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Standard Specification for Highway Weigh-In-Motion (WIM) Systems with User Requirements and Test Methods[1]

This standard is issued under the fixed designation E 1318; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

ϵ^1 NOTE—Editorial corrections applied throughout November 2000.

1. Scope

1.1 *Weigh-In-Motion*—This specification describes Weigh-In-Motion (WIM), the process of measuring the dynamic tire forces of a moving vehicle and estimating the corresponding tire loads of the static vehicle. Gross-vehicle weight of a highway vehicle is due only to the local force of gravity acting upon the composite mass of all connected vehicle components, and is distributed among the tires of the vehicle through connectors such as springs, motion dampers, and hinges. Highway WIM systems are capable of estimating the gross weight of a vehicle as well as the portion of this weight, called load in this specification; that is, carried by the tires of each wheel assembly, axle, and axle group on the vehicle.

1.2 *Other Traffic Data*—Ancillary traffic data concerning the speed, lane of operation, date and time of passage, number and spacing of axles, and classification (according to axle arrangement) of each vehicle that is weighed in motion is desired for certain purposes. It is feasible for a WIM system to measure or calculate these traffic parameters and to process, summarize, store, display, record, hard-copy, and transmit the resulting data. Furthermore, differences in measured or calculated parameters as compared with selected control criteria can be detected and indicated to aid enforcement. In addition to tire-load information, a WIM system is capable of producing all, or specified portions of, these traffic data.

1.3 *Standard Specification*—Highway WIM systems generally have three applications: collecting statistical traffic data, aiding enforcement, and enforcement. This specification classifies four types of WIM systems according to their application and details their respective functional, performance, and user requirements. It is a performance-type (end product-type) specification that says what is to be done—not how to do it. Exceptions and options to the specification may be included in any specification prepared by the user as part of the procurement process for WIM equipment or services, and vendors may offer exceptions and options in responding to an invitation to bid.

1.4 *Units*—The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units[2] which are provided for information only and are not considered standard.

1.5 The following precautionary caveat applies only to the test method portion, Section 7, of this specification. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

E 867 Terminology Relating to Vehicle-Pavement Systems[3]

2.2 *AASHTO Standards:*

AASHTO Interim Guide for Design of Pavement Structure—1972[4]

AASHTO Guide for Design of Pavement Structures—1993[4]

3. Terminology

3.1 *Definitions:*

3.1.1 *weigh-in-motion (WIM), n*—the process of estimating a moving vehicle's gross weight and the portion of that weight that is carried by each wheel, axle, or axle group, or combination thereof, by measurement and analysis of dynamic vehicle tire forces. (See Terminology E 867)

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *accuracy, n*—the closeness or degree of agreement (within a stated tolerance and probability of conformity) between a value measured or estimated by a WIM system and an accepted reference value.

3.2.2 *axle, n*—the axis oriented transversely to the nominal direction of vehicle motion, and extending the full width of the

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[2] Standard Practice for Use of the International System of Units (SI): The Modern Metric System, IEEE/ASTM SI 10-1997, The Institute of Electrical and Electronics Engineers, Inc., 345 East 47th Street, New York, NY 10017-2394, USA and American Society for Testing and Materials (ASTM), 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA, ISBN 1-55937-901-4.

[3] *Annual Book of ASTM Standards*, Vol 04.03.

[4] Available from American Association of State Highway and Transportation Officials, Washington, DC.

vehicle, about which the wheel(s) at both ends rotate.

3.2.3 *axle-group load, [lb (kg)], n*—the sum of all tire loads of the wheels on a group of adjacent axles; a portion of the gross-vehicle weight.

3.2.3.1 *Discussion*—An axle group can be defined in terms of the number of axles included in the group and their respective interspaces.

3.2.4 *axle load [lb (kg)], n*—the sum of all tire loads of the wheels on an axle; a portion of the gross-vehicle weight.

3.2.5 *dynamic vehicle tire force, [lb (kg)], n*—the component of the time-varying force applied perpendicularly to the road surface by the tire of a moving vehicle.

3.2.5.1 *Discussion*—In addition to the force of gravity, this force can include the dynamic effects of influences such as road surface roughness, vehicle acceleration, out-of-round tires, dynamically-unbalanced wheels, tire inflation pressure, vehicle suspension and aerodynamic features, and wind. For purposes of this specification, the WIM System shall be adjusted or calibrated to indicate the magnitude of the measured dynamic vehicle tire force in units of mass, lb (kg). (See 3.2.13.1).

3.2.6 *gross-vehicle weight, [lb (kg)], n*—the total weight of the vehicle or the vehicle combination including all connected components; also, the sum of the tire loads of all wheels on the vehicle. (See 3.2.13.1).

3.2.7 *single-axle load, [lb (kg)], n*—the load transmitted to the highway by the tires of all wheels lying between two parallel transverse vertical planes 3.3 ft (1 m) apart, extending across the full width of the vehicle; a portion of the gross-vehicle weight.

3.2.8 *tandem-axle load, [lb (kg)], n*—the total load transmitted to the highway by the tires on all wheels of two consecutive vehicle axles that are more than 3.3 ft (1 m) and not more than 8 ft (2.4 m) apart; a portion of the gross-vehicle weight.

3.2.9 *tire load, [lb (kg)], n*—the portion of the gross-vehicle weight imposed upon the static tire at the time of weighing, expressed in units of mass, due only to the vertically-downward force of gravity acting on the total mass of the static vehicle.

3.2.10 *tolerance, n*—the defined limit of allowable departure of a value measured or estimated by a WIM system from the true value.

3.2.11 *triple-axle load, [lb (kg)], n*—the total load transmitted to the highway by the tires on all wheels of three consecutive vehicle axles, with not more than 12 ft (3.7 m) between the two axles furthest apart; a portion of the gross-vehicle weight.

3.2.12 *weigh, v tr*—to measure the tire load on one or more tires by using a vehicle scale, an axle-load scale, a portable axle-load weigher, or a wheel-load weigher.

3.2.12.1 *Discussion*—Refer to Sec. 2.20, of *National Institute of Standards and Technology (NIST) Handbook 44* **(1)**[5] for a definition of each type of weighing device. These devices are usually subjected to field standard test weights at each locality of use and are adjusted to indicate units of mass (See Sec. 3.2, Appendix B, *NIST Handbook 44*).

3.2.13 *weight, [lb (kg)], n*—the external force of gravity acting vertically downwards upon a body with a magnitude equal to the body's mass multiplied by the local acceleration of free fall.[2]

3.2.13.1 *Discussion*—The force of gravity—thus, the acceleration of free fall—is different at various locations on or near the surface of Earth; therefore, weighing devices in commercial use or in official use by government agencies for enforcement of traffic and highway laws or collecting statistical information are usually used in one locality and are adjusted or calibrated to indicate mass at that locality. **(1)** The indicated mass can be converted to weight (in units of force) by multiplying by the local value of the acceleration of free fall, if it is known. The conventional value adopted by ISO is 9.806 65 m/s^2. Weight is a special case of force, as weight is due only to the local force of gravity, that is always directed vertically downwards. For purposes of this specification, and in accordance with common weighing practice, the WIM System shall be adjusted or calibrated to indicate the magnitude of estimated weight and load in units of mass, pounds [avoirdupois] (kilograms), and the direction of the associated force vector will always be downwards toward the approximate center of earth.

3.2.14 *wheel load, [lb (kg)], n*—the sum of the tire loads on all tires included in the wheel assembly on one end of an axle; a wheel assembly may have a single tire or dual tires.

3.2.15 *WIM System, n*—a set of sensors and supporting instruments that measures the presence of a moving vehicle and the related dynamic tire forces at specified locations with respect to time; estimates tire loads; calculates speed, axle spacing, vehicle class according to axle arrangement, and other parameters concerning the vehicle; and processes, displays, stores, and transmits this information. This standard applies only to highway vehicles.

