Publication 408
Compaction Requirements and Equipment Factors

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Compaction Requirements and Equipment Factors

► **Prior to issuance of Publication 408/2016 Change 3, the Construction Specifications:**

- Did not address compatibility between materials, test methods, and compaction equipment
- *Allowed compaction equipment that may not be appropriate for material being compacted*
- Placed responsibility for quality control (QC) and quality assurance (QA) of material compaction on PennDOT instead of the contractor

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► **Publication 408/2016 Change 3 updates included:**

- New material definitions
- Incorporation of Proof Rolling/Special Rolling
- Additions to material placement requirements
- *Compaction and minimum equipment performance requirements*
- New QC/Acceptance Testing and Verification Testing requirements
- New and/or Updated Test Methods
- New and/or Updated Inspection Forms

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► **Publication 408 Updates:**

- *Section 108: Performance and Progress*
- *Section 206: Placement and Compaction of Embankment and Fill*
- Section 210: Subgrade
- Section 350: Subbase
- Section 601: Pipe Culverts

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► **Laboratory and Field Test Method Updates:**

- PTM 106: The Moisture Density Relations of Soils (Using a 5.5-lb. Rammer and a 12” Drop)

- PTM 402 – Determining In-Place Density and Moisture Content of Construction Materials by Use of Nuclear Gauges

- PTM 418 – Nuclear Gauge Calibration and Standard Count Verification of Troxler Moisture/Density Nuclear Gauges

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► **Construction Manual and Standard Form Updates:**

- Publication 2, Project Office Manual (POM), Part B, Section 6
- Form CS-206: Minimum Quality Control Plan for Nuclear Gauge Compaction Testing
- Form TR-4247A: Method of Calculation of Moisture Density Relationship
- Form TR-478A: Report on Compaction Density Non-movement

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► **Outcomes/Benefits of these updates:**

- Improved quality of construction
- Improved operational efficiency
- Minimized construction problems and conflicts
- Clarified contractor responsibilities and requirements

Compaction Equipment Factor Equations
Section 108.05(c)

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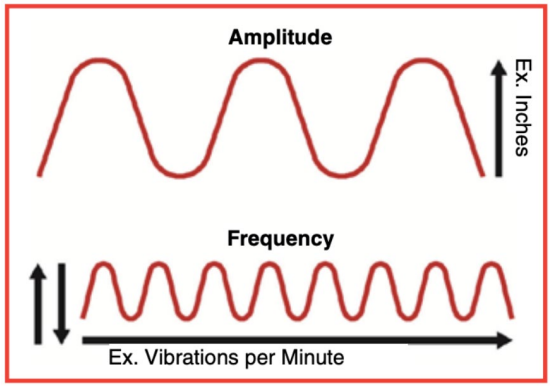
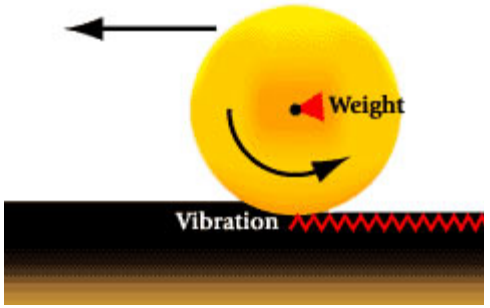
► Equipment Factor Equation Terms:

- **Amplitude** is the measure of total peak vertical movement of a drum or vertical travel of a plate, per complete cycle. This term is typically reported in inches (in).
- **Frequency** is the measure of number of complete cycles or revolutions of the weight around the axis of rotation over a given length of time. This term is typically reported in vibrations per minute (vpm), blows per minute (bpm), or hertz (Hz).
- **Centrifugal Force** is created by rotating eccentric weight or weights. The mass of the weights, their offset distance from the center of rotation to center of gravity, and speed of rotation all contribute to production of this force. This term is typically reported in pounds (lb).





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► Section 108.05(c)3.d, Self-propelled Trench Type Rollers

$$RF_t = (F_c*(f*A)^2)/(W_d*650)$$

where,
RF_t = Trench roller factor (dim)
F_c = Maximum centrifugal force (lb)
f = Minimum vibration frequency (Hz)
A = Maximum vibration amplitude (in)
W_d = Drum width (in)

* with a minimum trench roller factor (RF_t) of 2.0

- This equipment is permitted for use on the following materials:
  - Soil, Section 206.3(b)1.a
  - Granular Material, Type 1, Section 206.3(b)1.b
  - Granular Material, Type 2, Section 206.3(b)1.c
  - Shale, Section 206.3(b)1.e
  - Random Material, 206.3(b)1.f

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► Section 108.05(c)3.i, Smooth Single-Drum Vibratory Roller

$$RF_v = (F_c*(f*A)^2)/(W_d*1{,}000)$$

where,
RF_v = Vibratory roller factor (dim)
F_c = Maximum centrifugal force (lb)
f = Minimum vibration frequency (Hz)
A = Maximum vibration amplitude (in)
W_d = Drum width (in)
* minimum vibratory roller factor (RF_y) of 2.0

