Southwire®

UNDERGROUND DUCT BANK AMPACITY

CALCULATION CONCERNS & CONSIDERATIONS

"This correspondence is neither intended, nor should it be relied upon to provide professional consultation or service. It is only my technical opinion and for general information purposes."
Mohammad Sadrzadeh | National Southwire Solutions Professional

WHAT'S WRONG WITH THIS UNDERGROUND DUCT BANK? IS IT ONE THING, EVERYTHING, NOTHING?

Sometimes when designing electrical power systems, it is necessary to calculate underground cable's ampacity.

There are various methods being used recently including Code Books and Ampacity Tables, Neher McGrath Calculation method, IEEE835 method, Computer Programs and Simulators, etc.

The most common and convenient method seems to be using Ampacity Tables. A technical designer can easily look up the related diagrams, tables and sizes of cable instead of using the actual Neher -McGrath Method with almost 20 equations that sometimes can be confusing. When using Ampacity Tables, we must bear in mind that these tables are subject to several assumptions. The values in these tables mostly came from the Neher-McGrath Method, but they only exist for simplification. Thus, they can only be used for more simple and smaller projects, which is reasonable.

Ampacity tables in the Electrical Code Books (e.g., NEC, CEC, etc.) are sufficient for some installations but contain several rough approximations, therefore include a significant safety margin. Also, there are many instances in actual life that we cannot find any instructions in a Code Book to address certain issues. I will discuss some examples shortly.

We can agree that if a Duct Bank's layout matches the Code Book's Configuration Diagrams, we can use the corresponding tables and charts to size our cables.

For example, if we are basing our calculations on CEC for cables, which are not rated for more than 5Kv and Non-Shielded, we can refer to tables 1 to 4 and/or Appendix D. In Appendix D, we can find a few different Installations Diagrams for different designs. Including Installation configurations for Direct Buried Cables (Diagram D10), Conduit/Raceway (Diagram D11), ...

For the sake of this article, we are going to choose a Conduit/Raceway Configuration (Diagram D11) as an example. This offers 7 layout details labeled from DET1 to DET7 and their corresponding Tables D11A & D11B to size the cable/s for any or each Diagram (DET1 to DET7). As mentioned, this is a great tool to avoid a complicated calculation and to save time in selecting the type and size of the cables, if we can configure our duct bank exactly like one of these configurations.

There are many occasions in real life that a Duct Bank's configuration cannot exactly match with one of those configurations and these instances are rapidly growing in numbers. For example, cables must be buried way deeper than indicated 760 mm, or the number of cables is more than 7, or there are other heat sources (steam pipes, another underground power cable raceway, etc.) are adjacent to the duct bank in question. In these cases, can we make assumptions or disregard the adjacency of the other systems to select our cable? Would this cable satisfy job requirements while protecting the integrity of the system and its expected life cycle? How can we verify the effect and severities of these deviations on our duct bank?

PRIMARY CABLE DERATING FACTORS:
1. Number and size of conduits and conductors
2. Configuration of the conduits and conductors
3. Conduit spacing both horizontal and vertical
4. Burial depth of the conduits and conductors
5. RHO factor. (Thermal resistivity of the race way and back-fill material).
6. Load factor of the conductors.
7. The actual design load of the system

Cable's derating factors are not limited to above mentioned.

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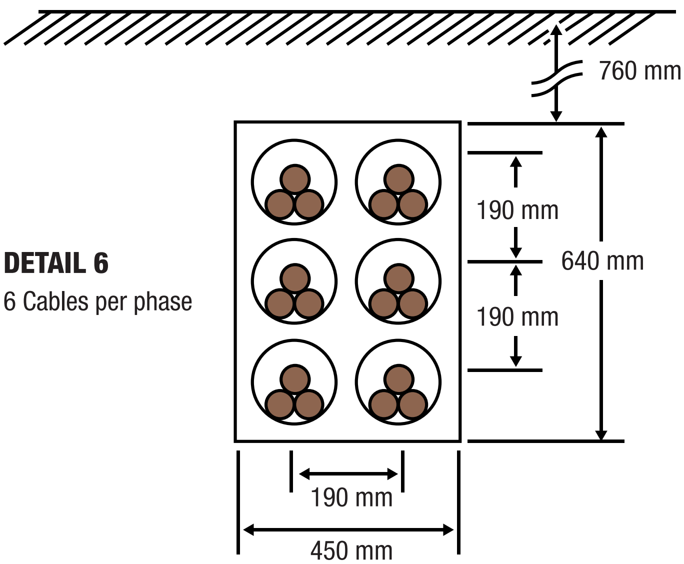
HOW ABOUT WE USE AN EXAMPLE TO INVESTIGATE A COUPLE?