4. Classification

4.1 *Types*—WIM systems shall be specified to meet the needs of the user for intended applications in accordance with the following types. Exceptions and options may be specified (See 1.3). All systems shall be designed to operate on 110V, ac, 60-Hz power, and lightening protection for affected system components shall be provided by the vendor. The user may specify as options a completely battery-powered system or battery-backup power in case of failure of normal power. All systems shall allow the user to select at the beginning of each data-taking session the units of measurement: either U.S. customary units or SI units[2]. The units setting shall remain where last assigned unless changed by the user at the beginning of a data-taking session. Load and weight values shall be expressed in units of mass: pounds [avoirdupois] in U.S. customary units, or kilograms in SI units. The SI recommends expressing large values of mass in megagrams, Mg. In commercial usage, which includes most applications and interpretations of WIM data, 1 Mg = 1000 kg = 1 metric ton = 1 tonne.

4.1.1 *Type I*—This type of WIM system shall be designed for installation in up to four lanes at a traffic data-collection site and shall be capable of accommodating highway vehicles moving at speeds from 10 to 80 mph (16 to 130 km/h), inclusive. For each vehicle processed, the system shall produce

[5] The boldface numbers given in parentheses refer to a list of references at the end of the text.

all data items shown in Table 1. A user-controlled feature of the system shall allow tire-force information from the wheel(s) on only one end of an axle to be used to estimate axle load. Provisions shall be made for entering selected limits and tolerances for wheel, axle, axle-group (including bridge-formula grouping **(2)**) loads, and gross-vehicle weights as well as speed, and for detecting and indicating suspected violation of any of these limits plus tolerance by a particular vehicle. A feature shall be provided so that the user can determine whether or not the WIM system will prepare selected data items for display and recording. Use of this feature shall not inhibit the system from receiving and processing data. Data shall be processed on-site in such a way that all data items shown in Table 1 can be displayed in alphanumeric form for immediate review. This may be accomplished by connecting a portable (for example, laptop) computer, furnished and supported by the vendor as a part of the WIM-system equipment, directly to the on-site instruments. Means shall be provided for temporary, on-site storage of data items 1, 5, 6, 8, 9, 10, and 11 for each vehicle processed by the WIM system, or for only those vehicles with a front-axle or front-wheel load that exceeds a value set into the on-site system by the user at the beginning of a data-taking session. Also, means shall be provided for rapid, efficient transfer of these data to files made available on a compatible host computer (furnished by either the user or the vendor, as specified for the specific site by the user) at a remote location according to an appropriate time schedule and data format specified by the user. The vendor shall furnish, document, and support software for use on the host computer for processing the transferred data items in such a way that all data items shown in Table 1 can be displayed in alphanumeric form for immediate review and subsequent use by the host computer user. This same software shall be provided on the portable computer for use when it is connected directly to the on-site instruments. On-site presentation of a hard-copy of all data items produced by the system shall be an optional feature (Option 1) of the system. Option 2 for this type of WIM system shall additionally provide means for counting and for recording hourly the lane-wise count of all vehicles traveling in each lane, up to a maximum of ten lanes, at a data-collection site, including lanes without WIM sensors. Option 3 shall provide for counting, classifying (via axle arrangement), measuring the speed of, and recording the hourly totals concerning all such vehicles by class (according to axle arrangement) and by lane of travel.

TABLE 1 Data Items Produced by WIM System

1.	Wheel Load
2.	Axle Load
3.	Axle-Group Load
4.	Gross-Vehicle Weight
5.	Speed
6.	Center-to-Center Spacing Between Axles
7.	Vehicle Class (via axle arrangement)
8.	Site Identification Code
9.	Lane and Direction of Travel
10.	Date and Time of Passage
11.	Sequential Vehicle Record Number
12.	Wheelbase (front-most to rear-most axle)
13.	Equivalent Single-Axle Loads (ESALs)
14.	Violation Code

4.1.2 *Type II*—This type of WIM system shall be designed for installation at traffic data-collection sites and should be capable of accommodating highway vehicles moving at speeds from 15 to 80 mph (24 to 130 km/h), inclusive. For each vehicle processed, all data items shown in Table 1 except Item 1 shall be produced by the system. All other features and options of the Type II WIM system shall be identical to those described in 4.1.1 for the Type I WIM system.

4.1.3 *Type III*—This type of WIM system shall be designed with sensors installed in one or two lanes off the main highway lanes at weight-enforcement stations to identify vehicles operating at speeds from 15 to 50 mph (24 to 80 km/h), inclusive, that are suspected of weight-limit or load-limit violation. Or alternatively, the sensors may be installed in the main lanes. In this case, the Type III system will not be required to measure vehicle acceleration, but it shall accommodate the same speed and accuracy criteria as a Type I system. For each vehicle processed, the system shall produce all data items shown in Table 1 except 7, 12, and 13 and shall also estimate acceleration (while the vehicle is over the WIM-system sensors). Provisions shall be made for entering selected limits and tolerances for wheel, axle, axle-group (including bridge-formula grouping **(2)**) loads, and gross-vehicle weight as well as speed and acceleration, and for detecting and indicating suspected violation of any of these limits plus tolerance by a particular vehicle. Means shall be provided for automatically controlling official traffic-control devices that will direct each suspect vehicle to a scale for confirmation weighing and guide all non-suspect vehicles past the scale without stopping. Manual operation of these official traffic-control devices shall be included as a feature of the Type III WIM system. Information used in determining a suspected violation shall be displayed in alphanumeric form for immediate review and recorded permanently. Option 1 shall provide means for presenting this information in hard-copy form if requested by the system operator. Option 2 may be specified to exempt the Type III WIM system from producing wheel-load information (Item 1 in Table 1) if this data item is not of interest for enforcement. Option 3 for this type of WIM system shall provide for recording the following data items shown in Table 1 for every vehicle processed by the system: 1 (2 in lieu of 1 when Option 2 is specified), 5, 6, 8, 9, 10, and 11. These basic-data items allow subsequent computation of statistical traffic data.

4.1.4 *Type IV*—This type of WIM system has not yet been approved for use in the U.S.A., but for conceptual development purposes, it shall be designed for use at weight-enforcement stations to detect weight-limit or load-limit violations. Speeds from 0 to 10 mph (0 to 16 km/h), inclusive, shall be accommodated. For each vehicle that is processed, the system shall produce all data items shown in Table 1 except 7, 9, 12, and 13 and shall also estimate acceleration (while the vehicle is over the WIM-system sensors). Provisions shall be made for entering and displaying selected limits and tolerances for wheel, axle, axle-group (including bridge-formula grouping **(2)**) loads, and gross-vehicle weights as well as speed and acceleration, and for detecting and indicating violation of any of these limits and tolerances by a particular vehicle. Information used in determining a violation shall be displayed in alphanumeric form for immediate review and recorded permanently. Option 1 shall provide means for presenting this information in hard-copy form if requested by the system operator. Option 2 may be specified to exempt the Type IV WIM system from producing wheel-load information (Item 1 in Table 1) if this data item is not of interest for enforcement.

5. Performance Requirements

5.1 *Accuracy*—Each type of WIM system shall be capable of performing the indicated functions within the accuracy shown in Table 2. A test method for determining compliance with these requirements under prevailing site conditions is given in Section 7. The stated accuracy should be maintained for ambient air temperatures at the WIM site from –20 to 120 °F (–28 to 50 °C); however, the user shall specify at the time of system procurement the range of temperatures within which the WIM system must operate properly. The vendor shall supply evidence that the system offered is capable of compliance. After computation of the data items shown in Table 2, no digit that indicates less than 100 lb (50 kg) (load or weight), 1 mph (2 km/h) (speed), or 0.1 ft (0.03 m) (axle spacing) shall be retained.

5.2 *Vehicle Class*—Vehicle classification according to axle arrangement shall be accomplished by Type I and Type II WIM systems. The vendor shall incorporate software within each Type I and Type II WIM system for using the available WIM-system axle-count and axle-spacing information for estimating the Federal Highway Administration (FHWA) Vehicle Types described briefly in Table 3. See *U.S. Department of Transportation Traffic Monitoring Guide* **(2)** for the complete description of FHWA Vehicle Types. The axle-spacing values used for this process shall be associated with each vehicle classified via the software. The values shall be made readily accessible to the user, and a means shall be provided for the user to modify the values easily. The FHWA Vehicle Type shall be indicated by the 2-Digit Code shown in Table 3. A vehicle type code 14 shall be applied to any vehicle that the software fails to assign to one of the types shown.

