WEIGH-IN-MOTION POCKET GUIDE

PART 2

WIM SITE SELECTION, DESIGN, AND INSTALLATION GUIDE

U.S. Department of Transportation
Federal Highway Administration
Office of Highway Policy Information

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NOTICE

QUALITY ASSURANCE STATEMENT

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AASHTO	American Association of State Highway and Transportation Officials
AC	Asphalt concrete
ACF	Axle Correction Factor
ALDF	Axle Load Distribution Factors
APT	Axles per Truck
B-WIM	Bridge WIM
BP	Bending plate
CDS	Comparison data set
CPU	Central Processing Unit
DC	Direct Current
DOT	Department of Transportation
DOW	Day of the week
ESAL	Equivalent single axle loadings
FHWA	Federal Highways Administration
GFCI	Ground-Fault Circuit Interrupter
GPS	Global Positioning System
GVW	Gross Vehicle Weight
HDF	Hourly Distribution Factor
HOD	Hour of the day
IRI	International Roughness Index
LC	Load cell
LPR	License plate reader
LTPP	Long-Term Pavement Performance
MAF	Monthly Adjustment Factors
MEPDG	Mechanistic-Empirical Pavement Design Guide
MOT	Maintenance of traffic
MOY	Month of the year
MUTCD	Manual for Uniform Traffic Control Devices
NCR	Non-Compliance Report
NEMA	National Electrical Manufacturers Association
OWL	Optimal WIM Locator
PCC	Portland cement concrete
PPE	Personal protection equipment
PV	Photovoltaic

PVC	Polyvinyl Chloride
PVF	Per Vehicle Format
QA	Quality assurance
QC	Quality control
RMC	Rigid metal conduit
SIM	Subscriber identity module
SPS	Special Pavement Studies
TMG	Traffic Monitoring Guide
TMAS	Travel Monitoring Analysis System
TPF	Transportation Pooled Fund
U.S.	United States
UL	Underwriters Laboratories
VCD	Vehicle Class Distribution
VWS	Virtual Weigh Station
WIM	Weigh-in-Motion

INTRODUCTION TO PART 2

Overview

The Federal Highway Administration (FHWA) Weigh-In-Motion (WIM) Pocket Guide consists of three main text documents, four instructional video supplements, and six appendices. The video supplements and appendices are only available on the FHWA website: https://www.fhwa.dot.gov/policyinformation/knowledgecenter. Part 1 of the Guide includes a description of each element of the FHWA WIM Pocket Guide. Part 2 was developed to assist a WIM/traffic engineer or senior WIM specialist with site-level decision making, including the meticulous selection of the WIM site location, development of WIM system installation plans, and WIM system installation oversight.

WIM Standards and Performance Requirements

The ASTM International E1318-09 *Standard Specification for Highway Weigh-In-Motion (WIM) Systems with User Requirements and Test Methods* is a primary WIM standard accepted in the U.S. *(1)*. Other countries have their own standards *(2, 3)*. The ASTM E1318-09 standard classifies WIM systems according to four distinct types, depending on the application and functional performance requirements.

Table 1 summarizes the ASTM E1318-09 WIM system performance requirements. The 95 percent compliance defined in ASTM E1318-09 specifies the minimum percentage of measurements (i.e., no less than 95 percent) that should be within the specified tolerances to satisfy the performance requirements. Since Type IV WIM systems have not yet been approved for use in the United States, specifications for these systems are not provided.

ASTM E1318-09 WIM Types

- **Type I and Type II systems:** Suitable for traffic data collection purposes, with Type I systems having slightly more stringent performance requirements. Vehicle speed range to meet functional performance requirements is 10 to 80 mph.
- **Type III systems:** Suitable for screening vehicles suspected of weight limit or load limit violations and have stricter functional performance requirements than Type I and Type II systems. Vehicle speed range to meet functional performance requirements is 10 to 80 mph.
- **Type IV systems:** Not approved for use in the United States but intended for use at weight enforcement stations. Vehicle speed range to meet functional performance requirements is 2 to 10 mph.

Table 1 – ASTM 1318E-09 Functional Performance Requirements for WIM Systems

Function	Tolerance for 95% Compliance		
	Type I	Type II	Type III
Wheel Load*	±25%		±20%
Axle Load	±20%	±30%	±15%
Axle-Group Load	±15%	±20%	±10%
Gross Vehicle Weight	±10%	±15%	±6%
Speed	±1 mph		
Axle-Spacing and Wheelbase	±0.5 ft		

*Includes single or dual tires

Enhanced WIM performance requirements were developed under the FHWA Long-Term Pavement Performance (LTPP) Program in an effort to collect research-quality WIM data *(4).* LTPP tolerances are the same as in ASTM E1318-09, but instead of 95 percent compliance, LTPP uses a statistically computed 95 percent confidence interval plus mean error to characterize the spread of measurement error and compares it with the tolerances listed in Table 1. The LTPP performance requirements include provisions for performance testing at three temperature and three speed ranges, requirements for road smoothness, and requirements for the accuracy of the vehicle length measurements.

WIM SITE SELECTION

Site Selection Considerations

WIM sensors should be installed within a desired road segment at a location that would minimize weighing errors due to adverse site characteristics. Certain site characteristics must be avoided, as their effect on measurement accuracy cannot be controlled through equipment calibration or maintenance. The most important aspects to consider when evaluating a candidate WIM site include:

- Roadway geometrics that may introduce adverse truck dynamics, such as bouncing, side-to side rocking, swerving, acceleration, or deceleration. To avoid this, special attention should be paid to horizontal curvature, grade, cross slope, lane width and markings, nearby bridges and ramps, and speed and exit signs.
- The following traffic conditions should be avoided: stop-and-go traffic, lane-changing, passing, signalization and intersections, lane shifts, exit lanes, and vehicle velocity changes.
- Weak pavement structures and thin pavements should be avoided, along with rough pavement surfaces and pavements that show surface distresses like cracking, rutting, raveling, joint faulting, and potholes.

When selecting a site for new WIM installation, additional factors to consider include:

- Availability of power and communications (cellular, fiber optic, or landline service)
- Technician safety
- Cabinet location
- Drainage and existing equipment

- Test truck turnarounds
- Anticipated roadway work within the next 5 years

Detailed criteria and processes for WIM site selection are provided in the ensuing sections.

WIM Installation Site Selection Process Overview

The WIM site selection process consists of two parts. Part 1 involves a preliminary WIM site selection using information available in the office. Part 2 involves field verification and confirmation of the conditions at the potential WIM site locations and the final selection of the preferred site for the WIM system installation.

The following sections describe a sequence of steps involved in the WIM site selection process. Action items are identified using the checkmark (✓) icon.

Preliminary Off-Site WIM Site Selection

Preliminary WIM site selection is often accomplished remotely, typically in the office, using all available supporting documentation and data. The entire roadway segment, or corridor, selected to meet traffic data needs must be evaluated to ensure that it meets the ASTM E1318-09 requirements for horizontal alignment and for structure.

The goal of the preliminary site selection is to identify roadway sections of no less than ½ mile in length that are acceptable for a WIM installation, using the criteria described below.

Horizontal Curvature and Grade

According to ASTM E1318-09, the horizontal curvature of the roadway lane for 200 feet prior to and 100 feet beyond the WIM sensors shall have a radius not less than 5,700 feet measured along the centerline of the roadway. The vertical grade should be no more than 2 percent for ASTM E1318-09 WIM Types I, II, and II and 1 percent for Type IV.

- ✓ Review the available roadway construction plans to determine the horizontal curvature and the vertical grade of a proposed roadway segment and record findings.

Pavement Structure

Adequate pavement structure is needed to accommodate the WIM system sensors throughout their service life. The expected longevity of pavement structure and the ability of the agency to maintain the pavement within the WIM scale section should be evaluated based on current pavement condition and planned maintenance activities.

Bending plate and load cell sensors should only be installed in portland cement concrete (PCC) pavements. Strip-type sensors such as a polymer piezo, coaxial piezo, quartz piezo, or strain gauge strip sensors could be installed in either PCC or asphalt concrete (AC) pavement.

AC pavements should be relatively stiff with adequate AC thickness to prevent sensor depths from achieving 75 percent of the total depth of the AC layer. The AC pavement thickness should be no less than 4 inches, to prevent breaking of the structural pavement layer (i.e., cracking through the asphalt layer). A top layer consisting of a high performance pavement mix of 1.5 to 2 inches in thickness is preferred. Roadways utilizing a slurry top coat would significantly reduce the life of a project and should not be considered acceptable under normal conditions. Pavements experiencing significant changes in pavement stiffness due to environmental effects may contribute to weighing errors. Softening of the AC layer during hot months or weakening of the subgrade during spring thaws could affect the performance of piezo sensors due to changes in the structural support that the pavement provides for the sensor.

A section of continuously reinforced concrete pavement of sufficient length, based on the formula below, is preferred for WIM installations in PCC pavements. For typical highway speeds, the slab length should be 300 to 400 feet, which includes 75 feet required after the sensors.

Slab length in ft =2.93(Truck Speed in mph) + 150*

When a jointed PCC pavement is constructed without dowels, slab curling and warping could contribute to vehicle dynamics and reduce the accuracy of weight measurements due to the excessive dynamic forces being measured by the sensors. Pavement joints may also contribute to road roughness.

WIM sensor installations in smooth PCC pavement have longer periods of time between failures than installations in flexible pavements. PCC pavements are not susceptible to rutting caused by truck loading.

- ✓ Request from the pavement design or management office information about pavement structure, pavement surface condition data, and road roughness.
- ✓ Record pavement type, pavement thickness, and road condition information.

Pavement Smoothness

The pavement surface should be smooth and free of medium- and high-severity distresses to ensure the integrity of the WIM sensor installation throughout its service life. The ideal roadway segment would have smooth pavement, or the proposed WIM site should be part of a new roadway construction or pavement rehabilitation plan. Future repaving should not be anticipated or planned for the next 5 years.

The candidate WIM sensor installation roadway section must meet the smoothness requirements specified in section 6.1.5 of ASTM E1318-09 *(1).* Pavement smoothness assessment based on the ASTM E1318-09 criteria is performed during the on-site evaluation, described later in this guide.

Preliminary pavement smoothness analysis may be accomplished in the office using American Association of State Highway and Transportation Officials (AASHTO) M331-13, Standard Specification for Smoothness of Pavement in Weigh-in-Motion (WIM) Systems *(5)*. This analysis uses the profile data (collected with a high-speed profiler) and the Optimal WIM Locator (OWL) module of the Pro-Val profile data analysis software. The OWL software uses pavement profile information to identify optimal WIM sensor locations. WIM site planners must note that OWL does not consider the type of sensor array or the sensor type and may be overly conservative for bending plate or load cell arrays. Both ProVAL and the OWL modules are free. Information on ProVAL and the OWL module can be obtained through the LTPP Customer Support Service Center.

When all WIM scale roughness indices calculated from the pavement profile records are less than the lower threshold indicated in AASHTO M331-13, it is likely that the WIM site will produce an acceptable level of weighing error for a selected sensor type. The upper threshold value provided in AASHTO M331-13 is that above which a WIM site is likely to produce an unacceptable level of weighing error. A location should be chosen that will result in acceptable index values.

According to AASHTO M331-13, an acceptable WIM scale roughness index value is required for a minimum of 131 feet prior to the chosen location.

- ✓ Use the OWL module of the Pro-Val software to compute WIM scale roughness index and compare it against threshold values provided in AASHTO M331-13.
- ✓ If the pavement condition is found to be unsuitable for WIM installation, consider grinding the pavement or applying a thin overlay to reduce roughness. If pavement improvement is not feasible, search for a different location that would meet the users' needs and would be favorable for accurate weighing in motion.
- ✓ Record findings.