Let us assume that we are going to install a 2000 Amps, 3 Phase, 4 wire Underground Duct Bank. Our system is rated for 75 degrees Celsius, and we would like to use 6 cables (or less if possible). Obviously, we would like to find the smallest suitable cable for our application. For the sake of this test, let us say our configuration is exactly like DET6 below, that we can use an ampacity table which is handy:

DETAIL 6
6 Cables per phase



If using a code book, we must be vigilant with notes and references to other rules and subrules (if there are any). To name one related to this conversation reference to temperature limitations which is explained in Rule 4-006 and Appendix B.

e.g.
**** Temperature limitations Rules: 4-006, 12-1104, 12-1154, 12-1210, 12-1508, 12-1604*
**** As per form Rule 4-006 in regards with Temperature limitations of Conductors, where the maximum conductor termination temperature for equipment is not marked, the maximum conductor termination temperature shall be considered to be 60 °C for equipment (i) rated not more than 100 A; or ii) marked for use with No. 1 AWG or smaller conductors. Or 75 °C for equipment (i) rated more than 100 A; or ii) marked for use with conductors larger than No. 1 AWG.)*

As per the notes below and in reference to Table D11A & D11B from the CEC, we can see that allowable ampacity values listed on these tables are based on 90 degrees C rated system. (Equipment, Cable, Termination,….). So a 90 C rated cables doesn't necessarily means that we can use the listed ampacities without applying a derating factor (here the 0.886 multiplier) for all applications. If our system is rated for 75 Celsius, then we must apply the indicated multiplier (derating factor).

Going back to our example, having the total required load 2000 amps, and the number of cables, we should be able to find about minimum ampacity requirement of each cable. 2000 / 6 = 333.3 amps. In this case our system is rated at 75C which is very common, thus we must apply the detrating factor of 0.886 as per CEC.

333.33/0.886 = 376.22 AMPS.

Knowing the number of the cables (and probably its conductor type) and min. required ampacity of the cable we should be able to look into the proper ampacity table and identify the size of the cable.

- From Table D11A (Copper conductors), we can see that 750 Kcmil Cu shows the closest ampacity to our desired load.

- Alternatively from Table D11B (Aluminum conductors), the 1250 Kcmil Al, shows the closest ampacity the 374.22 in question.

Now, let's put this under test before we dive into the other scenarios which deviate form CEC's Configuration Diagrams.

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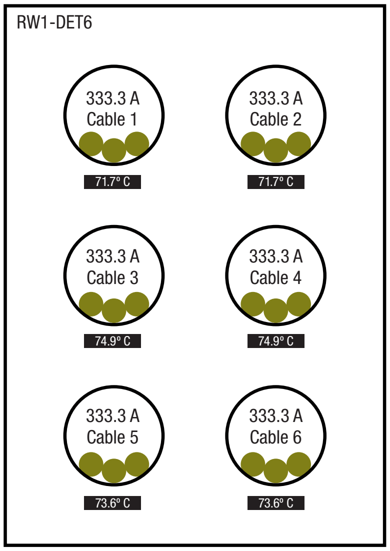
RHO EFFECT



Graph 1 - Underground Duct Bank, Encased in Concrete, backfilled with Soil

IN CONCRETE ENCASEMENT (RHO55)

System is rated for 75 Degrees C.
System Amps: 2000 Amps (333.3 amps / cable)
Cable/s: 750 Kcmil, RW90 Cu, Rated 90 C.
Ambient Temp.: 20 Degree C.
System Voltage: 347/600V 3-Phase, 4 W Conduits: 4" PVC, Sch 40
Conduits encased in concrete (Rho 55), backfilled with Soil (Rho 90)

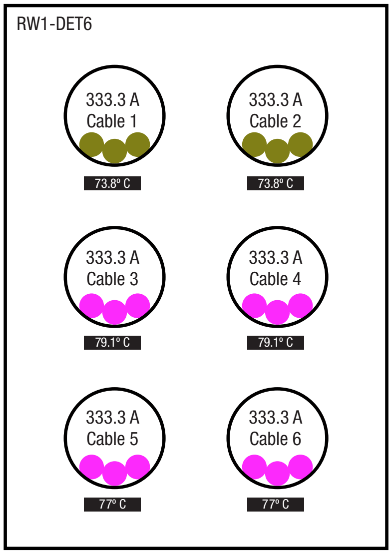
This looks great. From Table11A, derated Amps per cable for a 750 Kcmil Cu and Det 6 is 330.24 Amps. which translates to 330.242 * 6 = 1981.44 (Total Load).

