The Principles of Static Electricity
in a Dust Collection System
by Rick Christopherson

Preface to the Preface (February 2008):

Several times now, I have considered deleting this article from my website because it is not significantly applicable to a home workshop dust collection system. However, I have received enough email questions from industrial applications to realize that removing this information would be a great disservice to those people where this information is most critical.

If you are reading this article because you have a home workshop dust collection system with PVC piping, then don't panic with what you read below. However, if you are in an industrial application, then you should take heed to this information. I almost deleted this article last month when I cleaned up my website, but today I received another email from a non-woodworking relating reader where an explosion hazard is extremely great. It is for this reason that I am maintaining this article.

Preface:

I do not condone the use of PVC ducting for dust collection systems, and this article should not be construed as a solution to that end. The original purpose of this discussion was to cover one specific aspect of this discussion, and it remains to be the primary focus, however, it does also cover many other aspects in reaching this goal. It was stated by some at the time, that a wire wrapped around the outside of a PVC line is just as effective as a wire on the inside. This conclusion is not correct, and the following discussion is geared toward that purpose.

In addressing this one issue, this treatise does cover many educational discussions, and frankly, some of them get pretty deep into electrical theories. Much of this cannot exactly be classified as light reading (although I have stripped out some of the tech-talk from the original discussions).

What you do in your shop is not for me to dictate, and so I have added some information to this subject to assist you, should you choose to proceed. I also acknowledge the realities of home-shop dust collection systems, in that they may be less prone to the problems of static-induced dust explosions.

What is Static Charge

A few years ago, a little known scientist named Benjamin Franklin, observed that a glass rod rubbed with silk will take on a positive charge, and a plastic rod (shell-

lac back in his time) rubbed with fur would take on a negative charge. Actually, Franklin is credited with naming the *positive* and *negative* charges for these two situations.

The plastic rod strips electrons away from the fur, thereby giving the plastic a net, negative charge. The same situation occurs when an air/dust mixture passes over a plastic surface. The plastic will extract electrons from the flowing air. This will make the plastic negatively charged and the air/dust positively charged.

Static charge is the result of an area or surface having too many electrons (negative charge), or too few electrons (positive charge).

Static Versus Flowing Electricity

Static electricity is just as it sounds; the electrons are not moving, but are stationary or "static". The electrical current flowing through the wires in your home is made up of electrons. In this case, the electrons are moving or "flowing". This is the only distinction between static electricity and flowing electricity. When static electricity suddenly moves, like in a spark, it is no longer static. (Just in case there is a nuclear physicist reading, this is a macroscopic discussion to avoid confusion or argument.)

Electric Charge and Insulators

An insulator is a material which does not readily permit the movement of free electrons. While there is actually no material which is a perfect insulator, the resistivity of insulators is so high, that they are for all practical purposes, completely non-conducting. The resistivity for fused quartz is 10^{25} times greater than that of copper. (that's 10 to the power of 25) Which means fused quartz is ten-billion-billion-billion-billion times more resistive than copper. I unfortunately do not have resistive values for other insulating materials, but suffice it to say, the values are quite large before they are even considered insulators.

Because an insulator like glass, plastic, or PVC does not permit the movement of electrons, the charge placed on these materials (by rubbing with silk, etc) will remain in the same place where it was rubbed. One end of a glass rod will be charged while the other end, which you are holding will not be charged.

Contrary to initial belief, you can also charge a metal rod in the same fashion, but the charge placed on the rod will spread out across the whole surface. If you are touching the rod with your hand (you are also a conductor) the charge will dissipate (spread out) through you as well. The difference between the metal rod and the plastic rod is that the charge will "spread out" in the metal rod. Like charges will repel one another, and the electrons, which are free to move in metals, will spread themselves out across the entire surface of the metal rod (or in our case, the entire dust collection system.) As a result, the entire system will be at the same voltage.