Test Truck Turnarounds

The test truck turnarounds should be close enough to enable testing to be completed in 1 or 2 days. A turnaround (one loop of the test vehicle) that takes 20 minutes or less to complete is recommended. Reducing test turnaround time makes more efficient use of time for WIM validation or calibration.

- ✓ Use online mapping tools to find the optimal locations for test truck turnarounds for the WIM site.
- ✓ Use video logs or virtual drive software to identify roadside features and roadway characteristics, potential turnarounds, and relative pavement condition near the potential WIM site location.

On-Site Evaluation of Proposed WIM Location

After one or more acceptable WIM sensor locations have been identified through the off-site data assessment, on-site investigation must be performed by a trained WIM specialist using this manual and the ASTM E1318-09 criteria to complete the assessment. Figure 1 is a photo of a site identified as acceptable.

- ✓ Safety personal protection equipment (PPE) should be worn, including hard hat and safety vest.
- ✓ A spotter should watch traffic and warn the inspector of any oncoming vehicles.
- ✓ Appropriate lane closure maintenance of traffic (MOT) devices should be installed in accordance with the Manual on Uniform Traffic Control Devices (MUTCD) *(6)*.

Figure 1 – Acceptable Pavement Section for WIM

Longitudinal Alignment (Roadway Grade)

To avoid adverse driver behaviors, including braking and acceleration, the longitudinal gradient (roadway grade) of the road surface for 200 feet in advance and 100 feet beyond the WIM sensors shall not exceed 2 percent, per ASTM E1318-09. The following procedure is recommended:

1. Place a 16-foot straightedge in the center of the lane, parallel with the pavement markings. A digital level is then placed on top of the straightedge and the angle is measured and converted into gradient and then to slope as a percentage.
2. Use the following mathematical procedure to convert the angle to percent slope:
   - Calculate the tangent function of the angle with your calculator. For this example, the tangent of 2 degrees equals approximately 0.03492. This is the slope as a gradient.
   - Multiply the gradient by 100 on your calculator to obtain the percentage of the slope. For this example, multiplying 0.03492 by 100 equals 3.5 percent.

3. Repeat this process every 50 feet until the entire 300-foot section has been tested. Any result over 2 percent is a failure of the test.
4. Record the findings.

Lateral Alignment (Transverse Slope of Roadway or Cross Slope)

To avoid adverse driver behaviors, including veering and lane wander, and to ensure balanced truck loads, the cross slope (lateral slope) of the road surface for 200 feet in advance and 100 feet beyond the WIM sensors shall not exceed 3 percent for Type I and Type II WIM systems and 1 percent for Type III systems, per ASTM E1318-09. To check the roadway slope:

1. Position a 10-inch or 24-inch digital level on top of a 10-foot straightedge, placed laterally in the travel lane near the proposed sensor location to measure the cross-slope of the roadway.
2. Use the following mathematical procedure to convert the angle to percent slope:
    - Calculate the tangent function of the angle with your calculator. For this example, the tangent of 2 degrees equals approximately 0.03492. This is the slope as a gradient.
    - Multiply the gradient by 100 on your calculator to obtain the percentage of the slope. For this example, multiplying 0.03492 by 100 equals 3.5 percent.
3. Repeat this process every 50 feet until the entire 300-foot section has been tested. Any result over 2 percent is a failure of the test.
4. Record the findings

Lane Width and Markings

To properly install the WIM sensors, the travel lanes for the proposed WIM site must be wide enough to ensure proper layout of the weighing sensors and sufficient spacing between the inductive loops.

The lane width for WIM sensor installations must be at least 10 feet, and between 12 and 14 feet is optimal. The lanes must be clearly marked with painted lines, 4 inches to 6 inches in width, throughout the WIM section.

To measure lane width and markings:

1. Use measuring tape to measure the lane and shoulder widths and the width of the pavement markings
2. Record measurements and condition of the markings.

Traffic Composition and Traffic Flow Characteristics

If no site-specific traffic volume, vehicle classification, and speed data are available during the preliminary investigation phase, conduct a portable traffic volume, vehicle classification, and vehicle speed count to obtain detailed hourly and day of week truck volumes and speed information. Minimum count duration is 48 hours. Seven-day count studies may be required for some locations that have traffic flow issues on weekends (retail, recreational, etc.). Collected truck volume data will be used to develop an initial calibration plan and possible auto calibration plan if needed.

The WIM systems should be in an area of free traffic flow with good sight distances, including:

- No stop-and-go traffic
- Minimal lane-changing
- Minimal passing
- Constant vehicle velocities

If poor traffic flow is identified from the data or video log review, the site may be excluded from further consideration.

To assess traffic composition and traffic flow characteristics while on site:

1. Find a safe location that could be used for an extended period of time (minimum of 3 to 4 hours).

2. Evaluate the traffic conditions when the highest volume of traffic is anticipated, such as during rush hour.
3. Measure and record the distances to all intersections and signalization within the road segment.
4. Measure and record distances to nearby roadway assets.
5. Record any presence and frequency of stop-and-go traffic, lane-changing, and vehicles passing.
6. Depending on site characteristics, conduct 48-hour or 7-day traffic volume, vehicle classification count, and speed data collection. Compute hourly and day of week truck volumes and speed frequency distribution. Speed by class information may also be helpful.

For two-lane roadways with two-way traffic, it is recommended that the state agency work with the local agency district office to create a “no-passing” zone within the 300-foot WIM scale area. WIM site planners should also avoid intersections and driveways that could cause irregular traffic dynamics in the area of the WIM sensor location.

Pavement Condition

The pavement surface should be free of distresses (cracking, raveling, faulting, rutting, potholes, etc.) and any transitional joints. Information regarding the evaluation of pavement surface condition can be found in the *Distress Identification Manual for the Long-Term Pavement Performance Program (7).*

To assess pavement condition:

1. Visually inspect the pavement. If a lane closure is not practical, the evaluation can be conducted from the shoulder, as shown in Figure 2.
2. Use 16-foot-long straightedge to identify any pavement rutting.
3. Record any distresses (cracking, faulting, rutting, potholes, etc.) within the WIM scale section that would adversely affect the accuracy of the WIM system (by inducing truck bounce or non-uniform movement).

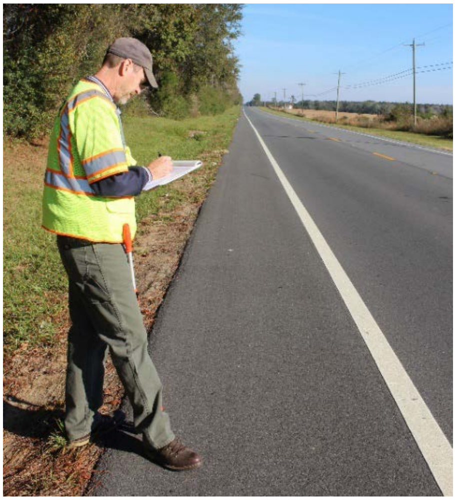

Figure 2 – Pavement Inspection

Pavement Surface Smoothness

The goal of the pavement smoothness analysis is to determine if a 300-foot section is available within the selected roadway segment that satisfies ASTM E1318-09 pavement profile and smoothness criteria for WIM sensor installation. The pavement smoothness analysis may be accomplished by any one of the following methods:

1. On-site profile data collection using a high-speed profiler, followed by in-house data analysis using ProVal software. The preferred equipment is an inertial profiler meeting the Class 1 standards as specified in ASTM E950-98.
2. Pavement smoothness testing in accordance with section 6.1.5.1 of ASTM E1318-09, following the procedure of using the 16-ft-long straightedge, such as an I-beam or box beam that will not flex, and the 6-inch-diameter by 0.125-inch-height aluminum disc. For a distance of 300 feet before and 75 feet after the WIM sensor location, the roadway surface shall be maintained in a condition such that a 6-inch-diameter circular plate 0.125 inches thick cannot be passed

beneath a 16-foot-long straightedge. This method requires a lane closure.

Pavement-Truck Interaction

Trucks must be observed as they approach, traverse, and leave the proposed sensor area to determine if there is any visible truck bounce that may affect the performance of the WIM scales. Figure 3 shows a truck approaching the WIM scale area. Specific roadway locations that demonstrate consistent truck dynamics should be investigated closely to determine the cause, including dips or bumps in the roadway. Also, a verification that trucks track down the center of the lane must be performed.

- ✓ Based on site observations, record any adverse vertical or horizontal truck movement, or side-to-side truck rocking motion.

Figure 3 – Truck Traversing WIM Scale Area

WIM Cabinet Location and Safety Setbacks

When deciding where to place the WIM cabinet, consider such elements as technician safety, equipment protection, accessibility to power and communication services, drainage, and proximity to test truck turnaround locations.

Preferably, the cabinet should be in a safe location out of the clear zone or located behind a guardrail, so that it cannot be hit by a vehicle leaving the roadway, and it should have a clear line of sight to the sensors and an unobstructed view of passing traffic. Figure 4 shows a cabinet located in a safe location.

Figure 4 – Protected Cabinet Location

The WIM site should have a large flat area for the technician to park the service vehicle outside of the clear zone, also known as the recovery area, or behind a protective barrier such as a guardrail. The MUTCD and AASHTO's Roadside Design Guide provide clear zone dimensions for roadways based on the speed of traffic *(6, 8)*.

- ✓ Evaluate if the cabinet location provides a safe location for technicians to stand and not have their back turned to oncoming traffic.
- ✓ Sketch the proposed location of the cabinet, conduit pushes, and pull boxes. Indicate safe parking areas for the service vehicle that are outside of the recovery area, not in the clear zone, and do not require technicians to cross the roadway to access the cabinet.

Maintenance of Traffic

From a safety standpoint and MOT design considerations, it is recommended that the proposed WIM site should provide the opportunity to use basic MOT designs for WIM installation and ongoing maintenance actions and not be too complex.

Power and Communication Services

Although the standard WIM site design may include specifications for the type of power and communication devices to use, the on-site evaluation may be used to either confirm compliance with the specification or to develop a report justifying the exceptions to the specifications. Special circumstances discovered during the on-site evaluation may prohibit the use of certain types of communication services or alternating current (A/C) power service.

If A/C power or cellular, fiber optic, or landline telephone service is not available nearby, or the costs to bring power and phone supply line to the site are not affordable, solar power or other communications alternatives may prove to be the better option.

A/C Power

- ✓ If A/C power is preferred, determine if A/C power service is located nearby.
- ✓ Record the distance from the proposed cabinet location to the closest A/C power service.
- ✓ Identify the location of the nearest A/C power services on the site sketch.

Landline Telephone

- ✓ If landline telephone is preferred, determine the location of the closest telephone service box.
- ✓ Record the distance from the proposed cabinet location to the nearest telephone service location.
- ✓ Identify the location of the nearest telephone services on the site sketch.

Cellular Service

- ✓ If cellular service is preferred, or landline service is not available, measure the signal strength of the available cellular services. This can be done using a cell phone.
- ✓ Note the cellular signal strength of the inspection checklist.

Fiber Optic

- ✓ If fiber optic communications are preferred, determine the distance to the fiber optic service.
- ✓ Record the distance from the proposed cabinet location to the nearest fiber optic service.
- ✓ Identify the location of the nearest fiber optic services on the site sketch.
- ✓ Determine the location for the fiber vault, which will be required at the site to handle the waterproof case containing the fiber splice.