As per Graph 1, we even can expect 1999.8 Amps which is slightly higher and yet be compliant.

THERMAL RESISTIVITY DATA: (The lower the Rho the higher expected ampacity)

EXAMPLES OF THERMAL RESISTIVITY	
Engineered Backfill	Less than 55 Rho
Concrete - Good Choice	About 55 Rho
Uniform Crushed Limestone (3/8" diameter w/ clean sand)	~ 70 to 80 Rho
Uniform Crushed Rock Wet or Dry with Sand	~ 80 to 90 Rho
Sandy / Loose / Wet or Dry? Moist Loose Soil	~ 90 Rho

What would happen if conduits were direct buried?



Graph 1 - Underground Duct Bank, Direct Buried in Soil

DIRECT BURIED IN SOIL (RHO 90

System is rated for 75 Degrees C.
Total Load: 2000 Amps (333.3 amps / cable)
Cable/s: 750 Kcmil, RW90 Cu, Rated 90 C
Ambient Temp.: 20 Degree C.
Voltage: 347/600V 3-Phase, 4 W
Conduits: 4" PVC, Sch 40, C-C spacing 190 mm
Top of encasement to earth surface: 760 mm
Conduits are buried in Soil (Rho 90)

As we can see with changing only one factor (thermal resistivity of the encasement) the hottest cable temperature jumps 5 degrees C higher and makes our design non compliant.

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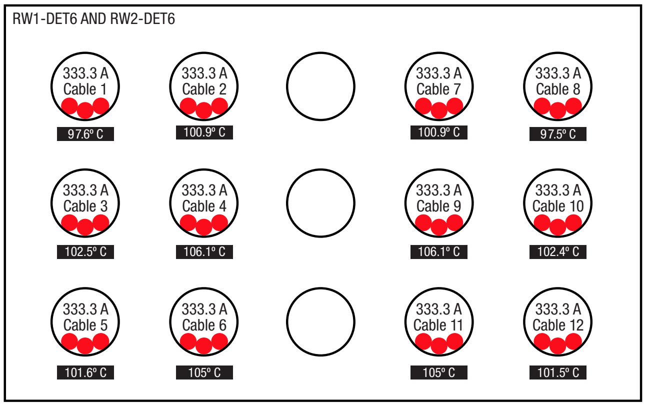
NUMBER OF CABLES

Another option from the Code Book which is very common is additional cables.

Let us use the Duct Bank in Graph one as an example. A raceway similar to the DET6 from the CEC which is shown to meet the standard. I am assuming that we have two of this raceway (**Graph 1**) and we would like to install both in a single trench. Obviously, we better have some space between these two raceways to avoid the risk of overheating our cables during operation. One question could be how much space is needed?

How about we use the common 190mm spacing between conduits, for these two phases? Below is the calculation result by using one of well know programs. The outcomes appear to be a drastic change in cable temperatures, unfortunately not in a positive way.

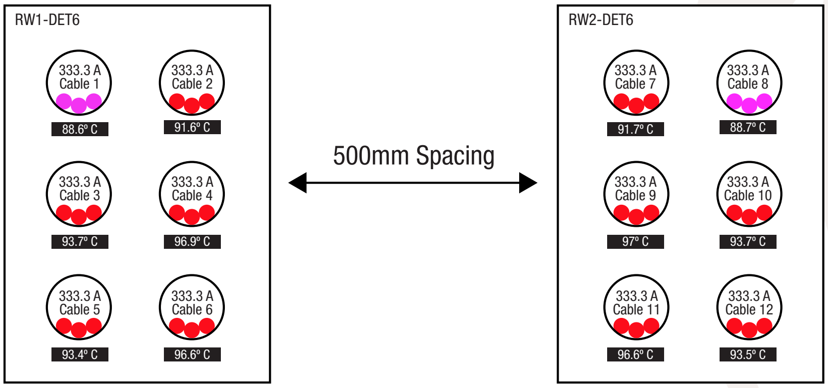


System is rated for 75 Degrees C.
Total Load: 2000 Amps (333.3 amps / cable) times 2
Cable/s: 750 Kcmil, RW90 Cu, Rated 90 C.
Ambient Temp.: 20 Degree C.
Voltage: 347/600V 3-Phase, 4 W
Conduits: 4" PVC, Sch 40, C-C spacing 190 mm
Top of encasement to earth surface: 760 mm
Conduits encased in concrete (Rho 55) and backfilled with Soil (Rho 90)

Graph 3 - Both 2000 Amps Services in One Concrete Encasement

The second-row cables RW1-DET6 (Graph 2) which showed to be 74.9 C earlier, jumped up to about 106 C. About 30 degrees change. Cable's temperatures which originally were slightly lower that their allowable rating now drastically exceeded Allowable Ampacity.