- This equipment is permitted for use on the following materials:
  - Granular Material, Type 1, Section 206.3(b)1.b
  - Granular Material, Type 2, Section 206.3(b)1.c
  - Rock, Section 206.3(b)1.d
  - Shale, Section 206.3(b)1.e
  - Random Material, 206.3(b)1.f

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► Section 108.05(c)4.a, Hand Operated Impact Rammer

$$RF_i = (w_o*(f*A)^2)/(W_p*L_p*400)$$

where,
RF_i = Impact rammer factor (dim)
w_o = Operating weight (lb)
f = Percussion rate or frequency (Hz)
A = Rammer stroke or amplitude (in)
W_p = Rammer plate width (in)
L_p = Rammer plate length (in)

* with a minimum required impact rammer factor (RF_i) of 2.0

- This equipment is permitted for use on the following materials:
  - Soil, Section 206.3(b)1.a
  - Granular Material, Type 1, Section 206.3(b)1.b
  - Granular Material, Type 2, Section 206.3(b)1.c
  - Shale, Section 206.3(b)1.e
  - Random Material, 206.3(b)1.f

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► Section 108.05(c)4.b, Hand Operated Vibratory Plate

$$PF_v = (F_c*(f*A)^2)/(A_p*100)$$

where,
PF_v = Vibratory plate factor (dim)
F_c = Maximum centrifugal force (lb)
f = Minimum vibration frequency (Hz)
A = Maximum vibration amplitude (in)
A_p = Effective plate area (in^2)

* with a minimum required plate factor (PF_v) of 2.0

- This equipment is permitted for use on the following materials:
  - Soil, Section 206.3(b)1.a
  - Granular Material, Type 1, Section 206.3(b)1.b
  - Granular Material, Type 2, Section 206.3(b)1.c
  - Shale, Section 206.3(b)1.e
  - Random Material, 206.3(b)1.f

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Examples

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► **Example 1**
Manufacturer: Wacker Neuson
Impact Rammer Models: AS60e, BS50-2

Impact Rammer Model >	AS60e	BS50-2
Operating Weight, wo (lb) =	155.2	130
Percussion Rate or Frequency, f (bpm) =	680.0	687.0
Percussion Rate or Frequency, f (Hz or /s) =	11.3	11.5
Rammer Stroke or Amplitude, A (in) =	2.00	2.50
Rammer Plate Width, Wp (in) =	11.0	9.8
Rammer Plate Length, Lp (in) =	13.4	13.4
Impact Rammer Factor, RF_i* (dim) =	1.35	2.03

*RF_i minimum = 2.0

$$RF_i = (w_o*(f*A)^2)/(W_p*L_p*400)$$

where,
RF_i = Impact rammer factor (dim)
w_o = Operating weight (lb)
f = Percussion rate or frequency (Hz)
A = Rammer stroke or amplitude (in)
W_p = Rammer plate width (in)
L_p = Rammer plate length (in)

- Wacker Neuson Model AS60e **does not** meet impact rammer requirements
- Wacker Neuson Model BS50-2 **does** meet impact rammer requirements

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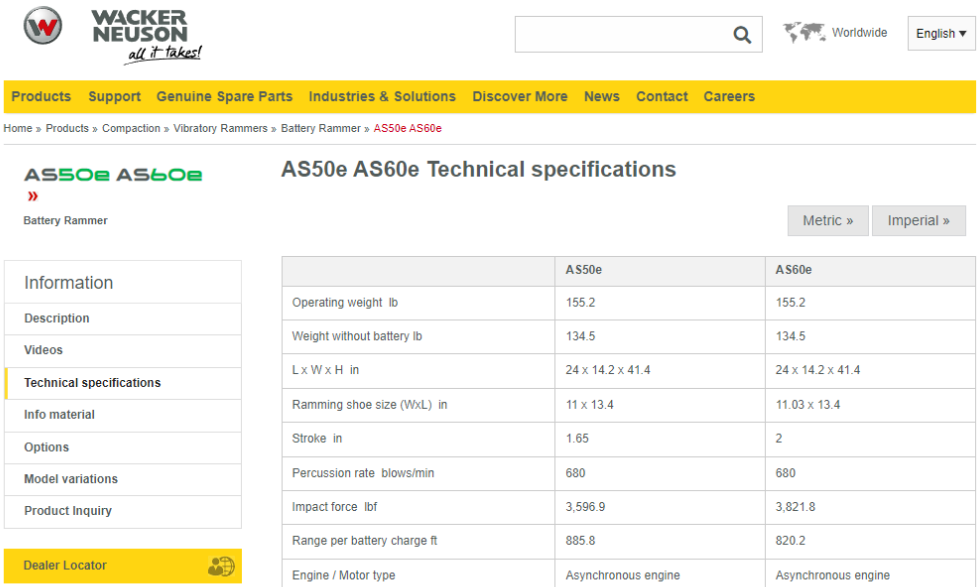
► Example 1
Screenshot of Technical Specifications – AS60e