Solar Power

- ✓ If solar power is deemed to be the best option, conduct a solar survey to determine if sufficient sunlight is available.
- ✓ Use a solar (sun) chart which incorporates azimuth and elevation. Azimuth shall be calculated starting true north as 0°, at solar noon the azimuth angle will be defined as 180°. A sample solar chart can be found at the following website: *http://solardat.uoregon.edu/SunChartProgram.php*
- ✓ The chart program creates a sun path in Cartesian coordinates.
- ✓ If solar power is to be used, check WIM manufacturer specifications to make sure that this is viable solution for the selected equipment and intended WIM data application. You may also need to consider the online current draw if the system may at some point be used in a continuous reporting mode, such as is done for emergency evacuations and other instances.

Photovoltaic (PV) solar electric modules require direct sun exposure in order to achieve the maximum level of performance. Any minor solar shading will significantly reduce the amount of energy produced. Sites with limited direct sun exposure may require an oversized PV solar module to compensate for the reduced electrical generation time periods. Wind power may also be a suitable alternative power source.

Drainage

To ensure that the equipment or sensor lead-ins will not be susceptible to water damage through flooding, it is important to select a site with adequate drainage or located on higher ground, especially in areas with heavy snow accumulation. It is best that the cabinet be located at a level that is higher than the pavement surface. Drainage for the pull boxes is also important. The pull boxes should not be installed in gullies or ditches.

To ensure proper drainage design:

- ✓ Develop a sketch showing the optimal locations for the cabinet and pull box. A “to scale” drawing is recommended.
- ✓ Identify on the sketch:
  - Location of any drainage assets with respect to the proposed cabinet
  - Orientation to north
  - Any conduit pushes
  - Ground rod location
  - Anticipated power and/or communication conduits
  - Pull box locations

Existing Equipment for Possible Upgrade

If a traffic monitoring site is being evaluated for upgrade to a WIM site:

- ✓ Inspect all existing equipment components and evaluate each item to determine if it is structurally

sound and in good physical and operational condition, and will last as long as the newly installed equipment.
- ✓ Verifying the grounding at the site with a megger.
- ✓ Record information about existing equipment and all test readings.

Calibration Test Truck Turnarounds

One of the greatest contributors to the cost of a WIM calibration is the amount of time spent on site. The on-site time can be reduced if the test truck turnarounds are reasonably close to the WIM site to provide the quickest, safest truck route possible. Another option is to use a racetrack circuit pattern using parallel streets instead of turnarounds. It is recommended that WIM systems be installed no closer than 1/2 mile, and preferably no farther than 5 miles from the nearest turnaround in each direction.

To establish turnarounds:

- ✓ Drive to the turnaround locations identified through analysis of aerial maps to verify that they are suitable for the safe and repeated turnaround of semi-tractor trailer trucks.
- ✓ If necessary, request permission from private landowners to use their land for turning the trucks around.
- ✓ Record the global positioning system (GPS) coordinates and or distances for acceptable truck turnaround locations.

Proximity to Certified Truck Scale

The test trucks must be measured at a certified truck scale just prior to calibration. To reduce the amount of time spent on site, and to ensure that pre-calibration measurements are accurate, a truck scale that is closest to the WIM location should be used.

Coordination with Local Highway Office

Once on-site evaluations have been completed and the proposed site has been determined to be suitable for a WIM installation, coordinate with the local highway office:

- ✓ Contact district engineering staff and ask for a pavement rehabilitation schedule, other maintenance considerations, and any other activities that may impact installation and operation of a WIM site.
- ✓ Record information about current or planned pavement rehabilitation, maintenance, or any other activities that may impact installation and operation of a WIM site.

Site Selection Report and Location Approval

- ✓ Prepare a WIM site evaluation report using findings from off-site and on-site investigations, including:
    - Summary of findings from the off-site and on-site investigations.
    - Rating of site applicability for WIM installation.
    - Recommended location for WIM sensors, cabinet, pull box, power and telecommunications, and drainage features (GPS coordinates).
    - WIM site sketch with distances noted.
- ✓ Meet with the district engineer and the WIM data user staff to get final approval for site location.

WIM SITE DESIGN

Sensor Layout, Sensor Arrays, Dimensions, Depth, and Configuration

This section describes recommended sensor layout and configurations for different types of WIM sensors.

Bending Plate

The bending plate is typically 69 inches long, 20 inches wide, and 1 inch thick. It is placed into a metal frame that has been permanently installed into the pavement. The frames are installed so that the edge is aligned with either the outside edge of the painted lane line or the center line, depending on the configuration of the sensors, as shown in Figure 5.

Figure 5 – Bending Plate Installation

The excavation for the bending plate frame is 26 inches wide and 70 inches long. The maximum depth of the excavation is 4 inches in the center drain area. The excavation for the load-bearing portion of the bending plate frame is a minimum of 2.25 inches.

A cross section of the manufacturer's recommended excavation depth measurements is shown in Figure 6.

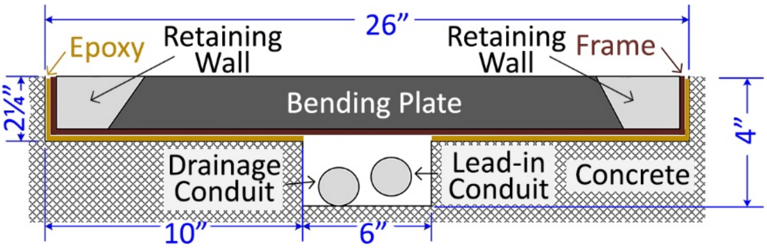

Figure 6 – Bending Plate Installation Detail

Each bending plate should be installed to cover one-half of the travel lane. Therefore, the preferred configuration consists of two bending plates installed in each lane. For ASTM E1318-09 WIM Type I and Type II WIM systems, the sensors are typically installed in a staggered configuration to provide more accurate speed and axle spacing measurements that reduce vehicle dynamic effects, as shown in Figure 7.

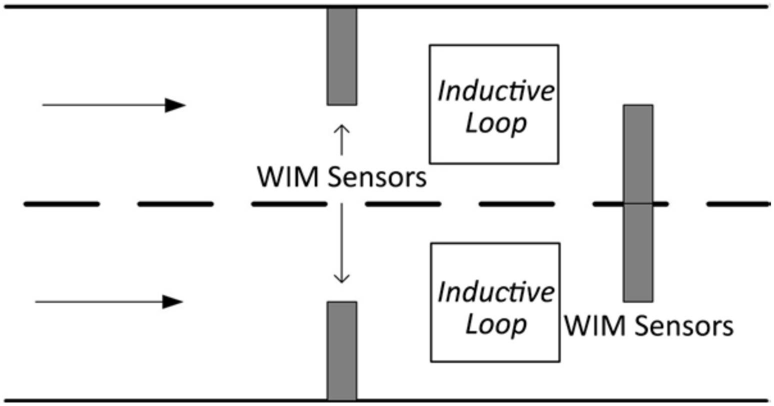

Figure 7 – 2-Lane Unidirectional Staggered Bending Plate Configuration

Alternatively, the in-line configuration provides a simpler installation, as shown in Figure 8. The speed and axle measurements are less accurate with this configuration than with the staggered configuration.

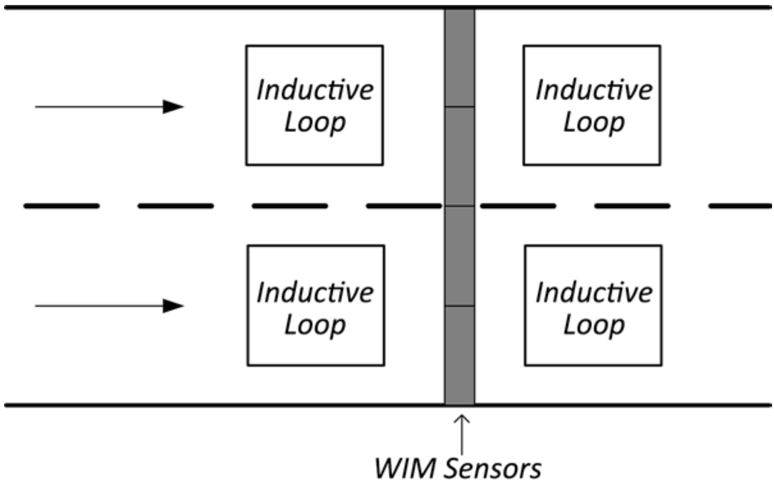

Figure 8 – 2-Lane Unidirectional In-Line Bending Plate Configuration

With either layout, the loops are placed in line across the roadway but should be separated by at least 5 feet to avoid interference (also referred to as "crosstalk").

There may be constructability and cost differences between the in-line and staggered bending plate installations. The staggered array requires a separate set of drainage and electrical conduits and may take longer to install and therefore costs more.

For ASTM E1318-09 Type III WIM systems that require highly accurate weight data, the double in-line configuration is used. For this configuration, two in-line bending plates are installed prior to and after the second loop.

Load Cell

Each load cell sensor is typically 72 inches long, 38 inches wide, and 5 inches thick. The load cell is installed in a metal frame that is permanently installed into a concrete pit. The frames are installed so that the edge is aligned with either the lane line or the center line, depending on the configuration of the sensors.

The size of the load cell pit, which is able to house two sensors in a side-by-side configuration, is up to 14 feet wide and up to 3 feet deep. The length and depth of the concrete vault differs among manufacturers. In addition, a concrete slab up to 20 feet in length may be required for the frame to rest on.

The preferred load cell configuration consists of two load cells and at least one inductive loop and may include one axle sensor. The load cell threshold is placed across the traffic lane. It may use an in-line configuration or a staggered configuration with the scale almost touching at the corners as shown in Figure 9, or separated by up to 2 feet. The WIM scales operate independently from one another.

Off-scale detectors may be integrated into the scale assembly to sense any vehicles off the weighing surface, as shown in Figure 10. The inductive loop is placed upstream of the load cell to detect vehicles and alert the system of an approaching vehicle.

If a second inductive loop is used, it is placed downstream of the load cell to determine the completion of the vehicle detection. An axle sensor may be placed downstream of the load cell to determine axle spacing and vehicle speed.

Figure 9 – Load Cell Installation (Staggered Configuration)

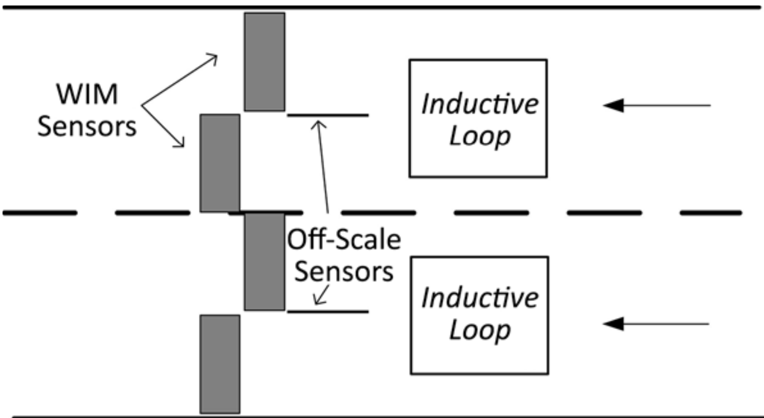

Figure 10 – 2-Lane Unidirectional Staggered Load Cell Configuration

The arrays for each lane may be placed in line across the roadway, or they may be staggered to allow for loop homerun cuts for both lanes to go to the same side of the roadway. With either configuration, the loops should be separated by at least 5 feet to avoid interference (crosstalk).

Quartz Piezo Sensor

Each quartz piezo sensor is 1.5 or 2 meters in length and can be combined in varying lengths to provide half-lane or full-lane width coverage. The quartz piezo WIM sensor is approximately 2 inches wide, 2 inches thick, and weighs 12 to 20 pounds, depending on the length of the sensor.

The slot for the quartz piezo sensor is 2.75 inches wide and 2 inches deep, as shown in Figure 11. The length of the excavation depends on the length of the sensor to be installed but is typically 6 feet or 12 feet, depending on the overall lane width.