5.3 *Site Identification Code*—Provisions shall be made in Type I, Type II, Type III, and Type IV WIM systems for entering, displaying, and recording a ten-character alphanumeric site identification code for each data-taking session. This code can be used to incorporate information required for FHWA Truck Weight Data Collection **(2)**.

5.4 *Lane and Direction Code*—A lane and direction-of-travel code for each vehicle processed by Type I, Type II, and Type III WIM systems shall consist of a number beginning with 1 for the right-hand northbound or eastbound traffic lane and continuing until all the lanes in that direction of travel have been numbered; the next sequential number shall be assigned to the lanes in the opposite direction of travel beginning with the left-hand lane and continuing until all lanes have been numbered. Provision shall be made for 12 numbers in the code. This code may be used to incorporate information required for FHWA Truck Weight Data Collection **(2)**.

TABLE 3 FHWA Vehicle Types

2-Digit Code	Brief Description
01	Motorcycles
02	Passenger Cars
03	Other Two-Axle, Four-Tire Single Unit Vehicles
04	Buses
05	Two-Axle, Six-Tire, Single Unit Trucks
06	Three-Axle, Single Unit Trucks
07	Four-or-More Axle Single Unit Trucks
08	Four-or-Less Axle Single Trailer Trucks
09	Five-Axle Single Trailer Trucks
10	Six-or-More Axle Single Trailer Trucks
11	Five-or-Less Axle Multi-Trailer Trucks
12	Six-Axle Multi-Trailer Trucks
13	Seven-or-More Axle Multi-Trailer Trucks
14	Not Classified

5.5 *Date*—Date of passage shall be indicated numerically for each vehicle processed by Type I, Type II, Type III, and Type IV WIM systems in the following format: MM/DD/YY, where M is the month, D is the day, and Y is the year.

5.6 *Time*—Time of passage shall be indicated numerically for each vehicle processed by Type I, Type II, Type III, and Type IV WIM systems in the following format: hhmm:ss, where h is the hour beginning with 00 at midnight and continuing through 23, m is the minute, and s is the second.

5.7 *Vehicle Record Number*—Type I, Type II, Type III, and Type IV WIM systems shall provide sequential-numbering (user-resettable) for each recorded vehicular data set.

5.8 *Wheelbase*—Type I and Type II WIM systems shall compute wheelbase as the sum of all axle spacings between centers of the front-most and the rear-most axles on the vehicle or combination that have tires in contact with the road surface at the time of weighing. This value shall be rounded to an integer value (in feet) (or to the nearest 0.1 m) before display or recording.

5.9 *ESALs*—Type I and Type II WIM systems shall compute Equivalent Single-Axle Loads (ESALs) using American Association of State Highway and Transportation Officials (AASHTO) procedures (see 2.2 and **(3, 4)**). for single, tandem, and triple axles for both flexible and rigid pavements, and

TABLE 2 Functional Performance Requirements for WIM Systems

Function	Tolerance for 95 % Probability of Conformity				
	Type I	Type II	Type III	Type IV	
				Value ≥lb (kg)[A]	±lb (kg)
Wheel Load	± 25 %		± 20 %	5000 (2300)	300 (100)
Axle Load	± 20 %	± 30 %	± 15 %	12 000 (5400)	500 (200)
Axle-Group Load	± 15 %	± 20 %	± 10 %	25 000 (11 300)	1200 (500)
Gross-Vehicle Weight	± 10 %	± 15 %	± 6 %	60 000 (27 200)	2500 (1 100)
Speed	± 1 mph (2 km/h)				
Axle-Spacing	± 0.5 ft (0.15 m)				

[A] Lower values are not usually a concern in enforcement.

provision shall be made for the user to select one of these pavement types for application at the beginning of any given data-processing session. These computations must be made using only U.S. customary units. The system shall compute the total ESALs for each vehicle or vehicle combination and prepare these data for display as part of each vehicle record. When displayed, this value shall be truncated to two digits following the decimal and presented in the following format: FESAL = for flexible pavements, and RESAL = for rigid pavements. The parameter for serviceability at the end of time *t*, P_t, shall be adjustable by the user, but 2.5 shall be programmed as a default value. Similarly, the value for structural number, *SN*, used for computing flexible pavement equivalency factors shall be user adjustable, but shall be defaulted to 5.0 (see 2.2). The value for thickness of rigid pavement slab, *D*, used in computing rigid pavement equivalency factors shall be user adjustable, and shall be defaulted to 9.0 in. (see 2.2) in the WIM-system program. Provision shall be made in the program to list on demand all parameters actually utilized in the ESAL computation during any given data-processing session.

5.10 *Violations*—Violations of all user-set parameters plus tolerance shall be determined by Type I, Type II, Type III, and Type IV WIM systems. A 2-character violation code, such as shown in Table 4, shall be used for each detected violation and shall be included in the displayed data. Provision shall be made for the user to define up to 15 violation codes. An additional optional feature that calls attention to any data items that are in violation of user-set limits plus tolerance may be specified by the user, for example, flashing, underlining, bold-facing, or audio tones.

5.11 *Acceleration*—Type III and Type IV WIM systems shall measure vehicle acceleration, which is a change in velocity. Negative acceleration is also called deceleration. The forces acting on a vehicle to produce acceleration can effect significant change in the distribution of the gross-vehicle weight among the axles and wheels of the vehicle as compared to the distribution when the vehicle is static. Therefore, any severe acceleration while the vehicle is passing over the WIM-system sensors can invalidate wheel and axle loads estimated by the system. Average acceleration of 2 ft/s^2(0.6 m/s^2) or greater during the time that the wheelbase (see 5.8) of the vehicle is passing over the tire-force sensors should be considered as a violation. This value shall be user-adjustable, but the vendor shall program 2 ft/s^2(0.6 m/s^2) as the default value in these WIM systems.

5.12 *User-Assignable Code*—For Type I, Type II, Type III, and Type IV WIM systems, provision shall be made to allow manual entry of a user-assignable three-digit code into any vehicular data set prior to recording.

TABLE 4 Violation Code

Violation	Code
Wheel Load	WL
Axle Load	AL
Axle—Group Load	AG
Gross-Vehicle Weight	GV
Bridge—Formula Load	BF
Over Speed	OS
Under Speed	US
Acceleration	AC
Deceleration	DE

5.13 *Tire-Force Sensor*—As the tires of a vehicle being weighed in motion might travel anywhere between the instrumented traffic lane edges, it is necessary for the magnitude of the signal from the tire-force sensor(s) in the lane to be the same (within tolerance) for a given applied tire force(s), regardless of the lateral position of the tire(s) within the lane, if consistent load and weight estimates are to be made by a WIM system.

5.13.1 Therefore, the user shall specify that every tire-force sensor installed for use with a Type I, Type III, or Type IV WIM system shall be certified by the vendor to have been tested prior to installation and found to produce signals that were proportional to simulated tire load at three levels of load (10, 50, and 90 % of rated capacity) when each level of load, known to be within 0.25 % of its true value, was applied at five equally-spaced intervals laterally along each half-lane-width portion; nominally, 6 ft (1.8 m); of the sensor. The maximum allowable difference (tolerance) between the highest and the lowest of the five signal values at any load level shall be 1 percent of the highest value.

5.13.2 The user shall specify that every sensor, usually a piezo-type axle-load sensor, nominally 12 ft (3.6 m) long to cover a full lane width, installed for use with a Type II WIM system shall be certified by the vendor to have been tested under known impact loads applied at multiple, evenly-spaced intervals along the length of the sensor prior to installation and found to meet Class I signal-uniformity tolerances (better than seven percent) **(5)**.

6. User Requirements

6.1 *Site Conditions*—In order for any WIM system to perform properly, the user must provide and maintain an adequate operating environment for the system's sensors and instruments. Construction or selection of each WIM site, as well as continuing maintenance of the site and the sensors, are extremely important user considerations. The following site conditions, or better, shall be provided by the user if the performance criteria given in this specification are to be realized, consistently. The user must recognize that the performance of the WIM system depends uniquely upon the quality of the sensors and their prevailing operating environment. System performance is degraded by less-than-ideal site conditions, even though the WIM-system sensors, instruments, and algorithms are capable of high-quality performance. The user can require quality of performance only in proportion to the quality of the site conditions provided.