Probably we shouldn't put them both in the same trench, correct? They could be just fine if we would dig another trench a little further for the second phase, Correct? How about ½ meter spacing between these two phases?



System is rated for 75 Degrees C.
Total Load: 2000 Amps (333.3 amps / cable) each phase
Cable/s: 750 Kcmil, RW90 Cu, Rated 90 C.
Ambient Temp.: 20 Degrees C.
System Voltage: 347/600V 3-Phase, 4W
Conduits: 4" PVC, Sch 40, C-C spacing 190 mm
Top of encasement to earth surface: 760 mm
Conduits encased in concrete (Rho 55) and backfilled with Soil (Rho 90)

Graph 4 - Two identical Duct Bank in Separate Trench, Enased in Concrete

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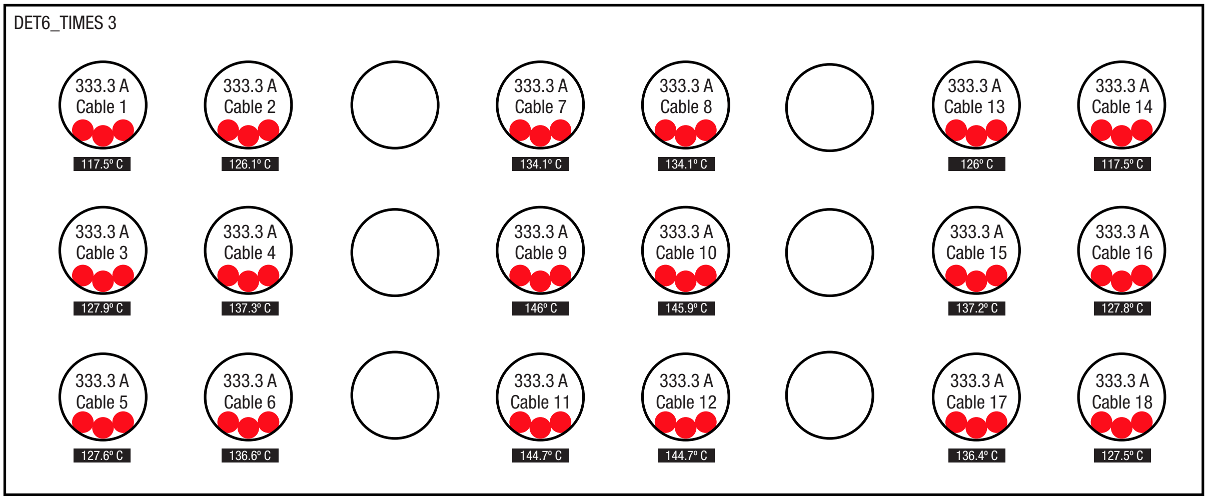
NUMBER OF CABLES CONT.

Comparing Graph 3 with Graph 4, we can see that adding more spacing and dedicating a trench to each phase would help; however, it won't necessarily make our system compliant.



Graph 5 -Cable Ampacities are not Governed only by their Current Carrying Capacity!

CONCLUSION

Following above-mentioned examples (Graphs 1-4), we can tell that Underground Duct Bank Design can be way more sophisticated than some might normally expect. Calculation of the underground cable ampacity is very complex process that requires analysis of many different variables and we must be very cautious about it.

Hope you find this letter of interest and please do not hesitate to reach out to me with any questions, comment, and suggestions.

ABOUT MOHAMMAD SADRZADEH, B.SC. ENG.

Mohammad Sadrzadeh is the National Southwire Solutions Professional. He has over 25 years' experience in variety of different technical fields including 7 years of wire & cable experiences gained through many institutional and commercial projects across Canada.

Mohammad has done many jobsite surveys, technical calculations, conduit optimization, and cable pull planning set ups, etc. He is very passionate about sharing his expertise on better and safer Underground Duct Bank Configuration, Conduit Optimization, and Cable Installations.

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