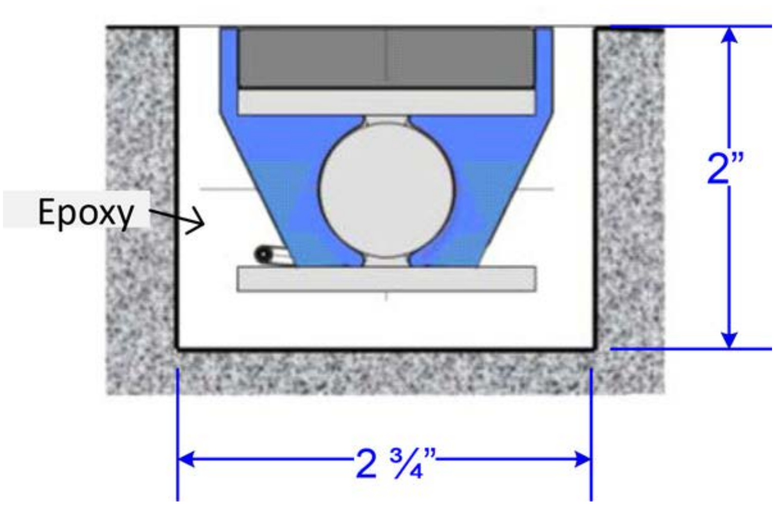

Figure 11 – Quartz Piezo Installation Detail

The preferred configuration, which provides better weight measurement accuracy, consists of two sets of two half-lane sensors, as shown in Figure 12. The sensors are staggered in the travel lane, each wheel path set spaced approximately 12 to 16 feet apart. The preferred configuration shown in Figure 12 provides a double threshold.

The loops may be placed in line across the roadway, or they may be staggered to allow for homerun cuts for both lanes to go to the same side of the roadway. With either configuration, the loops should be separated by at least 5 feet to avoid interference (crosstalk).

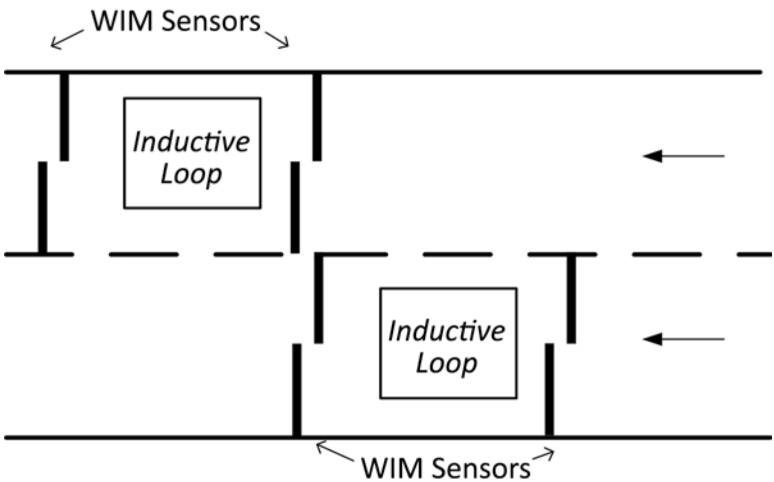

Figure 12 –2-Lane Unidirectional Staggered Quartz Piezo Configuration

Strain Gauge Strip Sensors

Each strain gauge strip sensor is 59, 69, or 79 inches long and is installed in sets of 1 to 4 pairs (2 to 8 strip sensors) that can be combined to cover different road widths, with one pair covering the width of a single road lane. Each strain gauge WIM strip sensor is approximately 3 inches wide, 3 inches tall, and weighs 45 to 65 pounds, depending on the length of the sensor and cable length. Sensors less than 3 inches tall have recently become available.

As shown in Figure 13, the slot for the strain gauge strip sensor is 3 inches wide and 3 inches deep. The length of the excavation depends on the length of the sensor to be installed but is typically 6 feet or 12 feet, depending on the overall lane width.

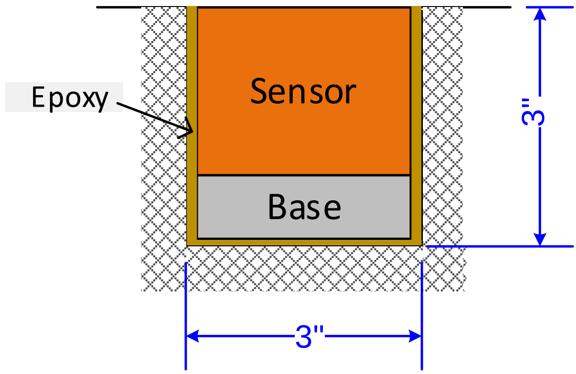

Figure 13 – Strain Gauge Strip Sensor Installation Detail

Each sensor is installed to cover one-half of the travel lane. Working in pairs, the two sensors are installed in a staggered configuration in each lane, the left side staggered 2 feet in front of the right sensor and each set of sensors for each wheel path is placed 16 feet apart. The inductive loop is installed before the leading set of WIM sensors, as shown in Figure 14.

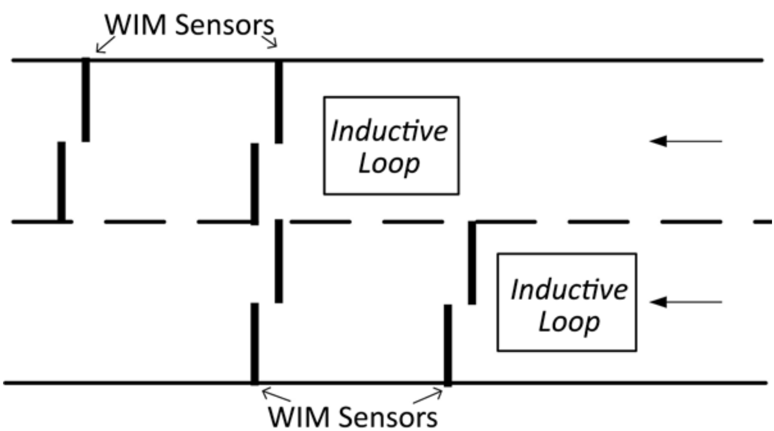

Figure 14 – 2-Lane Unidirectional Staggered Strain Gauge Strip Sensor Configuration

The loops may be placed in line across the roadway, or they may be staggered to allow for homerun cuts for both lanes to go to the same side of the roadway. With either configuration, the loops should be separated by at least 5 feet to avoid crosstalk.

Polymer Piezo Sensor

The polymer piezo sensor is produced in lengths from 6 feet up to 12 feet. The sensor is permanently installed into the slot with epoxy grout. The sensors are typically installed so that the ends align with the inside of the painted lane line, the center line, or both, depending on the configuration of the sensors.

The slot for the polymer piezo sensor is 0.75 inches wide, and the sensor should be placed in the slot so that there is at least 1 inch of grout cover, and held in place with plastic chairs, as illustrated in Figure 15 . The length of the slot depends on the length of the sensor to be installed but is typically 6 feet or 12 feet, depending on the lane width.

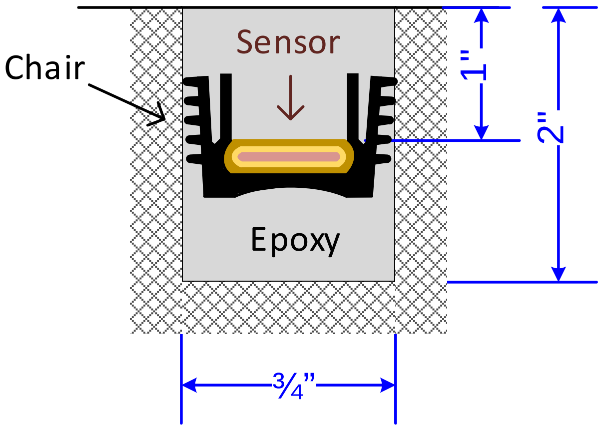

Figure 15 – Polymer Piezo Installation (not to scale)

Each polymer piezo sensor is typically installed for half-lane coverage, with four sensors installed in each lane, 2 inches deep, with at least 1 inch of grout cover. Each set of sensors in each wheel path is spaced 16 feet apart. A chair is used to hold the sensor in place during installation. This provides a dual-threshold capability. Figure 16 illustrates the layout. A single inductive loop is installed between the two sets of staggered WIM sensors to provide vehicle presence detection and vehicle length measurement. The sensors are placed in the travel lane perpendicular to the direction of travel.

The loops may be placed in line across the roadway or staggered to allow for homerun cuts for both lanes to go to the same side of the roadway. With either configuration, the loops should be separated by at least 5 feet to avoid interference (crosstalk).

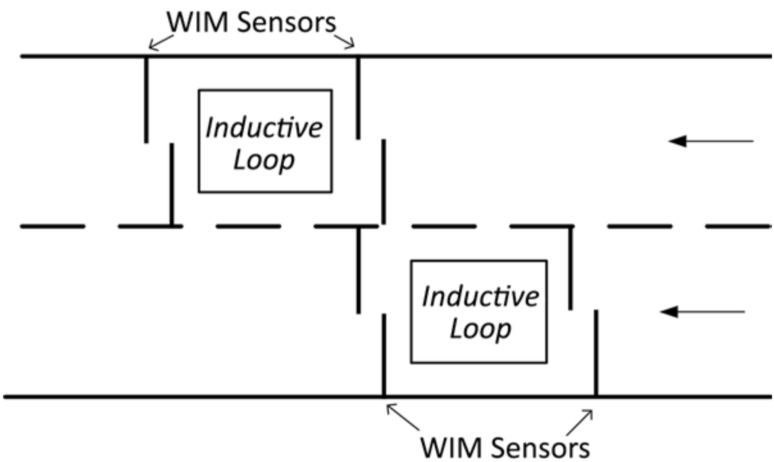

Figure 16 – 2-Lane Unidirectional Polymer Piezo 4-Sensor per Lane Configuration

An alternative to replacing sensors when pavement overlays occur is to leave the sensors in place. Polymer piezo sensors can be paved over with good long term results. Ohio Department of Transportation (DOT) and Virginia DOT used this strategy to increase service life for the sensors from 3-5 to 5-7 years. It requires coordination with the construction crew and use of the smaller aggregate size in the AC mix for the top pavement layer to ensure the transfer of the normal force from the tire footprint to the sensor that may be 1.5 to 2.5 inches below the surface. Also, the lane striping crew needs to know the offset from the pavement edge to properly place the line sensor and the loop (center of the lane). Buried sensors produce decreased voltages.

Portable Polymer piezo Sensor

For portable weighing operations, sensors each roughly one-lane width in length are either taped or fastened to the roadway, perpendicular to traffic. Normally, two full lane-width sensors are placed 10 to 16 feet apart in the same lane. Minnesota uses a 24 feet long portable WIM sensor to cover two lanes at a time that works in either unidirectional or bidirectional mode.

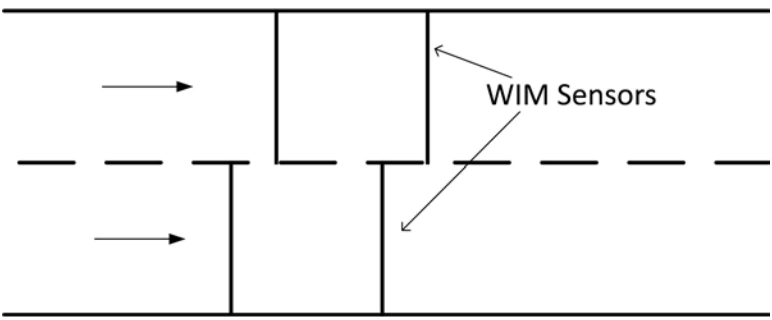

Figure 17 – 2-Lane Unidirectional Portable Polymer Piezo 2-Sensor per Lane Configuration

Cabinet Location

A cabinet rated National Electrical Manufacturer Association (NEMA) 3R should be located outside of the recovery or "safe zone," behind a protective barrier such as a guardrail, or constructed using a breakaway base. It should also be located close enough to the roadway and the door installed so that the technician can easily view the passing traffic.