6.1.1 *Horizontal Alignment*—The horizontal curvature of the roadway lane for 200 ft (60 m) in advance of and 100 ft (30 m) beyond the WIM-system sensors shall have a radius not less than 5700 ft (1.7 km) measured along the centerline of the lane for all types of WIM systems.

6.1.2 *Longitudinal Alignment (Profile)*—The longitudinal gradient of the road surface for 200 ft (60 m) in advance of and 100 ft (30 m) beyond the WIM system sensors shall not exceed 2 % for Type I, Type II, and Type III WIM-system installations, and shall not exceed 1 % for Type IV installations.

6.1.3 *Cross Slope*—The cross-slope (lateral slope) of the road surface for 200 ft (60 m) in advance of and 100 ft (30 m) beyond the WIM-system sensors shall not exceed 3 % for Type I, Type II, and Type III WIM system installations, and shall not exceed 1 % for Type IV installations.

6.1.4 *Lane Width and Markings*—The width of the paved roadway lane for 200 ft (60 m) in advance of and 100 ft (30 m) beyond the WIM-system sensors shall be between 12 and 14 ft (3.6 and 4.3 m), inclusive. For Type III, except those with sensors in the main highway lanes, and Type IV WIM systems, the edges of the lane throughout this distance shall be marked with solid white longitudinal pavement marking lines 4 to 6 in. (100 to 150 mm) wide. At least 3 ft (1 m) of additional clear space for wide loads shall be provided on each side of the WIM-system lane.

6.1.5 *Surface Smoothness*—To allow reliable WIM-system performance within the tolerances shown in Table 2, the surface of the paved roadway 200 ft (60 m) in advance of and 100 ft (30 m) beyond the WIM-system sensors shall be smooth before sensor installation and maintained in a condition such that a 6-in. (150-mm) diameter circular plate 0.125-in. (3 mm) thick cannot be passed beneath a 20-ft (6-m) long straightedge when the straightedge is positioned and maneuvered in the following manner:

6.1.5.1 Beginning at the longitudinal center of the WIM-system sensors, or sensor array, place the straightedge along each respective lane edge with the end furthest from the sensors at the distances from the longitudinal center of the sensors as indicated below, pivot the straightedge about this end, and sweep the end nearest the sensors between the lane edges while checking clearance beneath the straightedge with the circular plate.

Lane Edge	Longitudinal distance from Center of Sensors, ft (m)
Right	20, 30, 44, 60, 76, 92, 108, 124, 140, 156, 172, 188, 204 (6, 9, 13, 18, 23, 28, 33, 38, 43, 48, 53, 58, 62)
Left	20, 36, 52, 68, 84, 100, 116, 132, 148, 164, 180, 196, 212 (6, 11, 16, 21, 26, 30, 35, 40, 45, 50, 55, 60, 65)

6.1.6 *Pavement Structure*—The user shall provide and maintain an adequate pavement structure and surface smoothness to accommodate the WIM-system sensors throughout their service life and shall install and maintain the sensors in accordance with the recommendations of the system vendor. Experience has indicated that a Portland cement concrete (also called rigid) pavement structure generally retains its surface smoothness over a longer period of time than a bituminous (also called flexible) pavement structure under heavy traffic at a WIM site. Consideration should be given to providing a 300-ft (90-m) long continuously reinforced concrete pavement (CRCP) or a jointed concrete pavement (JCP), with transverse joints spaced 20 ft (6 m) or less apart, at permanent WIM sites on freeways and principal arterial highways. (See Terminology E 867 for definitions of pavement types.) The surface of every such rigid pavement should be ground smooth after curing and before installing WIM sensors. The user should assure that the skid resistance (See Terminology E 867) of the surface after grinding is at least as good as that of the adjacent surfaces. At a site with flexible pavement, a 50-ft (15-m) long section comprising full-depth-asphalt, or black-base, design should be considered for installation at each end of the Portland cement concrete pavement structure to effect a stiffness transition between the two pavement structural types. Maintenance, replacement, or repair activity at a WIM site under traffic is hazardous and expensive; therefore, the installation should be done right the first time.

6.1.7 *Instrument Environment*—The user shall provide and maintain a climatic environment for the WIM-system instruments in accordance with those specified by the user and agreed upon by the system vendor.

6.1.8 *Power*—The user shall provide and maintain an adequate 110V, ac, 60-Hz electrical power supply at each WIM site, or specify an optional battery-powered system as suggested in 4.1, or both.

6.1.9 *Data Communication*—The user shall provide and maintain an adequate data communication link between the WIM site and the remote host computer where data will be processed. This link can also serve to monitor the performance of the WIM system and adjust its settings from a remote location.

6.1.10 *Temperature Range*—The user shall specify the reasonable maximum and minimum ambient air temperatures in which the WIM system being procured will be operated, and the vendor shall supply evidence that the system offered is capable of performing properly within this temperature range.

6.2 *Options, Exceptions, and Additional Features*—Any desired optional features described in Section 4 and Section 5, any exceptions, and any additional features of the WIM system shall be specified by the user. The user shall also specify the data items to be included in the display, the number of vehicle records to be displayed simultaneously, and whether the ability to hold a selected record(s) on display without interference with continuous data taking by the system is required. The user should note that the number of data items selected will affect the number of vehicle records that can be displayed simultaneously.

6.3 *Recalibration*—The user shall recalibrate every WIM system following any maintenance or relocation, and at a minimum annually. Abrupt or unusual changes in data patterns can also indicate the need for recalibration. Recalibration of system Types I, II, and III should be performed in accordance with the method presented in 7.5, and system Type IV should be recalibrated in accordance with the method presented in 7.4.5 to ensure consistent performance.

6.4 *Acceptance Test*—As part of every new WIM system procurement contract, or any major modification contract on an existing system, the user shall specify the test method and the schedule for testing that will be accomplished prior to final acceptance by the user and final payment to the vendor. This test shall be conducted on-site by the user or the user's authorized representative in cooperation with the vendor, after the system has been installed or modified and calibrated (see 7.5). The specification shall state clearly the proportions of initial-calibration and acceptance-test expenses to be borne by the user and by the vendor, including the expenses for providing and operating test vehicles and for traffic control. The On-site Acceptance Test described in 7.6 may be referenced for this purpose.

6.4.1 *Implications of a Type-Approval Test*—The acceptance-test specification should require that the WIM system being offered by the vendor pass a rigorous type-approval test, conducted under excellent site conditions (see 6.1), to demonstrate that the system is capable of performing adequately under such conditions. This test verifies the functionality of all features of the system, as well as its highest potential accuracy when the sensors are subjected to loads from a wide range of vehicle types. If the vendor provides credible evidence that the type and model of system being offered has already successfully passed the applicable Type-approval Test described in Section 7 and the user provides site conditions that meet or exceed those given in 6.1, the system will be expected to perform at the site within the tolerances stated in Section 5. If it fails to perform within these tolerances in an on-site acceptance test where the site conditions meet or exceed those given in 6.1, the indication is that the installed system is faulty and the vendor shall be responsible for corrective action. However, if the vendor does not provide evidence of previous type-approval testing, the user will not be assured of the capability of the system and shall either require conduct of a type-approval test (expenses to be negotiated) wherein the user shall provide appropriate site conditions (see 6.1), or reach an agreement with the vendor before the on-site acceptance test begins as to the specific, quantified tolerance values that will be acceptable if the site conditions provided by the user do not meet or exceed those given in 6.1. In the latter case, the responsibility for inadequate WIM-system performance can lie with the vendor, the user, or both.

6.4.2 *On-Site Acceptance Test*—The On-site Acceptance Test described in 7.6 may be used in lieu of a full type-approval test under the circumstances outlined in 6.4.1. It is an abbreviated form of the Type-approval Test that indicates primarily the effects of the prevailing site conditions upon the performance of a capable WIM system.

