Ducting

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1. **Disclaimer**

   Because improperly designed ducting can cause fires, fail to meet local codes, etc., these drawings, plans, procedures and words are for information only. <u>USE THIS AT YOUR OWN RISK!</u> <u>HIRE A</u>

PROFESSIONAL ENGINEER to design, specify, test, and certify performance of any industrial dust collection system if you have a commercial or an industrial application, allergies, other medical problems, people working for you, a large shop, work with hazardous materials, or are subject to regulatory oversight. Neither I (Bill Pentz), American Air Filter, nor any other references or links on these pages will accept any liability for the applicability of this information to your specific situation or any damages or injury caused to people or property from the use of this information or from any associated links. No claims are expressed or implied as to the safety, usefulness, or accuracy of this information. Your actions are your responsibility - VERIFY and CHECK information out before proceeding, and don't attempt anything without the required skills.

2. **Ducting Introduction**

Ducting consists of all the hoods, tool ports, flex hoses, duct, wyes, blast gates and other piping components needed for good "chip collection" and good fine dust collection. This page shares what the experts who guarantee customer air quality advise us to do to fix our tools, tool hoods, tool ports, ducting, and ducting layout to provide good fine dust collection. If you have not already read the earlier pages, I recommend you do so as good ducting is not required for good fine dust protection.

1. **Getting Started**

Before staring we need to first decide on a suitable level of dust collection because our level of protection defines what we need to do. All hobbyists and six out of seven professional woodworkers work in small shops that are not government inspected or covered by any standards except what we choose to put in place for ourselves. There are four different levels of dust collection practiced in the U.S. Each level requires a different approach, more work, and higher cost.

The only enforced dust collection standard in the U.S. for larger commercial facilities is "chip collection". "Chip collection" keeps our tools, floors, and work surfaces clear to avoid injury and accidents. Chip collection collects the same dust we would otherwise sweep up with a broom.

All other levels of dust collection try to meet an air quality standard, but air quality standards are a mess. The U.S. Department of Labor, Office of Safety and Health Administration (OSHA) is charged with protecting the health and safety of workers in large commercial facilities. With most of these facilities already blowing their fine dust away outside facility owners complained strongly against the proposed OSHA standards saying the new requirements were unnecessary and cost prohibitive. Studies commissioned by facility owners appeared that make many false claims such as woodworking makes no fine dust, venting outside blows the fine unhealthy away, there are no health risks from wood dust, and because commercial facilities vent outside their workers receive almost no fine dust exposure. Although none of these studies were blessed as peer reviewed medical articles, they did cause enough confusion that they delayed and badly watered down the OSHA air quality standard. The OSHA standard totally ignores the unhealthiest fine invisible airborne dust. Large facility owners successfully lobbied amply to get this standard removed before it was fully implemented. Meanwhile, the American Council of Governmental Industrial Hygienists (ACGIH) recommend a five times tougher than OSHA standard. The ACGIH standard is what most larger commercial firms follow to avoid personal injury lawsuits. The medical recommendations, European Union and Environmental Protection Agency (EPA) agree on a standard that is fifty times tougher than the overturned OSHA standard.

As a biomedical engineer, long time university engineering instructor, and one who got badly blindsided after I trusted the "best" small shop cyclone system to protect my health, I strongly recommend all small shop workers pay very serious attention to fine dust. I personally set up my shop to meet the EPA standard and recommend you do the same.

2. **Chip Collection**

"Chip collection" has been a standard since the 1920s so is well researched with lots of experience. To get good "chip collection" we need hoods that block and control the fast moving airstreams from our blades, bits and cutters. We need about 350 cubic feet per minute (CFM) air volume with an airspeed of about 4000 feet per minute (FPM) to pick up and transport the dust and lighter chips. In spite of badly inflated advertizing claims where many vendors claim their dust collectors have over triple this airflow, only two of the best performing 1.5 hp dust collectors actually provide 350 CFM in real use when connected to standard 4" diameter ducts and tool ports. Vacuums, smaller collectors and smaller ducting collect too little.