The cabinet foundation should not be placed in a low area that may allow for water intrusion or on grade with a slope greater than 3:1.

For sites that will utilize solar power, the cabinet should be placed in a location that will enable sufficient exposure to the sun. Wind power has also been used at some sites.

The cabinet should be clearly marked as an electrical device, with digging warnings and agency contact information.

Directional Boring

If required, directional boring may be installed between pull boxes that are placed on either side of the roadway. The bore should be placed at least 24 inches below the road surface, and the conduit, shown in Figure 18, should be no smaller than 2 inches in outside diameter. It is preferred that the bore not be run underneath the location of the in-road sensors to avoid electronic interference. Conduit material is typically polyvinyl chloride (PVC).

Figure 18 – Bore Operation Conduit

Pull Boxes

Pull boxes should be large enough to accommodate the sensor lead-in cables, service loops, and splices. Pull boxes that are 12 inches wide, 16 inches long, and 16 inches deep should suffice for most WIM system applications. They should be installed leveled with grade and should be located at least 5 feet from the roadway, close to the location where the in-road sensor lead-ins meet the edge of the roadway. Figure 19 shows the interior of a pull box, and Figure 20 shows the exterior.

Figure 19 – Pull Box Interior

The pull boxes should be constructed of steel, concrete, or a polymer that would withstand being run over by a semi-tractor trailer. The tops of the pull boxes should be bolted down. They should be properly marked with the word “traffic.”

Figure 20 – Pull Box Exterior

Data Acquisition (Communications)

Modems

Modems capable of reliably and continuously transmitting data for the time required for data transfers should be installed in the cabinet. Consider if the site is powered by alternating current or direct current (A/C or DC), and make sure the electronics needed for the site use similar power sources.

The technician should program the modems prior to installation so that they will be able to communicate with the WIM controller. For cellular modems, a subscriber identity module (SIM) card will be provided by the cellular service company. Other site-specific or network-specific settings will then need to be entered into the modem.

Telephone Service

If landline service is utilized for site communication and data download, the service must be of high enough quality to allow for data transmission. Grounding for the communication drop location is needed for lightning protection. Figure 21 shows a landline phone service box.

Figure 21 – Landline Telephone Service Box

Fiber Optics

Fiber optics (optical fibers) are long, thin strands of very pure glass about the size of a human hair. They are arranged in bundles called optical cables and used to transmit signals over long distances.

The option of using fiber optics for data transmission has several pros and cons. The advantages of using fiber optic communication is the very fast speed (10 Gbps), which means that very large data files can be downloaded in split seconds or video imagery from a site can be streamed real-time. Additionally, optical fibers do not conduct electricity, preventing problems with ground loops and conduction of lightning. Conversely, the installation of fiber optics can be very expensive for remote sites, and transmission over fiber is limited by the attenuation and dispersion.

Cellular Service

If cellular service is utilized for site communication and data download, the service must be of high enough strength to allow for uninterrupted data transmission. The cellular signal must be measured at the site during the preliminary site selection and should be greater than -80 db. Signal dropout can be expected at strengths less than -90 db. Figure 22 shows a cellular modem.

Figure 22 – Cellular Modem

On-Site Data Storage

The WIM controller should be capable of storing at least 7 days of data between downloads. This would allow sufficient time for a technician to respond to a service call if communication between the host computer and the WIM controller is lost.

System Power

Solar Power Devices

All solar-powered sites require a combination of solar panels, a solar regulator, and batteries. The power circuit is designed so that the solar panels charge the batteries during the day above the power consumption of the devices drawing power from the circuit so that the batteries are fully recharged before sunset. These systems are designed to run indefinitely until the solar panel or battery service life ends. The wattage of the solar panels (sometimes multiple panels) and the number of batteries is determined by the total power consumption of the devices running on the power circuit and the latitude of the location. Figure 23 is an illustration of the various solar power system components.

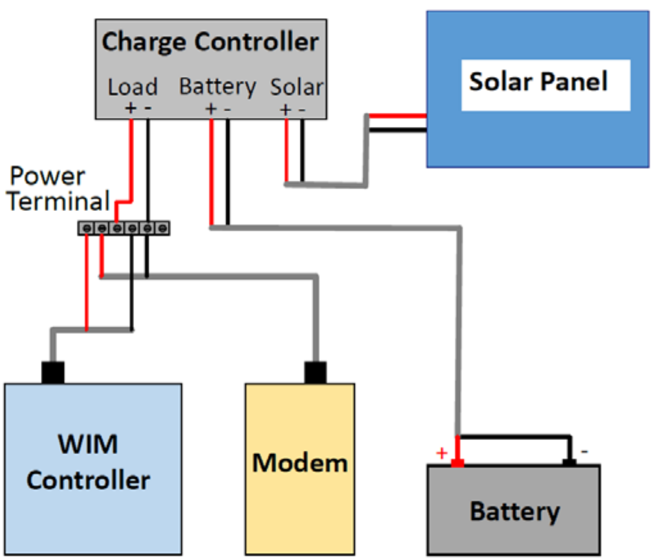

Figure 23 – Solar Power System Components

Solar Panels

Solar panels must generate enough power to the site to handle the power needs of the WIM controller and any peripheral devices, such as the modem, a cabinet light, or a fan. Most WIM systems require at least one 80-watt solar panel. WIM and other equipment vendors can provide guidance on the power requirements for their equipment.

The PV solar power supply shall feature a universal design suitable for a wide range of site conditions. The design shall account for degraded solar conditions and extended periods of weather related to solar blockage without having any power interruptions. The PV solar wattage to load wattage ratio will be sized to account for degraded conditions. System design shall provide for a reserve capacity for the battery for at least 7 days while maintaining normal operations.

In regions prone to localized solar blockage from weather-related conditions such as fog and clouds, and site-specific locations where shading create conditions with less than 1 solar energy hour per day, this design is not appropriate.

Solar panels, like the one shown in Figure 24, should be installed on the cabinet service pole at a height that will prevent theft and allow for sufficient sun exposure. The solar panels should be installed so that they are facing south and at angle related to the latitude of the site.

Figure 24 – Solar Panel (80-Watt)

Solar Regulator

A solar regulator (see Figure 25) is part of the solar charging circuit. It receives its input from the solar panel and provides a regulated (controlled) DC output to the battery to charge it. It ensures that the battery is not overcharged and may provide surge protection for the charging circuit.

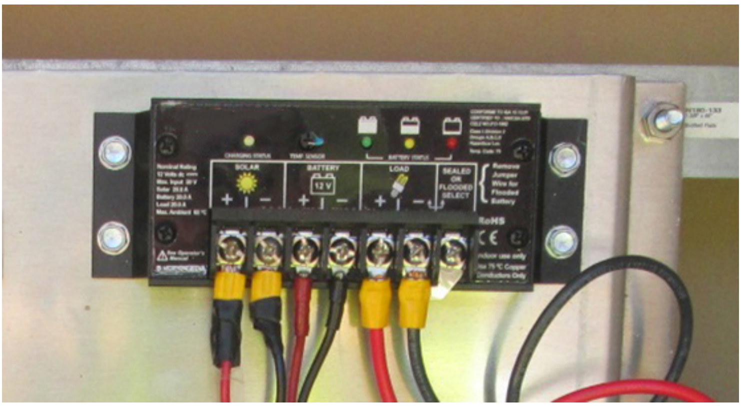

Figure 25 – Solar Regulator

To determine the size regulator required, note the amp ratings of the solar panels and add those ratings to determine the minimum size charge controller needed.

Battery

The battery (see Figure 26) supplies DC power to the WIM system devices, including the WIM controller, modem, fan, and heating element. The capacity of the battery is measured in amp hours. The size of the battery is determined by adding the amperage for all of the equipment that will be run from the battery. The battery should be able to provide continuous power, without charge, for at least 7 days.

Figure 26 – Battery

A/C Service Devices

A/C devices, such as circuit breakers, switches, terminals, and fuses should be installed in the cabinet to provide 120 volts of power switching and protection from power surges such as lightning. They should be suited for outdoor use and be securely mounted to the cabinet in a separate enclosure, such as a circuit breaker box, to prevent electric shock. Figure 27 shows an outdoor A/C power service meter mount.

Figure 27 – A/C Power Service Meter

Fans and Environmental Controls

Although WIM controllers are designed to withstand very cold and very warm temperatures, in places of extreme temperatures, air conditioning devices such as fans, heaters, or the thermostat shown in Figure 28 may need to be installed to ensure that the system does not get overheated or freeze.

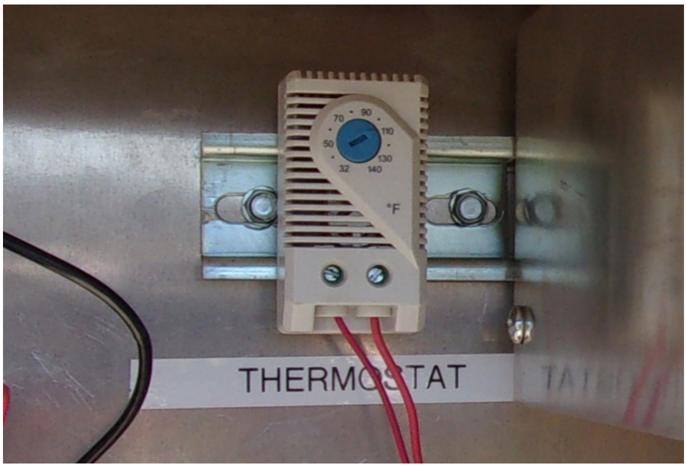

Figure 28 – Thermostat

Lightning Protection and Grounding

Surge Suppression

Direct lightning strikes almost always cause costly damage. Nearby lightning strikes can also result in costly damage if surge prevention devices are not properly installed. Primary surge suppression devices for the loops and WIM sensors are typically built into the signal processing cards. However, secondary protection from lightning strikes is available and is recommended. These are typically surge arrestors like the one shown in Figure 29, installed at the terminal strips where the in-road sensor lead-ins are connected.

Additionally, all power service lines and telephone lines should be protected from lighting and other sudden power surges using surge suppression devices and have proper grounding to a grounding rod. Equipment should be isolated from ground using devices such as gas-filled diodes to prevent surges from causing significant damage.

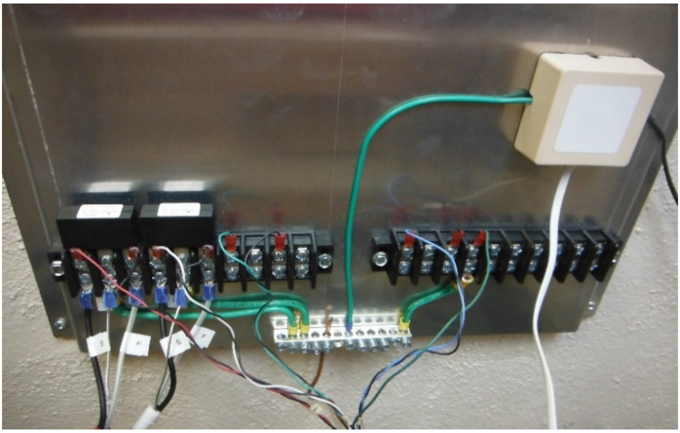

Figure 29 – Sensor and Telephone Surge Arrestor Devices

Grounding

Grounding is used to shunt power surges to earth. The grounding requirement for the system is a function of the device on the circuit having the most conservative requirement. A ground resistance requirement of 10 ohms or less is recommended. This may be met at most sites with a single 8-foot ground rod installed in the cabinet foundation or a nearby pull box, as shown in Figure 30. Other sites may require multiple ground rods to be installed on top of one another, or in an array.