7. Test Methods for WIM System Performance

7.1 *Scope*—Test methods for evaluating the performance of each type of WIM systems are presented in this section. Procedures are given for conducting a Type-approval Test (see 7.2, 7.3, 7.4) for any new or modified type or model WIM system, and an On-site Acceptance Test (see 7.6) for newly-installed equipment at a site. Also included in this section is a procedure for on-site calibration (see 7.5)—to remove as much bias as practicable from the weight, load, and axle-spacing estimates—to be used at the time of system installation or whenever site conditions or equipment have changed. Both tests and the calibration procedure require weighing and measuring static vehicles to determine reference values against which WIM-system-estimated values will be compared. The recommended procedure for weighing static vehicles is outlined next.

7.1.1 *Apparatus for Weighing Static Vehicles*—When wheel-load data are required from the WIM system, the corresponding reference tire-load values for Type I, Type III, and Type IV WIM systems shall be determined with wheel-load weighers that meet the respective tolerance specification of *NIST Handbook 44*. **(1)** The minimum number of wheel-load weighers required is 2 and the preferred minimum number is 6. Alternatively, an axle-load scale or a multi-platform vehicle scale that has approaches and aprons adjacent to the load-receiving platform(s) that can support the tire-pavement contact surfaces of all tires on the vehicle being weighed as described in 7.1.2 may be used to weigh wheel loads on one end of an axle by positioning the wheel(s) on the other end of the axle on the adjacent apron. When this alternative technique is used, the wheel loads on both ends of the axle shall be determined, and then used only to apportion the measured axle load between the wheels on each end of the axle. When wheel-load data are not required, axle-load scales, multi-platform vehicle scales, portable axle-load weighers, or a pair of wheel-load weighers that meet the respective tolerance specification of *NIST Handbook 44*, **(1)** shall be used for obtaining reference tire-load values for Type II and Type III WIM systems. Either an axle-load scale or a multi-platform vehicle scale, along with wheel-load weighers if required, shall be used for measuring reference tire-load values for Type III and Type IV WIM systems.

7.1.2 *Use of Apparatus for Weighing Static Vehicles*—The tire-pavement contact surfaces of all tires on the vehicle being weighed shall be within 0.25 in. (6 mm) of a plane passing through the load-receiving surface(s) of the multi-platform vehicle scale, wheel-load weighers, portable axle-load weighers, or axle-load scales whenever any tire-load measurement is made. The maximum slope of this plane from horizontal shall be 2 %. Suitable blocking or mats may be utilized, or the weighing device(s) may be recessed into the pavement surface to provide the required vertical orientation of the tire-pavement contact surfaces. When wheel-load information is required, wheel and axle load shall be measured simultaneously using a pair of wheel-load weighers. When wheel-load information is not required, axle-load shall be determined by positioning each axle to be weighed either simultaneously or successively on an axle-load scale(s), a multi-platform vehicle scale, a portable axle-load weigher(s), or a pair(s) of wheel-load weighers. Axle-group load shall be determined either by positioning all axles in the group simultaneously on the required number of weighing devices (preferred) or by successively positioning each axle in the group on a pair of wheel-load weighers or on an axle-load weighing device. The number of movements of the vehicle to accomplish the successive tire-load measurements shall be minimized. A tire-load measurement shall be made only when the brakes of the vehicle being weighed are fully released and all tires are properly positioned on the load-receiving surface(s) of the weighing device(s). Suitable means (for example, chocks) shall be used to keep the tires properly positioned while the brakes are released. Gross-vehicle weight shall be the sum of all wheel loads or axle loads for the vehicle. No tire-load measurement shall be taken until oscillations induced by inertial forces (for example, via a load of undulant liquid) of the vehicle have subsided to a point that indicated tire load is changing less than three scale divisions in 3 s.

7.1.3 *Procedure for Weighing and Measuring Test Vehicles to Obtain Reference Values*—Two test vehicles (see 7.5.3) are used for the Calibration Procedure, the Type-approval Test, and the On-site Acceptance Test. The following procedure shall be applied for obtaining reference load, weight, and axle-spacing values for each of the static test vehicles.

7.1.3.1 Measure the center-to-center spacing between successive axles on each test vehicle and record these data to the nearest 0.1 ft (0.03 m) as axle-spacing reference values.

7.1.3.2 Weigh each test vehicle three times, with brakes released, as described in 7.1.1 and 7.1.2 to measure tire loads for the wheel(s) on each end of every axle on the static vehicle. Move the vehicle completely away from the scale or weigher before beginning a new set of tire-load measurements, and always approach the weighing devices from the same direction for weighing. Sum the applicable tire loads to determine wheel, axle, and tandem-axle loads as well as gross-vehicle weight each time the vehicle is weighed.

7.1.3.3 Calculate the arithmetic mean for all wheel load, axle-load, tandem-axle-load, and gross-vehicle-weight values that resulted from weighing each test vehicle three times; also calculate the difference, in percent, from this mean of each individual value used in calculating the respective mean.

7.1.3.4 Compare these percent differences from the mean to the following specified limits for each applicable load or weight value for each test vehicle: gross-vehicle weight = ± 2 %, tandem-axle load = ± 3 %, axle load = ± 4 %, and wheel load = ± 5 %. These limits define a practicable range into which an individual observation must fall in order to demonstrate that the weighing process for the static vehicle is producing results that are suitable for use as reference-value loads and weights against which WIM-system estimates will be evaluated.

7.1.3.5 If any of the measured or calculated load or weight values exceeded the specified range, correct deficiencies in the reference-value weighing process and weigh each test vehicle three more times.

7.1.3.6 Repeat 7.1.3.5 until the weighing process yields reference-value loads and weights that are within the specified range.

7.1.3.7 For reference-value loads and weights against which to compare WIM-system estimates, use the calculated arithmetic mean value for the respective wheel load, axle-load, tandem-axle-load, and gross-vehicle-weight values that resulted from successfully weighing each test vehicle three times.

7.2 *Type-Approval Test for Type I and Type II WIM Systems*:

7.2.1 *Scope*—The type-approval test described here is for evaluating the performance capabilities of a new type or model WIM system under excellent site conditions and under traffic loading that is representative of that which will be of interest where Type I and Type II WIM systems will usually be applied. Performance requirements for each type of WIM system are given in Section 5 of this specification, and associated user requirements are given in Section 6. The WIM system being evaluated in the type-approval test shall be subjected to a loading test unit comprising two test vehicles plus approximately 51 additional vehicles selected from the traffic stream at the type-approval test site. Other types of vehicles may be added to the loading test unit by the user who is conducting the test at any type-approval test site where large numbers of vehicles in classes not already included are operating. Likewise, the user conducting the test may eliminate vehicles of a particular class(s) from the loading test unit if none appears at the site within a practicable duration of the test. For each vehicle eliminated, one of another class prevalent at the site shall be added to maintain a total of 51 vehicles in the loading test unit. The two test vehicles, that will make multiple passes over the WIM-system sensors at the minimum and at the maximum speed specified by the user between 10 to 80 mph (16 to 130 km/h), and at intermediate speeds, provide a basis for evaluating the performance of the WIM system over a range of speeds. The additional vehicles included in the loading test unit serve the function of subjecting the WIM system to loading by a representative variety of vehicle classes. All vehicles comprising the loading test unit shall be weighed statically on certified weighing devices as described in 7.1.1, 7.1.2, and 7.1.3 at a suitable site within reasonable proximity to the type-approval test site.

7.2.2 *Significance and Use*—Interpretation of the results from the type-approval test will allow the user to determine whether the tested Type I or Type II WIM system is capable of meeting or exceeding the performance requirements stated in Section 5. This can also indicate the potential upper limit of performance that can be achieved by the particular type and model of system, as the road surface conditions that potentially affect the location and magnitude of dynamic tire forces significantly, shall be the best available for conducting the type-approval test and shall, as a minimum, satisfy the user requirements given in Section 6.

7.2.3 *Site for Type-Approval Test*—Both the user (or a recognized representative of user's interests) and the vendor shall approve the type-approval test site as well as the WIM-system installation prior to conducting the type-approval test. The actual road-surface and WIM-system sensor conditions that prevail in each lane during type-approval testing shall be documented in terms that verify compliance with the user requirements given in 6.1.