Dust collection poses known fire and explosion risks. We must do our own regulation. Woodworking shops located in commercial buildings subject to fire marshal inspection must comply with local codes which mostly follow the National Fire Protection Association (NFPA) recommendations. There are many NFPA codes that our small shop vendors tend to misstate for their own convenience. For instance one popular cyclone vendor who sells ducting designs and parts strongly puts down the use of PVC duct because it does not meet NFPA standards. The NFPA standard is to prevent a static spark from causing a dust explosion. This standard does not apply to most small shops. Also, most small shops never create the right mix of airborne dust to create an explosion, and our systems do not generate enough static to ignite an explosion. This same vendor then justifies their sale of cyclones that fail to comply with the NFPA rule that all indoor cyclones must be fire and explosion proof because there has never been a reported incident of a small shop dust triggered explosion. Strangely, this same vendor totally ignores the NFPA guidelines and sells cardboard dust bins that are a bad fire risk, plus they only use aluminum impellers that the NFPA abandoned years ago. NFPA strongly recommends against use of aluminum impellers because when hit by a piece of metal such as a screw or staple aluminum launches sparks similar to sparklers. This thermite reaction drops white hot metal into our dust bins. These can smolder like a cigarette to create a fire long after we leave our shops.

3. **Fine Dust Risks**

I am not too worried about explosion, a little concerned about fire, and a lot more concerned about building up dangerously unhealthy amounts of fine dust in our shops. That is why I think all dust collection equipment should be placed or at least vented outside.

Starting in the early sixties insurance data and medical studies showed a strong causal relationship between airborne wood dust exposure and health problems with woodworkers. Most small shops trap the fine dust inside where it builds to such high levels that a typical small shop woodworker gets more fine dust exposure in a few hours of woodworking than a commercial worker receives in months of full time work. The much larger small shop woodworker exposures should get our attention. The medical insurance data show roughly one in eight woodworkers who work in facilities that vent outside develop such serious wood dust health problems that they are forced into early retirement. Wood dust poses three serious problems.

- First, woodworking makes lots of very fine dust that is invisible without magnification. The medical data clearly shows there is no safe level of this fine dust exposure. **Every fine dust exposure causes some measurable loss of respiratory function, some of this loss becomes permanent, and continued exposure over time builds debilitating health problems.** In fact, fine dust known by researchers as particle material (PM) is so extensively studied that a Google search on "PM health risks" will turn up over forty-seven million references.
- Second, the high silica (glass) content in wood creates sharp jagged fine invisible wood dust particles that cause even more damage to our skin and respiratory tissues.
- Third, wood dust is even worse because wood contains and carries toxic chemicals. Trees produce strong toxic chemicals to protect themselves from predators plus many woods are further contaminated with other toxic chemicals from insecticides, herbicides, preservatives, etc. These toxic chemicals can cause irritation, cause poisoning, cause neurological damage, increase our risk of certain cancers, and cause us to rapidly build dangerous allergic reactions. Roughly one third of all woodworkers eventually develop some allergic reaction to wood dust and about seven in thousand develop such strong allergies they must stop woodworking.

4. **Fine Dust Collection**

Facilities that fail to meet the air quality standards can be cited, fined and even closed down. The air engineering firms who guarantee customer air quality prepared for years to meet the new standards. They did considerable study, engineering and testing and now have over two decades of experience with most reaching the same basic conclusions with similar solutions. They found **fine dust spreads so rapidly even a big air cleaner or exhaust fan needs hours to bring the dust level down enough to be safe. During this time that dust will harm workers and shops will fail air quality checks**. Fine airborne dust spreads so quickly that **good air quality requires collecting the fine dust at the source** as it is made before it can spread. Air engineers went through years of testing and decades of refinement to work through the details to meet proposed OSHA air quality regulations. These firms found the most existing tools came with no dust collection or at best poor "chip collection" built in, so worked poorly for good fine dust collection. With costs to replace existing tools prohibitive, air engineers found they could get good fine dust collection at most older tools by moving enough air and upgrading tool hoods to better contain, control, and deliver the fine dust for collection. They developed new CFM requirement tables for each size and type of tool that with hood upgrades moved enough air to ensure capturing the fine dust. They found **the only effective way to get good airborne dust control at each tool source is to upgrade tool hoods to contain and control the fine dust, upgrade tool ports to not restrict airflow, move far more air to ensure collecting over a large area to capture the fine dust before it can escape, use larger diameter ducting able to carry ample airflow, separate off the heavier sawdust and chips, then get rid of the fine dust**. It was most cost efficient to exhaust the fine dust outside. When climate or local laws preclude exhausting outside, far more work and cost is required to amply filter the air for returning it safely into our shops. In