The number of ground rods required is a function of the soil composition/water content of the earth being grounding in. Additional ground rods are added until the circuit has the required resistance. For a grounding array, each ground rod is separated by 50 feet.

The ground rod or array is connected to the ground terminal panel in the cabinet using copper wire. Ground connections for all electronic devices in the cabinet are then connected to the ground terminal, as shown in Figure 30.

The ground resistance must be checked annually as it can change and more grounding may be needed.

Figure 30 – Grounding Rod with Cadweld™

WIM Site Plan

A WIM site plan should be developed to document the proper position and distances related to the road and WIM system components. It should include the following system components:

- In-road sensors
- Junction boxes
- Pull boxes
- Cabinet
- Power and phone sources
- Ground rod(s)
- Solar panels
- Conduit
- Bore
- Battery backup for power protection and temporary power
- Lightning protection panel or devices
- Other features such as guardrail

The site plan should include information such as road names, mile markers, GPS coordinates, speed limit, and cardinal direction. All special or non-typical installation notes should be provided on the sketch.

A typical WIM site design sketch and cabinet wiring diagram are provided in Appendix D.

Standard and Manufacturer Specifications

Examples of several standard WIM specifications are provided in Appendices C and D. They provide guidance on:

- Cabinet location
- Boring
- Pull boxes and junction boxes
- Solar panels
- Pedestals
- Cabinet foundations
- Conduit
- Grounding rod and bonding wire/joints
- Battery backup (larger capacity need if solar or wind powered)
- Loop wire
- Loop lead-in wire
- Splices

Reference manufacturer installation standards and specifications for guidance on:

- Sensor layout, sensor arrays, dimensions, depth and configuration (including drawings).
- Data acquisition (communications).
- Power requirements.
- Lightning protection.
- Memory needed for 15 days (minimum) to 30 days (best) of storage, based on vehicle volumes at the site.

WIM SITE INSTALLATION

The objective of the installation process is to provide a properly functioning WIM site for the design life. The proper installation of the WIM equipment is critical for collecting high-quality data. WIM sensors improperly installed in even the smoothest pavement will most assuredly provide unusable WIM data.

General Installation Requirements

ASTM E1318-09 requires that the WIM equipment be installed and maintained in accordance with the recommendations of the WIM system vendors. Therefore, this guide does not provide instructions for installing the vendor-specific WIM system components. The agency or inspector should contact the manufacturer to acquire the most recent installation manual.

The following generic installation requirements must be followed for any type of WIM system or sensor being installed:

- The installation should only be performed in good weather, not wet, freezing, or extremely hot (above 100 °F) conditions.
- The equipment must be protected from lightning and power surges.
- The equipment cabinet must protect the system electronics from vandalism, extreme temperature, dust, water, humidity, and insect or rodent infestation.
- The equipment must be installed so that routine maintenance can occur without disruption of data collection.
- Installation start date and time to complete installation work should be established and any press release information provided to the agency in advance of the field work.

- A vendor representative should be on-site to ensure that vendor requirements are met.
- An agent representing the contracting agency and experienced with WIM installations—the quality assurance (QA) inspector—should be on-site to ensure that agency requirements are met.
- Pre-construction meetings should be held before lane closures are set up to discuss safety and the work planned for the day.
- Complete site plans should be available on-site to ensure proper placement of equipment.
- All installations should be performed in accordance with the WIM manufacturer's specifications and any additional contracting agency requirements.
- Due to warranty liabilities, the installation must be carried out by persons who have successfully completed a vendor training course and hold a valid vendor certificate authorizing them to install the sensors.
- An accurate set of as-built plans should be developed after installation for future construction and maintenance work.
- The work is considered to be complete when all system components have been tested and accepted by the contracting agency and data verification testing has been completed.

Installation QA Inspector

The QA inspector represents or acts on behalf of the contracting agency and should have the authority of the agency. The QA inspector should be on-site to ensure that all elements of the WIM installation are performed in accordance with the contracting agency's requirements.

The QA inspector should be experienced with WIM installations and have proper certifications or training on the particular type of WIM system being installed. The QA inspector is required to have a digital or hard copy of all applicable manufacturer installation standards and specifications on-hand.

The QA inspector should document and photograph all stages of WIM site installation and prepare the WIM installation acceptance report and non-compliance report, as described in the following sections. The LTPP WIM System Installation and Calibration Audit can be found in the *LTPP Field Operations Guide for SPS WIM Sites (4)*.

Pre-Construction Meeting

Pre-construction meeting(s) of all personnel involved in the WIM system installation should be held prior to the beginning of work. Attendees may include:

- Contracting agency or their representative (QA inspector).
- Contractor's on-site superintendent.
- MOT contractor's on-site leader.
- Local road maintenance supervisor.
- WIM system manufacturer's representative.

Topics should include safety, lane closure time limits, work schedule, and a detailed discussion of the work to be performed. Contact information should be exchanged. The QA inspector should review all requirements related to the work to be performed. All equipment and materials should be checked for acceptable physical condition at that time.

Site Preparation

The following recommended procedures are not meant to supersede any established agency or manufacturer installation specifications. The QA inspector and the installation supervisor should review and be familiar with all contract, state, local and manufacturer installation standards and specifications for specific guidance and installation instructions prior to the start of any construction work.

Protection of Utilities

Before the installation of any support equipment, such as cabinets, conduit, grounding rods/wires, pull boxes, or electrical service or telephone devices, the QA inspector and the installation supervisor must examine all existing utility markings and verify that the location of utilities within the work area has been performed within the past 2 weeks. Figure 31 shows a site where the utility locations are clearly marked.

Figure 31 – Utility Location Markings

Equipment Inspection

Prior to installation, the QA inspector should inspect all equipment, and the installation supervisor should electronically test the equipment to verify that it is new, undamaged, and for electrical equipment, Underwriters Laboratories (UL) listed.

Maintenance of Traffic

The contractor must develop the traffic control plan based on the MUTCD and any supplemental work zone guide required by the agency, and the plan must be approved by the agency before work begins *(6)*. The QA inspector should review the plan and bring any deviation from the specifications and standards to the attention of the contractor's on-site supervisor for immediate remediation. The QA inspector should have the authority to halt work until proper remediation to traffic control is completed, or if they feel that the modifications are not meeting the needs of the road users. All portable changeable message signs (PCMS), such as the one shown in Figure 32, and arrow boards should be inspected to ensure that they are properly placed, fully illuminated and completely visible to the traveling public.

Figure 32 – Portable Changeable Message Sign Used for Traffic Control

WIM Site Installation Quality Assurance

This section describes installation QA activities and QA checks to ensure that the WIM system meets design life expectations.

Excavation and Conduit

The QA inspector must ensure that all excavation and installation of conduit used for the WIM installation is of the proper depth, type, and dimension, as stated in the design standards. The cabinet and junction boxes should be staked, conduit runs marked, and the outer limits of the array area marked on the edge of pavement. The QA inspector will use these to verify they will be installed in the correct locations prior to the start of any work. Adjustments may be needed and should be addressed prior to the start of work.

In general, site work on the side of the road is performed first so that when the sensors are installed in the road the homeruns can be run to the cabinet right away and are not at risk of being damaged if site work is done after sensor installation.

Separate conduits should be run from each loop and WIM sensor exit hole to the nearest pull box, as shown in Figure 33.

Figure 33 – Sensor Conduits from Exit Hole to Pull Box

The QA inspector must also ensure that the installation crew does not remove any more pavement material than is necessary and repairs any pavement damaged during the installation process. The QA inspector must perform the following:

- ✓ For the excavation and installation of conduit, observe the following to ensure that:

- Only material necessary for the installation is removed.
- Excessive pavement damage is repaired with like material or epoxy.
- Homerun conduits are installed at the proper depth.
- Locator tape is installed on all conduit runs.
- Sensor exit conduits should be driven deep enough into the pavement (about 3 to 4 inch depth) so that the home run wires are not susceptible to being ground off when a mill and overlay is done.
- All conduit end points have smooth edges.
- All conduit used within the travel lane is galvanized rigid metal conduit.
- Conduit openings are sealed with duct seal, as shown in Figure 34.
- Drain conduits used for the bending plate or load cell sensors are lower than the electrical conduit openings.
- Proper size of PVC conduit is used from the pull box to the cabinet and base.

Figure 34 – Pull Box Conduit Sealed with Duct Seal

- ✓ Record findings on the QA checklist, and take photographs as necessary.
- ✓ If any of the above conditions are not met, inform the installation supervisor of the deficiency and ensure that the deficiency is acceptably resolved.

Pole/Cabinet

The QA inspector shall inspect the pole and cabinet equipment to verify that they meet contract specifications.

- ✓ Ensure that the pole and cabinet are placed where:
  - They are not subject to rain runoff, standing or moving water.
  - They will not be hit by moving vehicle, preferably behind a guardrail.
  - The grounding rod and/or 4- to 6-gauge grounding wire and bonding joint can be installed.
  - They are accessible with clear line of sight to the sensors.
  - They are serviceable without technician endangerment.
  - The cabinet door can be fully opened.
- ✓ Inspect the cabinet attributes to ensure that they meet contract specifications, which may include:
  - Proper height and level.
  - Conduit is securely and properly attached to the cabinet.
  - Hinged door with lock and two set of keys.
  - Louvered vent with standard filter.
  - Air exhaust through roof overhang with temperature activated forced air fan system.
  - Wiring and equipment layout.
  - Switched light.
  - Ground-fault circuit interrupter (GFCI) duplex outlet and a circuit breaker for A/C input.
  - Surge suppression.

- ✓ Inspect the pole attributes to ensure that it meets contract specifications, which may include:
  - The pole is installed vertically.
  - The pole foundation is installed properly.
  - Break away pole mounting whenever possible.
- ✓ Record on the QA checklist that each of the items above is acceptable.
- ✓ If any of the above specifications are not met, inform the installation supervisor of the deficiency and ensure that the deficiency is acceptably resolved. Do not allow the installation contractor to use unapproved cabinet equipment without approval from the agency.

Solar Panels

The QA inspector must ensure that the proper solar panels and mounting equipment are installed.

- ✓ During the installation of the solar panels, the QA inspector should verify that:
  - The panels are facing the proper direction (8° west of magnetic south).
  - The panels are installed at the proper angle (latitude +15°). This pitch may vary by the state this is installed in. There are cell phone apps that allow measuring this angle from the ground using cell phone so if the panel is mounted beyond reach it is easily checked. Figure 35 shows an inspector checking the angle of the solar panel.
  - All vegetation that may block exposure to the sun has been removed from in front of the solar panel.
  - Panel height is high enough (16 to 18 feet) to thwart vandalism or theft.
  - Fastening hardware may include bolts and hardware that has torx or safety torx head to prevent stealing.
- ✓ Record on the QA checklist whether each of the items above is acceptable.

- ✓ If any of the above specifications are not met, inform the installation supervisor of the deficiency and ensure that the deficiency is acceptably resolved. Do not allow the installation contractor to use unapproved solar panels or mounting hardware without approval from the agency. Theft-proof hardware can be utilized if theft could potentially be an issue, based on history or location.

Figure 35 – Solar Panel Angle Check

Solar Panel Charge Circuit Devices

The QA inspector must ensure that the solar panel charge circuit devices have been verified and tested.