7.2.4 *Test Unit for Type-approval Test Loading*—The test unit for loading the WIM system being evaluated in the type-approval test shall comprise two test vehicles (see 7.5.3) that will make multiple runs over the WIM-system sensors at prescribed speeds along with other vehicles selected in random order from the traffic stream at the type-approval test site. The number of vehicles in each Vehicle Class (see 5.2) to be selected in random order from the traffic stream for inclusion in the test unit is shown in Table 5. See 7.2.1 concerning modification of the loading test unit.

TABLE 5 Composition of Test Unit for Type-Approval Test Loading of WIM Systems

Vehicle Class	Number of Selected Vehicles
05	5
06	5
08 (2S1)[A]	4
08 (2S2)	4
08 (3S1)	4
09 (3S2)	20
11 (2S1-2)	3
12 (3S1-2)[B]	3
13	3

[A] Two-axle tractor, single-axle semi trailer.
[B] Three-axle tractor, single-axle semi trailer, two-axle full trailer.

7.2.5 *Calibration and Certification*—Within 48 h prior to beginning the type-approval test, the WIM system shall be calibrated in accordance with the calibration procedure presented in 7.5.

7.2.6 *Procedure*—The following steps shall be performed in conducting the type-approval test.

7.2.6.1 As a joint effort between the user (or a recognized representative of user's interests) and the vendor, select the best available WIM-system site that, as a minimum, meets the applicable requirements stated in 6.1.

7.2.6.2 Ensure that a suitable site for weighing vehicles statically is available within a reasonable distance of the WIM site, that traffic can be controlled safely at this location, and that test vehicles can turn around safely and conveniently for multiple passes. Obtain approval from the public authority having jurisdiction over the site for the traffic control procedures that will be used during testing. Provide facilities at this site for weighing all vehicles in the loading test unit (see 7.1.1).

7.2.6.3 Install the WIM system in accordance with the vendor's recommendations and execute the calibration procedure that is presented in 7.5.

7.2.6.4 After agreement by both the user and the vendor, install the settings defined in 7.5.5.5 on the WIM-system.

7.2.6.5 Using traffic control procedures approved by the appropriate public authority and other reasonable safety precautions, have each test vehicle make five runs over the sensors in each lane at an attempted speed approximately 5 mph (8 km/h) less than the maximum speed, and then five more runs at an attempted speed approximately 5 mph (8 km/h) greater than the minimum speed, used during calibration (see 7.5.5.3). Weigh each test vehicle statically after or before every run over the WIM sensors (see 7.1.2). Record all data, and correlate the WIM-system vehicle record number for every run of each test vehicle with the corresponding static weighing record.

7.2.6.6 For reference speed values, measure the speed of the test vehicle each time it passes over the WIM-system sensors with a calibrated radar speed meter or by some other means (such as wheelbase/time) acceptable to both the user (or a recognized representative of user's interests) and the vendor, and record the observed speed.

7.2.6.7 Make the calculations shown in 7.2.7 for the 20 runs (five runs at two speeds by two vehicles) of the test vehicles and compare the functions and performance of the WIM system with all specification requirements, including speed and axle spacing. See Section 4 for functions and Section 5 for performance tolerances.

7.2.6.8 If any WIM-system function or more than 5 % of the load, weight, or axle-spacing values resulting from all test-vehicle runs fails to satisfy the specification, declare that the system failed to meet specification requirements. At least 95 % of all WIM-system-estimated values, including those resulting from the 51 additional vehicles that will be selected from the traffic stream, must meet the specified tolerances for type approval of the system. Report the test results to ASTM as in 7.2.8.

7.2.6.9 If continuation is approved, select vehicles from the traffic stream to complete the makeup of the test unit for type-approval test loading as specified in 7.2.4.

7.2.6.10 Allow each of the selected vehicles to pass over the WIM-system sensors at normal speed and require each vehicle to stop for weighing (see 7.1.1 and 7.1.2) and for measurement of axle spacing (see 7.1.3.1).

7.2.6.11 Make the calculations shown in 7.2.7 and compare the performance of the WIM system with the specification requirements stated in Section 5 for the remainder of the vehicles in the type-approval test unit.

7.2.6.12 Interpret and report the results as described in 7.2.8.

7.2.7 *Calculation*—Calculation is needed for defining the reference-value loads and weights of the static vehicle with which to compare WIM-system-estimated values, and evaluating conformity of data items produced by the WIM-system to specification requirements.

7.2.7.1 *Procedure for Calculating Reference-Value Loads and Weights*—Only certified weighing devices shall be utilized for determining reference-value tire loads. Reference-value loads and weights are calculated by summing tire loads. For WIM systems that produce estimates of wheel loads, calculate reference-value axle load by summing two wheel loads, axle-group load by summing the wheel loads for all wheels in each axle group, and gross-vehicle weight by summing the wheel loads for all wheels on the vehicle. For WIM systems that do not produce estimates of wheel loads, sum the appropriate axle loads to calculate axle-group loads and gross-vehicle weight, if wheel-load weighers are not used. If wheel-load weighers are used, use the procedure stated above for summing tire loads.

7.2.7.2 *Procedure for Calculating Percent of Non-Conforming Data Items*—For each data item that is produced by the WIM system and shown in Table 2, calculate the percent difference in the value and the corresponding reference value by the following relationship:

$$d = 100[(C - R)/R] \quad (1)$$

where:

d = difference in the value of the data item produced by the WIM system and the corresponding reference value expressed as a percent of the reference value, %,

C = value of the data item produced by the WIM system, and

R = corresponding reference value for the data item.

7.2.7.3 Determine the number of calculated differences that exceeded the tolerance shown in Table 2 for each data item and express this number as a percent of the total number of observed values of this item by the following relationship:

$$P_{de} = 100[n/N] \quad (2)$$

where:

P_{de} = percent of calculated differences that exceeded the specified tolerance value,

n = number of calculated differences that exceeded the specified tolerance value, and

N = total number of observed values of the data item.

7.2.8 *Interpretation of Test Results and Report*—If any specified WIM-system function failed, or if more than 5 % of the calculated differences for any applicable data item (specified in Section 4) resulting from all passes of the two test vehicles (each vehicle made five passes at two difference speeds) and from the single pass of each selected vehicle over the sensors at normal speed exceed the specified tolerance (specified in Section 5) for that item, declare the WIM system dysfunctional or inaccurate and report that it failed the type-approval test. Regardless of whether the system fails or passes the type-approval test, tabulate all data used in making the determination, including the surface conditions, and send the results to ASTM Committee E17 on Vehicle-Pavement Systems within 90 days after completion of on-site data collection so that statements about bias and precision of the test can be formulated as experience is accumulated.

7.2.9 *Precision and Bias*—A statement about precision and bias of a test method should allow potential users of the test to assess in general terms its usefulness for a particular purpose. It is intended to provide guidance as to the amount of variation that can be expected in test results when the test is conducted in one or more comparable laboratories or situations. This is a test method that produces pass-or-fail results. The precision and bias of the procedure and calculations in this acceptance test for Type I and Type II WIM systems are being determined.

7.3 *Test-approval Test for Type III WIM Systems*:

7.3.1 *Scope*—A procedure is given for conducting a type-approval test of a Type III WIM system. This type system is designed for installation at weight-enforcement stations with sensors off the main highway lanes to identify vehicles operating within a user-specified range of speeds between 15 and 50 mph (24 and 80 km/h), inclusive, that are suspected of weight-limit or load-limit, plus tolerance, violation. The system must also control official traffic-control devices that direct suspect vehicles to a scale for confirmation weighing and measurement and direct non-suspect vehicles past the scales without stopping. The type-approval test shall be conducted under excellent site conditions and under traffic that includes vehicles that are representative of the vehicle classes of interest where Type III WIM systems will usually be installed. Performance requirements for this type system are presented in Section 5, and user requirements are given in Section 6. Tolerances for Type III WIM systems are somewhat smaller than for Types I and II because speeds off the main highway lanes are lower and, with the required reference-value weighing devices continually available, on-site calibration is practicable at any chosen time. Test loading for the type-approval test is designed to allow evaluation of the variability in measured or calculated loads and weights of static vehicles as well as the accuracy of WIM-system estimates of the various data items produced by the system. Capability of the system to detect excessive acceleration of a vehicle while it is over the WIM-system sensors is also evaluated. All vehicles used for test loading the Type III WIM system shall be weighed statically as described in 7.1.1 and 7.1.2 using the certified scales installed at the weight-enforcement site where the type-approval test is conducted. When the sensors of the Type III WIM system are installed in the main highway lanes, the type-approval test procedure shall be basically the same as described herein except that the deceleration testing described in 7.3.6.1 will not be conducted, and the Type III system shall be required to accommodate the same speed and accuracy criteria as a Type I system.

