Conduit Sizing
WSDOT
Fall / Winter 2004

Presented by: Keith Calais
What is conduit fill?

- Conduit fill is the amount, in square inches, of conductors inside a section of conduit.

- NEC 2002 - Article 344 - Rigid Metal Conduit: Type RMC

- NEC 2002 – Article 352 - Rigid Nonmetallic Conduit: Type RNC (Note this Article includes PVC schedule 40 and PVC schedule 80 as well as HDPE schedule 40).
Why do we need to worry about Conduit fill?

• Dissipate heat.

• Pulling of wires.

• Potential high cost change orders when the conductors that you specified do not fit inside the conduit.
When do we need to worry about conduit fill?

• When you are installing new conduit and conductors.

• When you are adding new conductors to an existing conduit run.
Allowable conduit fill

• The maximum allowable fill for new conduit is 26% full. (Design Manual Chapter 850, page 840-15 (c) Conduit)

• The maximum allowable fill for existing conduits is 40% full. (NEC 2002 – Chapter 9, Table 1) and (Design Manual Chapter 850, page 840-15 (c) Conduit)
26% Conduit Fill → 1 ½” Conduit
Conductors → 4 - #2
= 0.532 in^2
40% Conduit Fill → 1 ½” Conduit
Conductors → 4 - #2, 2 - #4, and 2 - #8
= 0.838 in^2
60% Conduit Fill → 1 ½” Conduit
Conductors → 5 - #2, 2 - #4, 2 - #6, 3 - #8, 1 - #10, and 1 - #12
= 1.232 in^2
COMBINATION GALVANIZED STEEL CONDUIT (GSC) AND NON-METALLIC CONDUIT (NMC) APPLICATION

KEY
1 Service Neutral
2 Service Ground
3 Grounding Electrode Conductor
4 Bonding Jumper
5 Grounding Bushing (typ. all conduit terminations)
6 Service Neutral Bus (Copper)
7 Service Enclosure
8 Equipment Grounding Conductor
9 Junction Box
10 Electrical Load Support (luminaire pole)
11 Copper Split Bolt Clamp
12 Galvanized Steel Conduit (GSC)
13 Non-metallic Conduit (NMC)
14 Option A - 10' GSC with Field Bend
   - Approved Adapter Fitting
   - Grounding Bushing
Option B - 10' GSC
   - GS Factory Elbows
   - Approved Adapter Fitting
   - GS Coupling
   - Grounding Bushing
15 Ground Rod
16 Edge of Foundation, Pole or Service Support
17 Clamp
18 Junction Box or 8' Drain Tile with Approved Cover
19 Code Sized GSC
20 Service Neutral Bus
21 To Grounding Terminal or Connection to Equipment Grounding System

NOTES
1. If parallel circuits of different sizes are contained in one conduit, the size of the grounding conductor shall be determined on the basis of the largest conductor. Only one grounding conductor is required for each conduit regardless of the number of circuits contained.

2. Service ground per serving utility requirement. If the utility uses aluminum service conductors, an approved Al-Cu pressure type ground connector shall be used to secure the service neutral to the copper neutral bar in the service enclosure. Except for the above, all grounding conductors shall be copper.

3. Equipment grounding conductors and grounding electrode conductors shall be sized in accordance with the National Electric Code (No. 8 minimum).

SUPPLEMENTAL GROUND

Required to supplement equipment grounding for luminaire standards with direct burial, aerial feeds, or where required in plans.

SERVICE GROUND

Required at all services and separately derived systems.

GROUND ROD DETAILS

TYPICAL GROUNDING DETAILS

STANDARD PLAN J-9a

APPROVED FOR PUBLICATION

Clifford Hendricks

WASHINGTON STATE DEPARTMENT OF TRANSPORTATION

Olympia, Washington
<table>
<thead>
<tr>
<th>Conductor Type</th>
<th>Conductor Size (in²)</th>
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<th>Conductor Size (in²)</th>
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<tbody>
<tr>
<td>2C(sh)-#14</td>
<td>0.090</td>
<td>#12</td>
<td>0.026</td>
<td>1/0</td>
<td>0.222</td>
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<td>3C(sh)-#20</td>
<td>0.070</td>
<td>#10</td>
<td>0.033</td>
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<td>0.060</td>
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<td>5C-#14</td>
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<td>0.372</td>
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<td>7C-#14</td>
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<td>10C-#14</td>
<td>0.290</td>
<td>#3</td>
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<td>300</td>
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<td>6pcc-#19</td>
<td>0.320</td>
<td>#2</td>
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<td>RG59Ucc</td>
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<td>#1</td>
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<td>24 (SM) fiber</td>
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<td>48 (SM) fiber</td>
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<td>144 (SM) fiber</td>
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<tr>
<td>Conduit Size (inches)</td>
<td>Max Fill 26% (square inches)</td>
<td>Max fill 40% (square inches)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------------------</td>
<td>-----------------------------</td>
<td>-----------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>½”</td>
<td>0.082</td>
<td>0.125</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>¾”</td>
<td>0.143</td>
<td>0.220</td>
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</tr>
<tr>
<td>1”</td>
<td>0.231</td>
<td>0.355</td>
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<td></td>
</tr>
<tr>
<td>1¼”</td>
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<td>0.610</td>
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<tr>
<td>1½”</td>
<td>0.539</td>
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<td>3.000</td>
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<td>3½”</td>
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## Conduit Sizes – PVC schedule 40, and HDPE