- ✓ During the installation, verify that:
  - Batteries are the correct type and have the specified rating for amp hours.
  - Proper solar controller has been provided.
  - Wiring of solar panels, solar controller and batteries.
  - Settings on the solar controller.
- ✓ Record on the QA checklist whether each of the items above is acceptable.

Pull Boxes

The QA inspector must ensure that properly sized and traffic-rated pull boxes are installed at the locations shown on the WIM design plan and away from water collection areas.

- ✓ During the installation of the pull boxes, verify that:
  - The lid is flush with adjacent grade or surfaces.
  - Adequate drainage was installed (see Figure 36).
  - If required from WIM vendor, grounding rod is installed. Earth ground test with megger should be performed to ensure proper grounding to the cabinet, power drop, and communication drop.

Figure 36 – Drainage Gravel Depth Check

- ✓ Record on the QA checklist that each of the items above is acceptable.
- ✓ If any of the above specifications are not met, inform the installation supervisor of the deficiency and ensure that the deficiency is acceptably resolved. Do not allow the installation contractor to use unapproved pull boxes without approval from the agency.

Layout Marking and Cutting

To ensure that the WIM sensors and loops are placed properly in the travel lane as shown on the WIM site design plans and in the manufacturer's installation guide, the QA inspector must perform the following checks:

- ✓ Measure with a 100-foot tape measure and compare with installation documents to verify the following:
  - Square lines and markings are correct and match construction plan and specification tolerances.
  - Proper spacing between array elements (WIM sensors, inductance loops, axle sensors). Figure 37 shows measuring between loops.

Figure 37 – Loop Separation Measurement

- ✓ Observe the following to ensure that:
  - The WIM sensor array layout is squared in the lane per the 6-8-10 triangle method or by using a pre-made template. Figure 38 shows a reference line marked on the pavement.

Figure 38 – Reference Line

- All saw cuts are neat and straight.
- Saw cuts are at the proper width and depth (see Figure 39):
  - Loop slot depths measured every 2 feet and at corners.
  - WIM sensor channels measured at both ends and in the middle of each perimeter cut. This may be done using a custom depth gauge.

Figure 39 – Slot Depth Measurement

- If preferred, the corners of the loop may be drilled to the depth of the slots using a 1- to 1.5-inch rock drill bit.

✓ During the saw-cutting process, ensure that the saw cuts have been cleaned and dried with water and/or clean high pressure air, and that all residue and moisture is removed for proper epoxy adhesion.

✓ If any of the above conditions are not met, inform the installation supervisor of the deficiency and ensure that the deficiency is acceptably resolved.

✓ Photograph entire site layout in lane with all markings visible.

Loop Sensor Installation and Sealing (General)

The most critical element for WIM site installations is ensuring that the in-road loop sensors are installed in accordance with the contract specifications. This includes not only includes the proper placement (spacing, layout, depth, etc.) but also the proper mixing and application of the chemicals that are used to install the loop sensors.

✓ To ensure that the loop sensors are installed in accordance with the contract specifications, check the following:

a. Loop homerun cuts are wide enough to allow for complete encapsulation by the loop sealant for a minimum cover of 3 inches.
b. Loop wires are installed without the use of sharp implements and then secured with backer rod.
c. Loop wires are in bottom of the slot, wrapped 3 to 4 times per foot, depending on the operational requirements of the WIM controller’s loop detection circuit.
d. Loop wires run to the pull box without any splicing and are twisted around each other 3 to 4 times per foot.
e. Each loop wire pair is clearly labeled prior to pulling through the conduit.

f. Loop wires are completely covered with sealant and the sealant surface is flush with the pavement, with no voids or dips.
g. An earth ground/insulation test is performed before pulling the lane closure to ensure the loops are not compromised in any way.
h. Inductance test is performed to ensure the proper range of henries is obtained for each loop based on the loop size and distance to the pull box.

- ✓ Videotape the loop sensor installation to have the visual evidence in case the sensors do not work properly after installation.
- ✓ Record on the QA checklist that each of the items above is acceptable.
- ✓ If any of the above conditions are not met, inform the installation supervisor of the deficiency and ensure that the deficiency is acceptably resolved. Do not allow the installation contractor to install the WIM sensors incorrectly.

Load Cell Sensor Installation

The QA inspector should be experienced with the load cell installation process. The checks specific to the installation of the load cell WIM sensor include:

- ✓ During the installation of the load cell WIM sensors, verify that:
  a. Load cell sensor insulation resistance is pre-checked prior to installation.
  b. The load cell pit is properly installed.
  c. Only vendor-specified installation grout is used.
  d. Load cell sensors are installed to be as flush with the pavement surface as possible (within 1/8 inch).
  e. All voids in pavement around sensors are filled in with epoxy and/or caulk. All high spots in epoxy are ground flush.

f. All sensor lead-in wires exit the pavement through conduit and run all of the way to the pull box without splices.

✓ Record on the QA checklist that each of the items above is acceptable.

Bending Plate Sensor Installation

The QA inspector should be experienced with the bending plate installation process. The checks specific to the installation of the bending plate WIM sensor include:

✓ During the installation of the bending plate WIM sensors, verify that:

a. Frame excavation, as shown in Figure 40, should be deep enough to allow enough clearance below the frame and around conduits for epoxy.

Figure 40 – Excavated Bending Plate Pit (In-Line Configuration)

b. Bending plate sensor shield and Wheatstone bridge resistances are pre-checked prior to installation.

c. Only vendor-specified installation grout is used.

d. Bending plate sensors are installed (shimmed) to be as flush with pavement surface as possible (within 1/16 inch).
e. All voids in pavement around the frame are filled in with epoxy and/or caulk. All high spots in epoxy are ground flush as shown Figure 41.

Figure 41 – Completed Bending Plate Installation

f. All sensor lead-in wires exit pavement through frame conduit all the way to the pull box without severe bends.

✓ Record on the QA checklist that each of the items above is acceptable.

Quartz Piezo and Strain Gauge Strip Sensor Installation

The QA inspector should be experienced with the applicable strip sensor or quartz piezo installation process. Figure 42 shows a completed quartz piezo installation. The checks specific to the installation of the quartz piezo WIM sensor include:

✓ During the installation of the quartz piezo and strain gauge strip sensors, verify that:

a. Axle sensor channels are cut to the proper depth and width, based on the type of sensor.
b. Sensor insulation resistance is pre-checked in the cabinet prior to installation.
c. Only vendor-specified installation grout is used.
d. WIM sensors are installed in accordance with manufacturer specifications.
e. Each sensor is properly connected to the ground lead.
f. Sensors are ground flush with pavement.
g. All voids in pavement around sensors are filled in with epoxy and/or caulk. All epoxy high spots are ground flush to the surface and there are no bumps or dips in the surface greater than 1/8 inch.

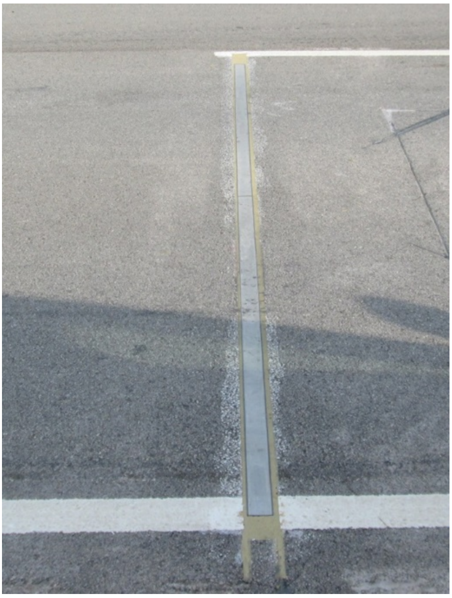

Figure 42 – Completed Quartz Piezo Installation

h. All sensor lead-in wires exit the pavement through conduit and run all of the way to the pull box without splices.

✓ Record on the QA checklist that each of the items above is acceptable.

Polymer Piezo Sensor Installation

The QA inspector should be experienced with the polymer piezo installation process. The checks specific to the installation of the polymer piezo WIM sensor include:

✓ During the installation of the polymer piezo WIM sensors, verify that:

a. The sensor are not dented, twisted, or bent.

b. The sensors are pretested for proper capacitance and resistance using a multi-meter and/or capacitance meter, as shown in Figure 43.

Figure 43 – Pre-Installation Sensor Testing

c. Sensors are placed in accordance with the site layout plan.

d. Sensor channels are cut ¾ inches wide and at least 2 inches deep. Saw cuts made in a single pass with a ¾-inch blade or two 3/8-inch blades ganged together are recommended. Check the slot depth as shown in Figure 44.

Figure 44 – Sensor Slot Depth Check

e. Pavement removal from the slots was done with care to ensure proper slot width and depth.
f. Slots were cleaned and dried before sensor placement (see Figure 45).

Figure 45 – Piezo Slot Clean and Dry Check

g. W-chairs are properly attached to the sensor, a minimum of 6 inches apart.
h. Completely clean the sensor no more than 20 minutes from installation to allow for proper bonding of the sensor to the epoxy.
i. The sensor must be checked along its entire length to verify it is being installed at the proper depth. The W-chairs must be adjusted within the slot to get the proper depth. Figure 46 shows a completed polymer piezo sensor installation.

Figure 46 – Completed Polymer Piezo Sensor Installation

j. The sensor is post-tested to ensure proper capacitance and resistance readings.
k. The sensor output signal is tested for proper voltage output.

✓ Record on the QA checklist that each of the items above is acceptable.

Cabling

During the installation of the sensor cabling from the side of the pavement, through pull boxes, and into the cabinet, the QA inspector must ensure that the cables are pulled carefully as to avoid damage to the external protection.

- ✓ During the cable installation, ensure that (see Figure 47):
  a. All cabling is clearly labeled in each pull box and in the cabinet.
  b. Service loops such that at least 5 extra feet of wire is left in each pull box and in the cabinet for repairs.

Figure 47 – Sensor Lead Labeling and Service Loops in Pull Box

  c. Splices are industrial quality, watertight, hermetically sealed, and made with bifurcated terminals to prevent shorting.
  d. Check each loop for proper inductance range is met before putting the splice kit on it.
  e. Splices, if used, are used in the closest pull box to the sensor.
  f. Each sensor is tested before final terminations are made.
- ✓ Record on the QA checklist that each of the items above is acceptable.
- ✓ If any of the above specifications are not met, inform the installation supervisor of the deficiency immediately

to ensure that the WIM sensor cables are not damaged during installation. Do not allow the installation contractor to pull on cables that appear to be stuck or difficult to pull. Damaged lead-in cables may require an expensive replacement.

Grounding

The QA inspector should observe the ground reading taken at the cabinet terminal strip after all the grounding components are installed and connected, i.e. all ground rods installed, with grounding clamps or exothermic welds and grounding wire run to the cabinet. The ground should be tested using an approved method. A suggested method includes the following steps:

- ✓ Attach the Earth Resistance Meter (megger) to the ground wire that is in the cabinet.
- ✓ Place the megger where the primary grounding rod is installed.
- ✓ Ensure that an earth ground test is performed (150-foot minimum distance) to make sure the value meets contract specifications, which typically call for a value of less than 10 ohms. Sometimes driving another rod and bonding them together is necessary in rocky areas.
- ✓ Verify the meter reads a resistance that is within specification.
- ✓ If the reading is higher than acceptable, notify the on-site supervisor.

Cabinet Equipment

Once the equipment has been installed, the technician has wired the sensors to the terminal strip, as shown in Figure 48, and the technician has set up the WIM system in accordance with the manufacturer’s specifications, the QA inspector must ensure that the system is operating properly by doing the following:

- ✓ Reference the manufacturer’s WIM user or operations guide for instructions to verify the proper operation of the WIM system.