7.3.2 *Significance and Use*—Interpretation of the results from the type-approval test will allow the user to determine whether the tested Type III WIM system is capable of meeting or exceeding the performance requirements stated in Section 5. This can also indicate the potential upper limit of performance that can be achieved by the particular type of system as the road surface conditions, that potentially affect the location and magnitude of dynamic tire forces significantly, shall be the best available for conducting the type-approval test and shall, as a minimum, satisfy the user requirements shown in Section 6.

7.3.3 *Site for Type-approval Test*—See 7.2.3.

7.3.4 *Test Unit for Type-Approval Test Loading*—The test unit for loading the WIM system being evaluated in the type-approval test shall be the same as specified in 7.2.4, except that each vehicle selected from the traffic stream for inclusion in the loading test unit shall have one or more of the following loads or weights that is 80 % or more of the applicable legal limit: gross-vehicle weight, axle-group load, axle load, or wheel load.

7.3.5 *Calibration and Certification*—See 7.2.5.

7.3.6 *Procedure*—The procedure for conducting the type-approval test for Type III WIM systems shall be the same as described in 7.2.6 with the following exceptions:

7.3.6.1 After 7.2.6.8, if continuation is approved, verify the ability of the WIM system to detect excessive acceleration by having the driver of each loaded test vehicle approach the WIM-system sensors at a speed between 30 and 40 mph (50 and 60 km/h) and apply heavy braking for approximately 1 s while the vehicle is passing over the sensor array. Excessive negative acceleration (deceleration) should be indicated by the Violation Code DE (see Table 4). Compare the WIM-system estimates of weights for these runs with those for steady-speed runs and include these comparisons in the data reported to ASTM Committee E17 on Vehicle-Pavement Systems. Proceed with 7.2.6.9.

7.3.7 *Calculation*—See 7.2.7.

7.3.8 *Interpretation of Test Results and Report*—See 7.2.8.

7.3.9 *Precision and Bias*—The precision and bias of the procedure and calculations in this type-approval test for the Type III WIM system are being determined.

7.4 *Type-Approval Test for Type IV WIM Systems*:

7.4.1 *Scope*—The Type IV WIM system is designed to detect weight-limit or load-limit violations by highway vehicles for enforcement purposes. Even though this type WIM system has not yet been approved for use in the U.S.A., a procedure for type-approval testing to determine conformity with the performance requirements specified in Section 5 is presented. The procedure includes data collection needed for evaluating the variability in reference-value tire loads measured by certified wheel-load weighers, axle-load scales, a multi-platform vehicle scale, or a combination thereof, as well as the performance of the WIM-system in either measuring the tire loads of a vehicle stopped on the WIM-system sensors or estimating the tire loads and dimensions of a static vehicle from measurements made with the vehicle moving at a steady speed of 10 mph (16 km/h) or less. Reference-value tire loads shall be measured by a multi-platform vehicle scale or an axle-load scale (see 7.1.1) when Option 2, exempting the Type IV WIM system from producing wheel-load information, (see 4.1.4) has been specified for the Type IV WIM system under test. When this option has not been specified, wheel-load values are required, and reference-value tire loads shall be measured by placing wheel-load weighers directly on the load-receiving surface of the multi-platform vehicle scale or the axle-load scale and raising all tire-pavement contact surfaces approximately into the same plane as described in 7.1.2. The sum of the tire-load values from the wheel-load weighers should compare, within applicable tolerances, with the corresponding value from the scale upon which they are placed; then, the wheel-load-weigher indications should be used only to apportion the axle load indicated by the scale between the wheels on the axle. Alternatively, an axle-load scale or a multi-platform vehicle scale that has approaches and aprons adjacent to the load-receiving platform(s) that can support the tire-pavement contact surfaces of all tires on the vehicle being weighed as described in 7.1.2 may be used to weigh wheel loads on one end of an axle by positioning the wheel(s) on the other end of the axle on the adjacent apron. When this alternative technique is used, the wheel loads on both ends of the axle shall be determined, and then used only to apportion the measured axle load between the wheels on each end of the axle.

7.4.2 *Significance and Use*—Interpretation of the results from the type-approval test will allow the user to determine whether the tested Type IV WIM system is capable of meeting or exceeding the performance requirements stated in Section 5. This can also indicate the potential upper limit of performance that can be achieved by the particular type of system as the test conditions at the weight-enforcement site shall be the best available for conducting the acceptance test and shall, as a minimum, satisfy the user requirements shown in Section 6.

7.4.3 *Site for Type-Approval Test*—Either an axle-load scale or a multi-platform vehicle scale is required at the site. Other site requirements are the same as 7.2.3. Neither the longitudinal profile nor the cross slope shall exceed 1 %.

7.4.4 *Test Unit for Type-Approval Test Loading*—See 7.3.4.

7.4.5 *Calibration and Certification*—Within seven days prior to beginning the type-approval test, the Type IV WIM system shall, when subjected to field standard test weights, be adjusted to meet the acceptance tolerance for wheel-load weighers or for portable axle-load weighers as stated in *NIST Handbook 44* **(1)**, depending upon whether wheel-load data or only axle-load data (4.1.4, Option 2) are of interest. All weighing apparatus used in the type-approval test for determining reference-value tire loads shall be certified as meeting the applicable maintenance tolerance specified in *NIST Handbook 44* **(1)** within 30 days prior to beginning the type-approval test.

7.4.6 *Procedure*—The procedure for conducting the type-approval test for Type IV WIM systems shall be the same as described in 7.2.6 with the following exceptions:

7.4.6.1 In 7.2.6.2, also ensure that an axle-load scale or a multi-platform vehicle scale is available at or near the site,

7.4.6.2 In 7.5.5.3, 7.2.6.5 and 7.2.6.10, the respective minimum, intermediate, and maximum speeds of the test vehicles shall be 0, 6, 8, and 10 mph (0, 10, 13, and 16 km/h),

7.4.6.3 In 7.2.6.9, calculate the difference in each load or weight from the arithmetic mean and compare the difference to one-half the applicable tolerance for a Type IV WIM system shown in Table 2.

7.4.6.4 After 7.2.6.8, if continuation is approved, verify the ability of the WIM system to detect excessive acceleration by having the driver of each loaded test vehicle approach the WIM-system sensors at a speed between 8 and 10 mph (12 and 16 km/h) and apply heavy braking for approximately 1 s while the vehicle is passing over the sensor array. Excessive negative acceleration (deceleration) should be indicated by the Violation Code DE (see Table 4). Compare the WIM-system estimates of loads and weights for these runs with those for steady-speed runs and include these comparisons in the data reported to ASTM Committee E17 on Vehicle-Pavement Systems. Proceed with 7.2.6.9.

7.4.6.5 In 7.2.6.11, calculate differences in weight and express the differences in pounds (kilograms).

7.4.7 *Calculation*—See 7.2.7 except as described in 7.4.6.5.

7.4.8 *Interpretation of Test Results and Report*—See 7.2.8.

7.4.9 *Precision and Bias*—The precision and bias of the procedure and calculations in this type-approvaltest for the Type IV WIM system are being determined.

7.5 *Calibration Procedure for Type I, Type II, and Type III WIM Systems*:

7.5.1 *Scope*—A procedure is given for on-site calibration of Type I, Type II, and Type III WIM systems. This procedure shall be conducted by the user with cooperation of the vendor, or by their authorized representatives. It requires that two loaded, pre-weighed and measured (see 7.1.3) test vehicles each make multiple runs over the WIM-system sensors in each lane at specified speeds.