<table>
<thead>
<tr>
<th>Conduit Size (inches)</th>
<th>Max Fill 26% (square inches)</th>
<th>Max fill 40% (square inches)</th>
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<tbody>
<tr>
<td>½”</td>
<td>0.074</td>
<td>0.114</td>
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<td>¾”</td>
<td>0.132</td>
<td>0.203</td>
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<tr>
<td>1”</td>
<td>0.216</td>
<td>0.333</td>
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<td>1 ¼”</td>
<td>0.378</td>
<td>0.581</td>
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<tr>
<td>1 ½”</td>
<td>0.516</td>
<td>0.794</td>
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<tr>
<td>2”</td>
<td>0.856</td>
<td>1.316</td>
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<tr>
<td>2 ½”</td>
<td>1.221</td>
<td>1.878</td>
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<tr>
<td>3”</td>
<td>1.890</td>
<td>2.907</td>
</tr>
<tr>
<td>3 ½”</td>
<td>2.532</td>
<td>3.895</td>
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</tbody>
</table>

(2002 NEC chapter 9, table 4 - Article 352 RNC)

## Conduit Sizes – PVC schedule 80

<table>
<thead>
<tr>
<th>Conduit Size (inches)</th>
<th>Max Fill 26% (square inches)</th>
<th>Max fill 40% (square inches)</th>
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</thead>
<tbody>
<tr>
<td>½”</td>
<td>0.056</td>
<td>0.087</td>
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<tr>
<td>¾”</td>
<td>0.106</td>
<td>0.164</td>
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<tr>
<td>1”</td>
<td>0.179</td>
<td>0.275</td>
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<td>1 ¼”</td>
<td>0.322</td>
<td>0.495</td>
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<tr>
<td>1 ½”</td>
<td>0.445</td>
<td>0.684</td>
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<tr>
<td>2”</td>
<td>0.747</td>
<td>1.150</td>
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<td>2 ½”</td>
<td>1.071</td>
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<tr>
<td>3”</td>
<td>1.675</td>
<td>2.577</td>
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<tr>
<td>3 ½”</td>
<td>2.259</td>
<td>3.475</td>
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</table>

(2002 NEC chapter 9, table 4 - Article 352 RNC)
Examples

New 1” **GRS** conduit with 3-#8
1” conduit 26% fill is 0.231 sq.in.
#8-0.056 sq.in. - 3*0.056=0.168 sq.in.
0.168 sq.in. < 0.231 sq.in.
Conduit fill OK.

Existing 1” **GRS** conduit with 5-#8
1” conduit 40% fill is 0.355 sq.in.
#8-0.056 sq.in. - 5*0.056=0.280 sq.in.
0.280 sq.in. < 0.355 sq.in.
Conduit fill OK.
Examples

New 2” GRS conduit with 6-#8, 3-#6, 4-#4, 3-#2

2” GRS conduit 26% fill is 0.89 sq.in.
#8-0.056 sq.in. - 6*0.056=0.336 sq.in.
#6-0.073 sq.in. - 3*0.073=0.219 sq.in.
#4-0.097 sq.in. - 4*0.097=0.388 sq.in.
#2-0.133 sq.in. - 3*0.133=0.399 sq.in.

1.342 sq.in.

1.342 sq.in. > 0.89 sq.in. Conduit fill is NOT OK

Try 3” GRS conduit 6-#8, 3-#6, 4-#4, 3-#2

3” GRS conduit 26% fill is 1.95 sq.in.
#8-0.056 sq.in. - 6*0.056=0.336 sq.in.
#6-0.073 sq.in. - 3*0.073=0.219 sq.in.
#4-0.097 sq.in. - 4*0.097=0.388 sq.in.
#2-0.133 sq.in. - 3*0.133=0.399 sq.in.

1.342 sq.in.

1.342 sq.in. < 1.95 sq.in.
Examples

New 2” PVC Schedule 40 conduit with 6-#8, 3-#6, 4-#4, 3-#2

2” PVC Schedule 40 conduit 26% fill is 0.856 sq.in.
- #8-0.056 sq.in. - 6*0.056=0.336 sq.in.
- #6-0.073 sq.in. - 3*0.073=0.219 sq.in.
- #4-0.097 sq.in. - 4*0.097=0.388 sq.in.
- #2-0.133 sq.in. - 3*0.133=0.399 sq.in.
  1.342 sq.in.