1989 when OSHA finally declared wood dust a nuisance and set air quality standards, most large commercial shops were already running OSHA compliant dust collection.

Many experts called OSHA air quality requirements too lax. Medical studies and insurance records already showed most workers in OSHA compliant facilities eventually developed dust related medical problems. The Australian Ministry of Health says this exposure level eventually leaves all ill with roughly one in fourteen forced into an early medical retirement due to dust related health problems. The American Conference of Industrial Hygienists (ACGIH) responded recommending five times lower airborne dust levels and these recommendations were supported by the Environmental Protection Agency (EPA). Many large commercial woodworking firms now voluntarily follow ACGIH recommendations. Although that upgrade helps, wood dust has since been classified as a cancer causing agent so medical experts recommended a fifty times higher than OSHA air quality standard which has already been adopted by the European Union. Meeting these higher air quality standards requires the same hood, port, and tool upgrades, but more airflow. In spite of ACGIH, EPA and the European Union activity, the 1989 OSHA standard remains the only U.S. standard. Moreover, only the largest woodworking facilities receive regular OSHA air quality testing, so most professional woodworkers and hobbyists remain on their own.

5. **Airflow**

Fortunately, the better air engineering firms share most of what they learned on the Internet covering what we need to do to capture the fine dust before it can escape. They established in tables like the Cincinnati Fan Engineering Data the air speeds measured in feet per minute (FPM) we need to collect various sized chips and transport those chips through ducting without plugging or building up dust piles. Plugging and dust piles pose a potential fire hazard and when these piles break loose over time they will destroy blower impellers, bearings and filters. This reference is also one of the best to understand more about airflow and blowers. It gives the airspeed we need to pick up and transport the dust. We need the same airspeed to pick up the chips as we do to keep it moving in vertical ducting runs, so collection and vertical transport speed are often interchanged. We can get by with a little less airspeed to keep the dust moving in horizontal runs because horizontal runs do not have gravity working against us. These material handling tables show we must maintain airspeed inside our ducts of at least 3800 FPM to collect (and vertical transport) most normal sawdust but larger chips need up to 4500 FPM airspeed for collection. About 2800 FPM is needed to keep the horizontal runs clear. Air engineers established most woodworking operations that do not make heavy big chips are well covered if they target their blowers and ducting to move 4000 FPM airspeed. If you try to pick up larger chips and small blocks this is not enough airspeed.

They did considerable experimenting and testing, followed by decades of refinement to establish the CFM requirements tables similar to the one linked from AAF that show what airflow measured in cubic feet per minute (CFM) we need to collect at each type and size of woodworking tool before it can escape. They also found these CFM tables are worthless unless we also modify our older tool designs that spray fine dust all over with better hoods, ports, and internal ducting to protect, control, and deliver the fine dust for collection as it is made. Also with permission below shares some of the vendor recommended hood and collection designs for most major tools.

Air engineers also came up with the formulas and tables to ensure we have the right ducting and blower. They came up with simple formulas and approaches to help design our ducting to move the needed air with ample volume and speed at each tool. They built static calculators like the one linked here that estimate the resistance created by our ducting, flex hose, duct fittings, hoods, filters, cyclones, separators, etc. They provide blower fan tables that let us use our airflow requirement and resistance level to look up what sized blower with the right size impeller and motor to move the amounts of air we need. They also formalized this process into something that most can follow without special training or expertise to come up with a good dust collection system. Since we use the same size and types of tools as smaller commercial tools, most of what we need to do for good fine dust collection is already laid out in detail. Each of us can go through this process to determine our needs, pick a blower large and strong enough, configure our ducting, separate off the heavier dust, and either exhaust the fine stuff outside or appropriately filter that dust.