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AS50e AS60e Technical specifications

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	AS50e	AS60e
Operating weight lb	155.2	155.2
Weight without battery lb	134.5	134.5
L x W x H in	24 x 14.2 x 41.4	24 x 14.2 x 41.4
Ramming shoe size (WxL) in	11 x 13.4	11.03 x 13.4
Stroke in	1.65	2
Percussion rate blows/min	680	680
Impact force lbf	3,596.9	3,821.8
Range per battery charge ft	885.8	820.2
Engine / Motor type	Asynchronous engine	Asynchronous engine
Engine / Motor manufacturer	Wacker Neuson	Wacker Neuson
Rated performance kW	2.1	2.24
Rated current A	41	44
Rated voltage V	51	51
Type of battery	Li-Ion	Li-Ion
Weight lb	20.7	20.7
L x W x H in	8.7 x 11.4 x 7.6	8.7 x 11.4 x 7.6
Energy content Wh	1,008	1,008

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► **Example 2**
Manufacturer: Dynapac
Smooth Single-Drum Roller Models: CA1300D, CA1300PD

Smooth Single-Drum Roller Model >	CA1300D	CA1300PD
Maximum Centrifugal force, Fc (lb) =	20,000	20,000
Vibration Frequency (vpm) =	2,100	2,100
Minimum Vibration Frequency, f (Hz or /s) =	35	35
Maximum Vibration Amplitude, A (in) =	0.067	0.059
Drum Width, Wd (in) =	54.0	54.0
Vibratory Roller Factor, RF_v* (dim) =	2.04	1.58

*RF_v minimum = 2.0

$$RF_v = (F_c*(f*A)^2)/(W_d*1{,}000)$$

where,
RF_v = Vibratory roller factor (dim)
F_c = Maximum centrifugal force (lb)
f = Minimum vibration frequency (Hz)
A = Maximum vibration amplitude (in)
W_d = Drum width (in)

- Dynapac Model CA1300D **does** meet vibratory roller requirements
- Dynapac Model CA1300PD **does not** meet vibratory roller requirements

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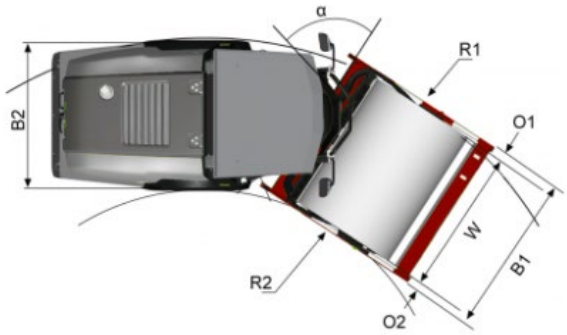
► Example 2
Screenshot of Technical Specifications – CA1300D



O1. Overhang, right	2 in
O2. Overhang, left	2 in
R1. Turning radius, outside	13 ft
R2. Turning radius, inside	8 ft
S. Drum shell thickness	0.87 in
W. Working width	54 in

Compaction	
Static linear load	73 lbs/in
Nominal amplitude	0.067 in
Vibration frequency	2,100 vpm
Centrifugal force	20,000 lb

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► Summary

- Verify the material type that is being compacted (Soil, Granular Type 1, etc.)
- Verify the equipment type is allowable for the material type, per Section 206.3(b).
- Check the calculated equipment factor ensuring that it meets a minimum of 2.0
  - Access equipment technical data via the manufacturer's website. **If the data is not provided, request it from the manufacturer's engineering department**
  - Confirm the input units of Amplitude, Frequency, Centrifugal Force, and equipment dimensions are as specified in Section 108.05(c)
- Approve or deny the equipment request received via CS-206 form
  - Refer to the two prior examples discussed. If a contractor submitted a request to use the Wacker Neuson BS50-2 Impact Rammer and the Dynapac CA1300PD Smooth Single-Drum Roller, the request for Impact Rammer should be approved the request for the Smooth Single-Drum Roller should be denied. **This does not mean that the use of an Impact Rammer is more efficient for use; it simply means that the class of Smooth Single-Drum Roller evaluated does not meet requirements**

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► Additional Resources

- **PennDOT gINT/Geotechnical website**

  www.penndot.gov/ProjectAndPrograms/Construction/Pages/gINT.aspx

  Under the "Documentation Links" Section refer to:

  - Compaction Manual 2020
  - Worked Examples will also be uploaded

- **Publication 222**

  https://www.dot.state.pa.us/public/pubsforms/Publications/PUB%20222.pdf

  - Refer to Section 3.6.3

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Questions?

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