1.342 sq.in. > 0.856 sq.in. Conduit fill is NOT OK

Try 3” PVC Schedule 40 conduit 6-#8, 3-#6, 4-#4, 3-#2

3” PVC Schedule 40 conduit 26% fill is 1.890 sq.in.
- #8-0.056 sq.in. - 6*0.056=0.336 sq.in.
- #6-0.073 sq.in. - 3*0.073=0.219 sq.in.
- #4-0.097 sq.in. - 4*0.097=0.388 sq.in.
- #2-0.133 sq.in. - 3*0.133=0.399 sq.in.
  1.342 sq.in.

1.342 sq.in. < 1.890 sq.in. Conduit fill is OK.
Examples

New 2” PVC Schedule 80 conduit with 6-#8, 3-#6, 4-#4, 3-#2

2” PVC Schedule 80 conduit 26% fill is 0.747 sq.in.

#8-0.056 sq.in. - 6*0.056=0.336 sq.in.
#6-0.073 sq.in. - 3*0.073=0.219 sq.in.
#4-0.097 sq.in. - 4*0.097=0.388 sq.in.
#2-0.133 sq.in. - 3*0.133=0.399 sq.in.

1.342 sq.in.

342 sq.in. > 0.747 sq.in. Conduit fill is NOT OK

Try 3” PVC Schedule 80 conduit 6-#8, 3-#6, 4-#4, 3-#2

3” PVC Schedule 80 conduit 26% fill is 1.675 sq.in.

#8-0.056 sq.in. - 6*0.056=0.336 sq.in.
#6-0.073 sq.in. - 3*0.073=0.219 sq.in.
#4-0.097 sq.in. - 4*0.097=0.388 sq.in.
#2-0.133 sq.in. - 3*0.133=0.399 sq.in.

1.342 sq.in.

1.342 sq.in. < 1.675 sq.in. Conduit fill is OK
Examples

New 1 1/2” GRS conduit with 3-#8, 3-#4

1 1/2” GRS conduit 26% fill is 0.539 sq.in.
#8-0.056 sq.in. - 3*0.056=0.168 sq.in.
#4-0.097 sq.in. - 3*0.097=0.291 sq.in.
0.459 sq.in.
0.459 sq.in. < 0.539 sq.in. Conduit fill is OK

New PVC Schedule 40 conduit with 3-#8, 3-#4

1 1/2” PVC Schedule 40 conduit 26% fill is 0.516 sq.in.
#8-0.056 sq.in. - 3*0.056=0.168 sq.in.
#4-0.097 sq.in. - 3*0.097=0.291 sq.in.
0.459 sq.in.
0.459 sq.in. < 0.516 sq.in. Conduit fill is OK

1 1/2” PVC Schedule 80 conduit 26% fill is 0.445 sq.in.
#8-0.056 sq.in. - 3*0.056=0.168 sq.in.
#4-0.097 sq.in. - 3*0.097=0.291 sq.in.
0.459 sq.in.
0.459 sq.in. > 0.445 sq.in. Conduit fill is NOT OK
Examples

Existing 2” GRS conduit with 6-#8, 3-#6, 4-#4, 3-#2

2” GRS conduit 40% fill is 1.36 sq.in.

- 8-0.056 sq.in. - 6*0.056=0.336 sq.in.
- #6-0.073 sq.in. - 3*0.073=0.219 sq.in.
- #4-0.097 sq.in. - 4*0.097=0.388 sq.in.
- #2-0.133 sq.in. - 3*0.133=0.399 sq.in.

1.342 sq.in. < 1.36 sq.in.
Conduit fill is OK.
Things to remember when sizing conduit

• Every time you cross a roadway put a spare conduit in.
• If the conduit crossing is for illumination or power supply, put in a spare 2” conduit.
• If the conduit crossing is for signal conduits at an intersection put in a spare 3” conduit. If the crossing is not at the intersection put in a spare 2” conduit.
• A 2” conduit should be the minimum size used for all crossings.
• Install a spare 2” conduit into a service cabinet.
• Install a spare 2” conduit between all transformers and the improvement the transformer is serving. (ITS cabinet, VMS cabinet, etc.)
Things to remember when sizing conduit

- Try not to use too many different sizes of conduit. It makes it easier to design your job and makes it easier for the contractor to build when you use less conduit sizes. Stick with even sized conduits (1”, 2” 3”, or 4”).

- Leave room for future conductors. Running 2” conduit near the service or where there is potential for future expansion usually provides plenty of future room.

- The conduit from the luminaire pole to the adjacent junction box 5’-10’ away shall be 1”. This is usually the only place you would ever run a 1” conduit in grade (except the grounded electrode conductor).
Mast Arm Wiring Detail

For Double Mast Arm, install additional cable and quick disconnects.

Typical Junction Box Location

Alternate locations allowed provided junction box to base distance does not exceed 10'.

Detail A

Light Standards Wiring Details

Wireing Detail Light Standard Slip Base

*Application for fixed base similar except no cable tie is required at junction box.

Standard Plan J-1e

Approved for publication by the Washington State Department of Transportation, Olympia, Washington.
Any Questions?