This engineering information shares most of the minimums we need for each type of dust collection. Roughly 350 CFM proved ample air volume to do good "chip collection at most of our larger small shop stationary tools and dustier operations. Their ducting formula FPM=CFM/Area shows that for our 4000 FPM and 350 CFM we need almost exactly 4" diameter duct. We can use smaller pipe, but then have to have a much bigger blower to generate extra pressure. Likewise, if we use bigger pipe, we then have to use a bigger blower to keep the airspeed up enough to avoid our pipes plugging and building up dust piles. Unfortunately the 350 CFM needed for good "chip collection" falls far short of the airflow needed for good fine dust collection. They found that meeting OSHA air quality requires just over 795 CFM and larger better hoods. Instead of just having to cover a 4" diameter area they found for good fine dust collection our hoods needed to cover roughly an 18" diameter collection area. The same simple ducting formula feeing in our 50 FPM needed to collect the fine dust over that 18" sphere shows we need. Rounding that to 800 CFM and keeping our 4000 FPM airspeed in our ducts to keep them clear says we need 6" diameter duct to move the 800 CFM needed to meet OSHA air quality standards. Their testing found we need about 900 CFM at our larger tools to cover a little more area and roughly 1000 CFM to meet medical air quality recommendations that are now the European standard. The same formulas show we need to use 7" diameter ducting to move the air for both the ACGIH and medical standards already adopted in Europe.

6. **Resistance**

Because air will compress, we assume we will get nearly the same flow on both sides of a small obstruction because the air will speed up to get around a small obstruction. Based on that knowledge, I assumed that we could minimize the length of that obstruction by using tapered adapters right at our machines and still use their built in 4" ports. I then received an email that asked me to further clarify, because in many instances this will not work. I pulled out my gauges and found out I was dead wrong.

Air at the low pressures we use in dust collection, air is more like water, and does not compress. Any obstruction, small pipe, or tight turn will kill our airflow dramatically just like closing a water valve. This means any obstruction, small port, undersized hood, restrictive internal air pathway in a tool, small section of hose, or restrictive duct fitting will act just like a water valve and seriously reduce flow. This also means our tapered and smaller adapters from our ducting to our tools are all but useless because they also kill our needed airflow.

When we have high resistance from an obstruction, that resistance will control the flow. To test this for yourself, try a simple experiment I learned in engineering classes long ago. Get a few feet of 1/8" interior diameter clear hose. Now cut off about a 1/2" of this hose. Without choking on that tiny piece, try to breathe through it. Most can but find it difficult. Now try to breathe through the longer piece. Most cannot because it has too much resistance. Now go back to the small piece and try to breathe through it quickly. You cannot because our lungs cannot create the pressure needed to overcome the high resistance of that small pipe. The same is true of our ducting. The resistance of the duct will define the airflow. If we use too small of ports, duct, fittings, or outlets, we kill the airflow needed for fine dust collection. (my thanks to Dave for reminding me that under typical dust collector pressures air is virtually incompressible).

Because air is near incompressible at the low pressures we use in dust collection, we end up with the pipe diameter controlling our air volume. This is just like water. We open and close a valve to regulate how much water comes out of our faucets. **To support the minimum 800 CFM we need for fine dust collection, we need to upgrade those 4" port connections to 6" and the ducting inside our machines to 6". Good fine dust collection requires 1000 CFM which requires 7" diameter ducting or using a bigger more powerful blower that generates the pressure to pull more air through a 6" duct.** For machines like my table saw with an interior duct, I had to use a larger port and a larger interior hose. Another serious resistance issue is the use of standard flex hose. Much of that hose is poorly made with ribs sticking into the airflow adding up to nine times the resistance of smooth pipe. Always buy and use a minimum of smooth interior walled flex hose as it that only adds about three times the resistance of smooth pipe.