In one of the Internet discussions, someone mentioned that the charge on a PVC pipe will flow around the outside of the PVC or across the surface and equalize. If that were the case, then the rod used in Ben Franklin's experiment would have discharged into his body, and he never would have developed the concept of

positive and negative charge. (Well, maybe he got frustrated doing all that rubbing for nothing and went out and flew his kite--who knows?)

Dielectric Breakdown

The two terms, *insulators* and *dielectrics* mean the same thing, just different terminology, but dielectric is a common term when discussing static charge. An insulator or dielectric will not, in practical terms, permit the flow of electricity. Air is a dielectric, yet we see lightning all the time. I just said that lightning (or a spark) is the sudden flow of electricity, so how can this be? Isn't that contradictory? No.

If there is a large enough voltage across an insulator, the insulation will *breakdown*, electrons will suddenly flow, and a spark will result. In our case, sparks are bad, as they also generate heat, and heat can ignite flammable materials. The voltage necessary for breakdown is dependent on both the material in question, and the thickness of the material. Furthermore, the longer the spark, typically, the hotter it gets. (Any mechanic will tell you this, with regard to the sparkplug gap setting.)

The primary point about dielectric breakdown, is that it takes far, far less voltage for a spark to jump through air, than it does to jump through PVC. This is the reason why it is absolutely pointless to wrap a ground wire around the outside of a PVC duct and expect protection against static buildup on the inside.

Below is a table of dielectric breakdown voltages for various materials. I have taken the liberty to convert these numbers into inches from the original millimeter data. This data is in the form of volts per inch of insulator. What this data tells us, is that it takes nearly 160,000 volts before a 1/8 inch thick PVC pipe will breakdown, and allow current to flow from the inside of the PVC to the outside where the ground wire is (I used polyethylene since PVC is not provided--1,270,000 volts per inch = 160,000 volts per 1/8 inch). Working backwards with this voltage, this translates into a spark in air which is nearly eight inches long! (That is one hot spark!)

Material	**Dielectric Breakdown (Volts/inch)**	**Thickness needed for 100,000 volt Protection**
Vacuum	infinite	N/A
Air (stp)	20,320	4.9"
Water	Conducts	N/A
Paper	355,600	0.28"
Fused Quartz	203,200	0.49"

Bakelite	304,800	0.33"
Polyethylene	1,270,000	0.08"
Polystyrene	635,000	0.16"
Neoprene	304,800	0.33"

In short, we will have a spark in the air long before we can dissipate the charge to the outside of the PVC.

The spark that travels can either be between the negatively charged PVC and the positively charged air, or it can be from surface to surface on the PVC. Since the PVC does not conduct, it will not equalize the charge throughout the length or even diameter of the pipe. As a result, there is the potential for the spark to jump from one section of the PVC to another. Even an internal ground wire will not prevent this, as the wire only covers a small portion of the surface.

Explosion

Any material that can burn can also explode under the right conditions. (I think it may even be possible for non-flammable materials to explode too.) This all relates to the concentration of the material. If the concentration is too low, then there is not enough proximity between particles to support a chain reaction. If the concentration is too high, then the mixture is considered too rich, and there will not be enough air available for rapid combustion. These two concentration levels are called the *Lower Explosive Limit* (LEL) and the *Upper Explosive Limit* (UEL). Looking at gasoline for example. It should be fairly obvious that too little concentration will not explode, otherwise gas stations would literally be "popping up" everywhere. What is a little more difficult to understand is the concept of the UEL. Do not try this! But I saw a match dropped into a small container of gas. Since there was not enough oxygen for combustion, there was no fire or explosion--the match went out. (This was a scientific demonstration under controlled conditions by an expert, do not try it yourself.)

I am not aware of any published LEL or UEL for sawdust as these numbers will vary depending on particle size, moisture content, etc. what I do know is that the finer the dust particle size, such as from a sander, the lower the concentration needed to combust.

Some Reality Checks

Q: Why doesn't my shop vac explode?
A: Because the air velocity in a shop vac is high, the static build up is also very high, and sparks happen frequently inside the hose. However, the same high velocity of the air also reduces the chance for an LEL concentration to develop

within the hose. In this case, you have the ignition source, but don't have the explosive concentration.

