed and worked as expected, proving that a central, onboard data collection and management system is possible on winter maintenance vehicles. Data were collected from the sensors, recorded, translated into common formats, and displayed on the MDT. Operators generally found the displays easy to read and operate.

In Phase II, data collected by vehicle sensors were stored on the MDT's removable PCMCIA card for transfer to CTRE. The study team's plan for Phase III is to implement real-time cellular communications as an interim step toward radio data communications. The MDT provides an RS232 interface to the in-circuit switched cellular mode of the MP205/210 modems. In Phase III, the modems will provide communications over an AMPS cellular network offering up to 14,400 bits per second (bps) using CCITT group V.32bis specifications. Practical limitations of the cellular network typically limit the maximum data rate to 9,600 bps.

With real-time data communications, the following trip events will trigger data transmission by the PlowMaster once every mile or every two minutes, whichever occurs first. If none of these events occurs, data transmission is every 10 minutes or five miles, whichever comes first.

- Friction degrading from good, to fair, to poor
- Temperature degrading from good, to fair, to poor
- Direction change greater than 45 degrees

Cellular data link information collected in the PlowMaster database and transferred during an event operation will include the following minimum, maximum, and average values:

- Bayesian friction
- F60 friction
- μ_{peak}
- Air temperature
- Pavement temperature

If costs are feasible, a digital data communications link may be activated via the DOT statewide radio network during Phase IV, fleet evaluation. At that time, the vehicle's mobile radio, mobile antenna, and handset will be implemented with the PlowMaster for data communications. When equipped with digital data communications capabilities, the PlowMaster will support 4,800- to 9,600 bits per second (bps) data transfer. The radio is typically configured

with one channel for voice communication and one channel for data communication. The FIA will switch the radio between voice and data channels as required.