7.5.2 *Significance and Use of Calibration*—The tire-force sensors of a WIM system are typically designed to produce a voltage signal, with respect to time, that is linearly proportional to the magnitude of the component of dynamic tire force applied perpendicularly to the road surface by the tires of a moving vehicle. The function of calibration is to define an algorithm and calibration factors, for subsequent execution within the WIM-system software, that will be used to correlate the observed vehicle speed and the calculated area (or a portion thereof) under the voltage (force) versus time curve from the sensor(s) with the corresponding tire load and axle spacing values for the static vehicle. The dynamic tire force results from a complex interaction among the vehicle components, the WIM-system sensors, the road surface surrounding the sensors, and other factors. Road-surface profiles and sensor installation are different at every WIM site, and every vehicle has unique tire, suspension, mass, and speed characteristics. Therefore, it is necessary to recognize the effects of these site-specific, speed-specific, and vehicle-specific influences on WIM-system performance and attempt to compensate for their adverse effects as much as is practicable via on-site calibration. The calibration procedure shall be applied immediately after the initial installation of a Type I or Type II, or Type III WIM system at every site. It should be applied again when a system is reinstalled or whenever site conditions or WIM-system components (including software and settings) have changed.

7.5.3 *Test Unit for Calibration Loading*—The test unit for calibration loading shall comprise two loaded, pre-weighed, and measured test vehicles that will make multiple runs over the WIM-system sensors in each lane at prescribed speeds. One of the loaded test vehicles shall be Class 05 and the other Class 09 (see Table 3). These test vehicles shall have a suspension type (that is, leaf spring, air, other) that is deemed by the user to be representative of most vehicles of their type operating at the site. They shall be loaded to at least 90 % of their respective registered gross-vehicle weight with a non-shifting, approximately-symmetric (side-to-side) load and shall be in excellent mechanical condition. Special care shall be exercised to ensure that the tires on the test vehicles are in excellent condition (preferably dynamically balanced) and inflated to recommended pressures. Reference-value weighing and measurement of the two test vehicles shall be in accordance with 7.1.3.

7.5.4 *Site Conditions*—Before initial calibration begins, the existing site conditions (see 6.1) in each lane where WIM-system sensors are installed shall be described quantitatively—or at least qualitatively—and made a matter of permanent record for future reference. It is especially important to describe the pavement structure and its surface condition. Surface smoothness shall be quantified (see 6.1.5), at least in each wheel path. Estimates of the location and magnitude of each observed pavement surface deviation greater than the 0.125 in. (3 mm) measured beneath the straightedge with the circular plate should be documented. Record the time and the approximate ambient air temperature at the beginning, during, and at the end of the calibration process.

7.5.5 *Procedure*—The following steps are involved in the on-site calibration process for each instrumented lane:

7.5.5.1 Adjust all WIM-system settings to vendor's recommendations or to a best estimate of the proper setting based upon previous experience.

7.5.5.2 With a calibrated radar speed meter or by some other means (such as wheelbase/time) that is acceptable to both the user (or a recognized representative of user's interests) and the vendor, measure the speed of each test vehicle every time it passes over the WIM-system sensors.

7.5.5.3 Using traffic control procedures approved by the appropriate public authority and other reasonable safety precautions, have each test vehicle (See 7.5.3) make a series of three runs over the WIM-system sensors at the minimum and at the maximum speed specified by the user who is conducting the test between 10 and 80 mph (16 to 130 km/h) for Type I and Type II systems and between 15 and 50 mph (24 and 80 km/h) for Type III systems. These two speeds should differ by at least 20 mph (30 km/h) and should be above and below the average speed of vehicles operating at the site. Then, have each test truck pass over the sensors three times at an intermediate speed that is representative of the prevailing speed of truck traffic at the site. Record all data, and note the vehicle record number for every run of each test vehicle.

7.5.5.4 Calculate the difference in the WIM-system estimate and the respective reference value for the two test vehicles for each speed, wheel-load, axle-load, tandem-axle load, gross-vehicle-weight, and axle-spacing value, express the difference in percent (see 7.2.7), and find a mean value for the differences for each set of values.

7.5.5.5 Make the necessary changes, according to the vendor's recommendations, to the WIM-system settings that will adjust the mean value of the respective differences for each value to equal approximately zero. For WIM systems that estimate wheel load, the adjustment will be to wheel-load estimates on each side of the vehicles, separately. For systems that estimate axle loads only, the adjustment will be for axle loads. Some WIM systems allow calibration factors to be defined and applied for selected wheels, axles, or axle groups in relation to their respective location on the vehicle or combination; this is a highly-desirable feature. It is also important for the WIM system to include a feature that invokes the proper set of calibration factors for use in estimating load, weight, and axle spacing values when the observed vehicle is running at a particular, measured speed. These factors can be derived from the measurements made when the two test vehicles each made three runs at three different speeds. Every vehicle interacts with the road surface differently at different speeds, but about the same at the same speed. Adjustment to the speed setting will probably affect axle-spacing estimates.

7.6 *On-site Acceptance Test for Type I, Type II, and Type III WIM Systems*:

7.6.1 *Scope*—This test method provides the WIM-system user with a practicable means for determining whether or not a new or modified Type I, Type II, or Type III system that has been installed at a particular site meets or exceeds specified functional and performance requirements (see Sections 4 and 5) and defines for the user and the vendor the test method that will be applied for evaluating the installed WIM system. It also requires the user to quantify and document the site conditions that exist at the site (see 6.1 and 7.5.4) when the test is conducted. It uses two test vehicles for the test loading unit and is an abbreviated form of the more-rigorous Type-approval Test (see 7.2 and 7.3) for these WIM-system types that may be used in lieu of a full type-approval test under the circumstances outlined in 6.4.1.

7.6.2 *Significance and Use*—In procuring a new WIM system or in contracting for a major modification to an existing system for use at a particular site, the user should specify (see 6.4) an acceptance test method and the schedule of testing that will be accomplished prior to final acceptance of the product or service by the user and final payment to the vendor. The on-site acceptance test described here may be referenced for this purpose in the specification.

7.6.3 *Procedure*—The test shall be conducted on-site by the user or the user's authorized representative, in cooperation with the vendor, immediately after a Type I, Type II, or Type III WIM System has been installed or modified. The following steps are required for each instrumented lane.

7.6.3.1 Execute the Calibration Procedure as presented in 7.5 and install the settings defined in 7.5.5.5 on the WIM-system.

7.6.3.2 With the settings agreed upon by both the user and the vendor installed on the WIM system, have each of the two test vehicles (see 7.5.3) make five runs over the sensors in each lane at an attempted speed approximately 5 mph (8 km/h) less than the maximum speed, and then five more runs at an attempted speed approximately 5 mph (8 km/h) greater than the minimum speed, used during calibration (see 7.5.5.3). With a calibrated radar speed meter, or by some other means (such as wheelbase/time) that is acceptable to both the user and the vendor, measure the speed of each test vehicle every time it passes over the WIM-system sensors. Record all data, and note the vehicle record number for every run of each test vehicle.

7.6.4 *Calculation*—Make the calculations shown in 7.2.7 for the 20 runs (five runs at two speeds by two vehicles) of the test vehicles and compare the functions and performance of the WIM system with all specification requirements, including speed and axle spacing. See Section 4 for functions and 4.1.3, Section 5, and 6.4.1 for performance tolerances.

7.6.5 *Interpretation of Test Results and Report*—All specified data-collection features, data-processing features, and options of the system type described in Section 4 shall be demonstrated to function properly before the system is accepted. If any of these fails to function properly, or if more than 5 % of the calculated differences for any applicable data item resulting from all passes of the two test vehicles exceeded the tolerance specified in 4.1.3, Section 5, or 6.4.1 for that item and WIM-system type, declare that the WIM system was dysfunctional or inaccurate and record the fact that it failed the on-site acceptance test. Regardless of whether the system fails or passes the test, tabulate all data used in making the determination, including the surface conditions, and send the results to ASTM Committee E17 on Vehicle-Pavement Systems within 90 days after completion of on-site data collection so that statements about bias and precision of the test can be formulated as experience is accumulated.

7.6.6 *Precision and Bias*—This is a new test method that produces pass-or-fail results. The precision and bias of the procedure and calculations in this on-site acceptance test for Type I, Type II, and Type III WIM systems are being determined.

8. Keywords

8.1 loading; pavement and bridge; traffic; vehicle; weighing vehicles; weigh-in-motion; WIM; weight enforcement

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