Q: Why are there so few occurrences of explosions in home shops?
A: Home shop explosions are not impossible, but they are rare. This is because you need both an LEL concentration and an ignition source at the same time and same place. The odds are low, but not zero.

When you are sanding, not only is the LEL concentration likely to occur, but the increase in particulate will also increase the frequency of electrical discharges within the pipe--it is just a matter of timing.

When you are cleaning out your ductwork system, not only do you have electrical discharge present from particulate travel, but you will also have frequent occurrences of LEL concentrations, whether in small pockets, or throughout the length of the system. The chances here are much higher.

Q: I have never had a dust explosion before, so why should I expect one in the future?
A: How do you know you have never had a minor dust explosion contained within the ducting? Not all dust explosions are catastrophic. Most are isolated to the limited space were an LEL concentration exists, and burn out quickly enough so as not to ignite the remainder of the dust system. I've never had a car accident before, but that doesn't mean I don't need my seat belt!

Q: Some publications have stated that I can wrap the outside of the PVC with a ground wire and be protected. Is this correct?
A: No! Wrapping the outside of the PVC will seem to be effective from the outside because the amount of static there is reduced. However, the danger is not on the outside of the pipe, it is on the inside of the pipe. Refer to the discussion on dielectrics to see why it makes no difference what happens on the outside.

Q: I have heard that I should run a wire through the inside of the pipe, and a second spiral around the outside for best protection. Does this add to my protection?
A: No! Wrapping the wire around the outside is a "convenience" issue for the operator, not a safety issue. This wire will reduce the "nuisance" jolts that someone may get in touching the outside of the pipe, or reduce the amount of dust piling up on the surface, but it has no bearing on the internal charges within the pipe, and again, the inside is where the danger is. It won't hurt to wrap the outside, but it adds no safety to the risk of explosion.

Q: I have heard that it is OK to have the wire outside as long as I drill holes and install rivets or screws through the PVC since these are penetrating into the inside area. Correct?
A: No! By following the same discussion on dielectrics as before, the sporadic spacing of the screws or rivets is not enough to eliminate potential arching. Using the analogy from above, the sparkplug on your car is hot enough to ignite gasoline with only a 1/16 inch gap. How close are your rivets going to need to be to prevent a hot enough spark to ignite the dust? (Much closer than 1 inch apart!

That's for sure.)

Q: I am going to run a wire through the inside of the pipe, but I have heard that I can use insulated wire, is this correct?
A: No! Using insulated wire will not help whatsoever. It must be bare wire.

Q: I have been told by an electrician that the ground wire for my dust collection system should be connected to an 8 foot copper rod driven into the ground for proper protection. My shop is all concrete, so how can I do this?
A: Save your money and your sweat. This is not necessary. The primary concern of the system is to keep all points at the same voltage. The amount of current flowing through the ground is very low, and any grounding location will suffice.

Q: Should I connect the ground wire through the pipes to the dust collector chassis, the tool chassis, or both?
A: To be safe, I would connect the wire to both the dust collector chassis and the tool chassis. This prevents any voltage difference between either device and the ductwork.

Q:So if running a ground wire inside the PVC still doesn't guarantee protection, what is the point in grounding at all?
A: I do not know if grounding a system helps to eliminate static discharges, but it should help in reducing them. There are no guarantees except metallic ducting. It will probably reduce the chances, but what I do know is that a wire wrapped around the outside is of no use to this end.

Q: Should I use PVC for the ducting?
A: This is the BIG question. I would recommend against it, but you should check for yourself. You may be surprised at the low cost of HVAC ductwork. Because the home dust collection system does not generate high static pressures, normal heating duct will work quite well without collapsing.

Q: If I install metallic ducting, do I need to worry about grounding the system?
A: Not really. The only exception would be if you used plastic blast gates. Even in this case, the static build up is minimal, and probably not worth the bother.