

# Nano-Dies for Cable Compacting – Why Do They Work?

## Nano-Dies are Different:

A Nano-Die is constructed by first manufacturing a Tungsten Carbide die, then coating the working surface of the die with two or three extremely fine layers of diamond in a CVD process. The crystalline structure at the surface of a Nano-Die is quite different from the surface of a PCD die.

PCD material is manufactured with the particles pointing in all directions at random, with a range of particle sizes distributed around the mean particle size.

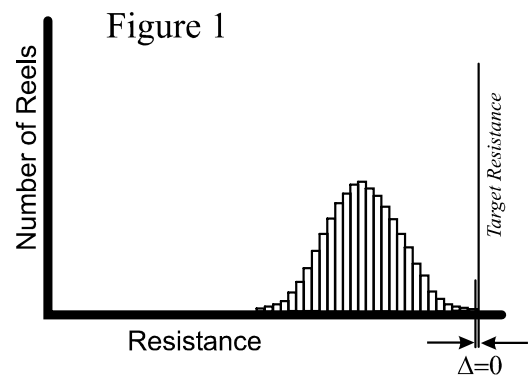
Nano-Dies are manufactured with the same sized nanocrystalline diamond particles locked together in a pattern. This is from where the Nano-Die derives its enormous hardness and strength.

When a Nano-Die fails, it is not like a Tungsten Carbide or PCD die in which a process of steady wear causes the die to go out of tolerance. A Nano-Die holds +0 tolerance throughout its working life. When it finally fails, it is due to collapse of the diamond surface caused by metal fatigue in the Tungsten Carbide foundation material. A Nano-Die typically holds its diameter +0 for 500-800 km [say 300-500 miles] of cable compacted. In some cases, the die will run for 1,000 km [say 620 miles] of cable compacted.

## Nano-Dies Create New Possibilities:

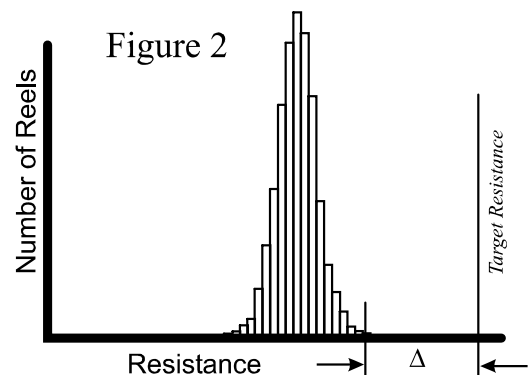
There are many variables in the process of cable compacting. What you want is to hit the Cable Electrical Resistance Target every time. What you get is a spread of results, much wider than you would like. It is not always easy to see exactly what factors are involved to cause such a spread of results, but we suggest a few:

- (a) Dies - variation due to wear.
- (b) Dies - failure to change on time when wear occurs.
- (c) Variations in resistivity of the raw material.
- (d) Temperature variations.
- (e) Damage to micro-structure of the conductors (caused by dies or by compacting too tightly)
- (f) Variability in performance of compacting machinery.



Here is an experiment that is rarely performed. But it throws a lot of light on the truth about cable manufacture. Consider the result if 1,000 reels of cable were manufactured to the same specification. All normal die changes and maintenance are performed. Results are recorded in a histogram format. The spread of results might appear as indicated in Figure 1. The results are shown that would be obtained by a company who had long experience of manufacturing these particular reels of cable to this particular specification. The cable has been designed to ensure that the Electrical Resistance Test is passed every time. We often hear of a “5% Safety Factor” being applied to raw material to ensure that the Resistance Test is passed, but the truth is as shown in Fig. 1. The results are spread in the form of a histogram and the cable is designed to place the upper tail of the distribution right on the Target Resistance.

Now imagine a second experiment. Replace the dies with Nano-Dies but leave everything else the same (as far as possible). Imagine that another 1,000 reels of cable are manufactured. The spread of results is noticeably different this time (Figure 2). The most important difference is that there is now a significant gap between the upper tail of the distribution and the Target Resistance. Call this gap  $\Delta$ .



In Figure 2, notice that Nano-Dies have significantly reduced the spread of results. This probably means that the original dies were the main cause of the results being spread widely in Figure 1. Also, the mean electrical resistance of the cable is reduced (i.e. the electrical resistance where the distribution is highest). We suggest two reasons for these improvements:

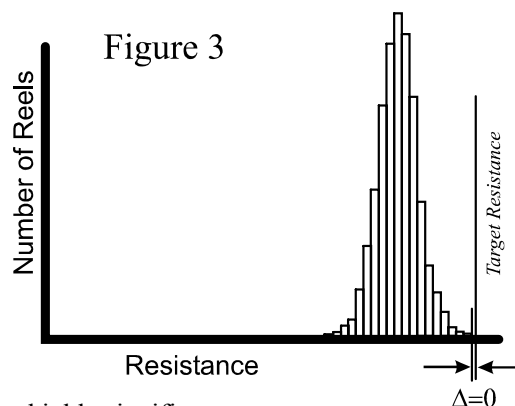
1. Nano-Dies hold +0 tolerance for 500 to 800 km of cable compacted (say 300 to 500 miles).
2. Nano-Dies have lower surface friction than PCD or Tungsten Carbide dies. Hence they do less damage to the micro-structure of the individual conductors.

[More information at: <http://www.sanxinamerica.com/nano%20dies.pdf> ]

### Taking Advantage of the New Information:

We really do not think that a die-maker has any place telling a cable manufacturer what he has to do next. What follows is just to complete the picture. Of course it is not necessary to actually manufacture 2,000 reels of cable just to make the above points. But the discussion is statistical in nature, and statisticians love big numbers. Back in the real world, cable manufacturers frequently adjust their designs incrementally, based on just a few measurements. In any case, it is now possible to make small adjustments to the design of the cable to optimize production for the new conditions presented as a result of using Nano-Dies. The dual objective is (a) Manufacture of fully compliant cable and (b) Conservation of raw material.

The small changes may include adjustments to the diameters of individual conductors, or to the number of individual conductors, or to the diameters of the stranding and compacting dies, or all of these things. But the objective is to push Figure 2 to the right, so that final cable resistance is still sure to be less than the Target Resistance, but not enormously less. What we want is to re-design for  $\Delta=0$  as shown in Figure 3, exactly as we had in Figure 1.



The reward is better raw material utilization. Up to 2-3% improvement is frequently achieved in this way. These savings are highly significant.

If your plant is already using PCD dies for compacting and stranding, this does NOT mean that the above benefits cannot be achieved. For larger diameters where PCD dies simply cannot be manufactured or are simply too expensive to even consider, Nano-Dies provide the full benefits noted above.

For the smaller diameters where PCD dies are still sometimes used, Material Utilization improvements up to 1-2% are achievable by replacing PCD dies with Nano-Dies. In other words, PCD dies are better than Tungsten Carbide dies, but their performance in cable compacting and stranding is still inferior to the performance of Nano-Dies. 1-2% raw material saving is highly significant. And please keep in mind that the cost of a Nano-Die is 3-6 times less than the cost of the equivalent PCD die.

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