- ✓ Ensure the WIM system is correctly classifying vehicles, reporting accurate axle spacings and axle or by-wheel path weights.
- ✓ Ensure that the system is properly collecting, storing, and transmitting data to the host computer.
- ✓ Record on the QA checklist that each of the items above is acceptable.

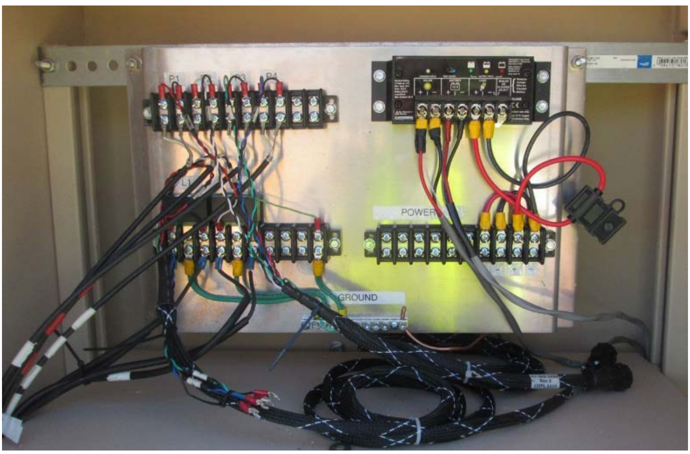

Figure 48 – Terminal Panel Labels and Connections

Initial Calibration

Calibration is the process of evaluating the measured weight and distance values reported by the WIM system against the known weights and axle spacings and making necessary adjustments to the WIM system operating parameters to compensate for those errors. Calibration is performed to ensure that the data accuracy remains consistent and within the performance specification. As a result of the calibration, the mean error in WIM measurements should be reduced to as close to zero as possible.

Since the WIM vendor or installer is usually obligated to perform the initial calibration of the system under the installation contract, it is recommended that the acceptance test criteria in section 6.4 of ASTM E1318-09 be included in the installation contract. The ASTM E1318-09 performance requirements were provided earlier in this document, in Table 1. In addition, it is important to have vehicle length measured within ±1.5 feet or within ±3 percent for vehicles greater than 50 feet long, based on LTPP specifications (4).

It is extremely important that the ASTM E1318-09 specification be followed closely for the initial calibration to ensure that the WIM system is providing the highest quality data possible. Other approved calibration methods may be used, if approved by the agency that initiated WIM installation.

Typically, the initial calibration is performed after a 2-week "burn-in" and after all initial "best guess" system settings have been entered. This allows the in-road sensor installation to "settle," the grout to fully cure, and the technician to determine if the system is operating as expected by analyzing a two-week data sample collected after the initial system settings were installed.

Just prior to the initial calibration, the QA Inspector should visually inspect each WIM system component and ensure that a complete electrical and operational test of the WIM system components are conducted:

- ✓ Inspect the in-road sensors from the shoulder.
- ✓ Audit the controller setup for proper settings.
- ✓ Check all cable connections.
- ✓ Test all sensor outputs.
- ✓ Observe passing vehicles in real time to verify reasonable weight, speed, and spacing measurement.

Critical items that the QA inspector should observe during the initial calibration include:

1. Measurement of Test Trucks
    a. A loaded FHWA class 9 truck or other heavy truck type that is most frequently observed at the site should be used. FHWA class 5 trucks are too light to be used as calibration vehicles, unless the WIM system is installed on a load-restricted road.
    b. Certified scales are used to obtain static weights, axle spacing, and overall length of test trucks.
    c. Truck tires and suspension are inspected for defects.
2. Pre-Calibration Test Runs
    a. The truck does not accelerate or decelerate in the WIM scale area and travels down the center of the travel lane.
    b. The test truck runs are conducted at the prevalent truck speeds and at the widest possible ranges of temperatures observed at the site.
    c. A sufficient number of pre-calibration runs are performed to quantify WIM measurement error percent: at least 10 test runs per truck, per lane.
3. Test Truck Run Data Analysis to Evaluate WIM Performance before Calibration
    a. For each test vehicle pass, the percent difference in the WIM-measured value and the corresponding reference value (i.e. static measurement) for each parameter listed in Table 1 Is calculated.
    b. Using all passes of the test vehicles over the sensors, the number of calculated differences that exceeded the tolerance value shown in Table 1 for each data item is determined and expressed as a percent of the total number of observed values of this item (i.e. percent of all test measurements for a given data item (example: Gross Vehicle Weight) that exceed the tolerance).
    c. If any specified WIM system function failed, or if more than 5 percent of the calculated differences for any applicable data item exceed the specified

tolerance for that item from Table 1, declare the WIM system as failed.

4. System Calibration
   a. Based on the WIM system measurement error calculated during Pre-Calibration runs, adjustments to the current WIM system weight and distance error compensation factors is calculated.
   b. New compensation factors are entered into the WIM system firmware for Post-Calibration testing.
5. Post-Calibration Test Runs and Evaluation
   a. Actions described in Step 3 are repeated to evaluate if WIM system met or failed ASTM E1318-09 tolerance requirements for 95 percent compliance after new compensation factors are installed. 20 or more post-calibration test truck runs is recommended. The number of runs may be reduced to 10 if the system demonstrates the following:
      - The speed dependency at each speed point has been eliminated or minimized (less than 2 percent average error for the each speed point).
      - The overall system bias computed based on the data from the available test runs is as close to zero as possible, (less than 2 percent error for the mean error).
      - None of the individual runs are outside of the ASTM E1318-09 tolerances for 95 percent compliance.
   b. Calibration process described in previous steps may be repeated until WIM system performance parameters are within tolerances specified in Table 1, up to 3 times if needed.
   c. The documented system settings and final calibration results should be stored in the cabinet.
   d. Save WIM data collected 2 to 4 weeks immediately after calibration to develop the comparison data set for future data quality control (QC).

Vehicle Classification Accuracy Validation

To validate accuracy of vehicle classification, use the following steps:

1. Obtain the agency's vehicle classification scheme or class tree to use for manual classification of vehicles.
2. Perform the vehicle classification testing during peak hours. Peak hours could be identified from the hourly truck volume data sample during pre-visit data analysis.
3. Collect a manual sample of at least 100 vehicles in FHWA vehicle classes 4 through 13 (using FHWA 13-bin classification), or as many samples as can be collected in 3 hours. In addition, collecting video of the traffic stream during manual study would be helpful for the follow-up analysis of misclassified vehicles.
4. During the manual data collection, record the vehicle ID and time stamp from the WIM records for any vehicle that does not match the classification from the manual observation.
5. Evaluate results using Method A or B.
    - Method A:
        a. Determine the total number of vehicle samples and the total number of misclassified vehicles in the manual sample for FHWA vehicle classes 4 through 13.
        b. Calculate the percent of misclassified vehicles in FHWA vehicle classes 4 through 13 in the manual sample. Compare misclassification percent for the sample with the agency's acceptable misclassification percent. The percentage of misclassified vehicles should be no greater than 2 percent.
        c. Calculate the number and percentage of vehicles in FHWA vehicle classes 4 through 13 in the manual sample that were not classified by

the WIM system. The percentage of unclassified vehicles should be no greater than 2 percent.

d. If fewer than 50 vehicles in classes 4 to 13 were observed in 3 hour period, record the number of vehicles that passed and failed classification and report that the minimum sample size to test classification was not met. In this case, 1 unclassified or misclassified vehicle can be allowed for classification test to pass.

- Method B:
  a. Calculate the percent of misclassified or unclassified vehicles in FHWA vehicle classes 4 through 13 in the manual sample.
  b. To pass the test, each individual class of vehicles from 4 through 13 may have a maximum 10 percent of misclassified vehicles.
  c. If the number of vehicles collected during the 3 hour testing period is under 30 for any vehicle class, use the following tolerance criteria for the maximum number of misclassified vehicles:
     - 20-29 for one class = +/-3 vehicles
     - 10-19 for one class = +/-2 vehicles
     - 0-9 for one class = +/-1 vehicle

6. Draw conclusions about whether the WIM system passed or failed the classification test. If the WIM system failed the classification test, analyze each misclassification instance by comparing individual vehicle records from the WIM output with the video images of moving trucks collected during manual study. Draw conclusion if changes to the WIM system's classification table are needed or if there are issues with the agency vehicle classification tree inputs.

WIM Site Acceptance and Reporting

Once all of the installation and initial calibration procedures have been completed, the QA inspector shall review the QA checklists with the installation supervisor to address any remaining "punch list" deficiencies that may still need to be addressed. Example QA checklists are available in the *LTPP Field Operations Guide for SPS WIM Sites (4)*.

Once all deficiencies have been addressed, the QA inspector should report about the completion of WIM site installation to the WIM program manager. The final acceptance should be reserved until the site has worked without any failures for 30 days. At the end of the successful 30-day testing period, the WIM program manager will accept the WIM site installation and verification as complete. Warranty periods should not commence until after the site has been fully accepted.

WIM Site Acceptance Report

After the WIM system installation has been completed, including calibration and acceptance testing, the QA inspector shall prepare a WIM system installation inspection report detailing all facets of the installation, including:

- Conduit and supporting structures installation.
- Sensor installation.
- Sensor electronic test readings.
- Support services electronic tests.
- Operational verification test results.
- Initial calibration report.
- Photographs.
- Non-compliance reports.
- As-built plans for future construction and maintenance work reference.
- Any approved exceptions.

The documented system settings and final calibration results should be stored in the cabinet.

WIM Site Non-Compliance Report

A Non-Compliance Report (NCR) template should be developed for routine use by QA Inspectors. The QA Inspector should use NCR template to document any refusals by the installation contractor to comply with the directions given by the QA inspector to resolve deficiencies. The report shall be signed by the contractor (installation supervisor) and immediately forwarded to the WIM program manager or other agency authority responsible for the installation project. An example of a non-compliance report is provided in Appendix D.

REFERENCES

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APPENDICES

The appendices for the FHWA WIM Pocket Guide are available on the FHWA website:

https://www.fhwa.dot.gov/policyinformation/knowledgecenter

General Appendices

- Appendix A – Technical Report Documentation Page Form DOT F 1700.7
- Appendix B – Acknowledgements

Part 1 Appendices:

- Appendix C – WIM Procurement Resources
    - Example WIM Contract Language (GDOT)
    - Example of IRD Standard Warranty Statement
    - Example of IRD WIM System Installation Standards

Part 2 Appendices:

- Appendix D – WIM Site Design and Installation Resources
    - Example Pavement Surfacing Plans (SDDOT)
    - Example Polymer Piezo Installation Plan
    - Example SLC Layout (Mettler-Toledo)
    - Example WIM Installation Standard (NJDOT)
    - Example WIM Site Design (MT DOT)
    - Example WIM Cabinet Wiring Diagram
    - Example Non-compliance Report

Part 3 Appendices:

- Appendix E – Maintenance and Calibration Resources
    - Example WIM Calibration Report (AZ DOT)
    - Example Calibration Test Truck Procurement (LTPP)

  - Example WIM Site Maintenance Forms and Reports (AZ DOT)

WIM Program Operation and Management Checklists

- Appendix F – WIM Program Operation and Management Checklists
  - WIM Technology Selection Table
  - WIM Site Selection Checklist
  - WIM Site Design Checklist
  - WIM Site Installation QA Checklist
  - Initial Calibration Checklist
  - WIM Site Acceptance Checklist
  - Test Truck Selection for WIM Calibration
  - Routine WIM Calibration Checklist
  - WIM Maintenance Tools, Materials, and Supporting Documentation
  - WIM Preventive Maintenance Checklist
  - WIM Troubleshooting Checklist
  - WIM Data QA/QC Checklist

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