7. **Ducting Diameter**

Ducting Diameter affects the amount of airflow just like the size of the pipe and water valve size affects water flow. Unlike a shop vacuum that generates roughly ten times the pressure, air from our blowers will not do a good job of squeezing around obstructions or through small openings. As a result size has everything to do with how much air you can move at a given pressure. We must size our ducting correctly. If made too small it kills our airflow needed for good fine dust collection. If made too large it does not maintain the airspeed in the ducting to avoid plugging and a buildup of dust piles. This makes sense as a garden hose would empty a city water tank far slower than a 6" diameter pipe because the garden hose is too small. We control water flow by opening and closing our faucet, meaning add just one constriction in the line and it can kill our flow. Opening the faucet wide gets you a flow limited by the size of the pipe. Getting a larger central storage tank has little effect unless you put it higher in the air where it can generate more pressure. As with water, getting a bigger blower with more horsepower does little good if the airflow is too restricted by the size of the ducting, tool ports, hoods, and duct openings.

For instance a 1.5 hp dust collector that can move a maximum of 1100 CFM moves far less air than that maximum depending upon what sized ducting we use. This typical small shop dust collector blower only generates 4" to 6" of pressure when working. With the added overhead of our filter and minimum ducting, that pressure is only ample to move about 800 CFM when hooked up with a short piece of 6" flex hose. That pressure will only pull about 550 CFM when connected with 5" flex hose and only about 350 CFM when hooked up with

4" flex hose.

Whether you have a modest 1/2 HP 600 CFM blower to a roaring 5 HP maximum 2300 CFM blower you need to balance the ducting size. We constantly trade off our ducting size to move the right air volume at ample speed with minimum resistance. The ideal is to have a full 1000 CFM at most small shop stationary tools. Typical dust collection blowers need 7" diameter duct and 7" diameter down drops that split into tool hoods that equal about the same as a 7" diameter circle. The only way to use smaller duct is to get higher pressures and we can do that either by speeding up our impeller or using an oversized impeller. It is hard to find 7" diameter duct and if you find it, it is expensive compared to readily available 6" duct. To get our 1000 CFM that larger tools need for good fine dust collection through a 6" duct or hose we need about 5,100 FPM and that takes at least a 15" diameter impeller when turned by a standard 3450 RPM direct drive motor. Without an oversized blower, if your duct is smaller than 7" to your larger machines, then it will not move enough air to capture the fine, most unhealthy dust. The best you can hope to do is make your system a little more efficient. That's why knowledgeable woodworkers use oversized blowers and 6" ducts and 6" flex or 7" ducts and 7" flex when using most cyclones and dust collectors. Unfortunately, the more air a blower pushes the higher the amp draw, so if you open things up too much with a dust collector smaller than 3 hp or cyclone smaller than 5 hp with a cyclone you can burn up your motors. Always check your motor with an amp meter before using larger duct.

8. **Leaks**

Leaks kill system performance and can cause all kinds of other problems. A leak between the collection barrel and cyclone will quickly clog your filters just like when the barrel gets too full killing any ability to collect the dust. Likewise, many small leaks in the ducting quickly add up to the equivalent of having an extra open blast gate that will severely cut the airflow at your machines killing performance and potentially leading to plugged ducting. I don't want to waste my electricity or limited capacity blower on leaks.

9. **Airflow Requirements**

Airflow Requirements for good dust collection are a paradox. It takes very little airflow to move really fine dust, yet we need far more airflow to capture that same fine dust than we need to pick up the same dust we get with a broom. To make sense of this on my other pages I share a simple experimental game moving a balloon and two straws. One person is only allowed to blow and the other to only suck. The one who blows always wins because sucking pulls air from all directions so airspeed falls off so much that you cannot affect the balloon unless your straw is almost toughing it. This is why we must move so much air to pull in dust from all around the working areas of our tools. Any fine dust that does not get trapped by the dust hood gets launched by almost any airflow from our tools, belts, cutters, motors, etc. The only way to prevent this is to have good hoods that keep the fine dust controlled and move enough volume of air to capture it before it gets launched. We measure that volume of airflow in cubic feet per minute or CFM for short.

10. **Power requirements**

Power requirements to move more air also differ from water greatly. Because air is compressible to double the amount of air you move measured in cubic feet per minute (CFM) you must double the fan speed or double the surface area of the fan. This will require a four-fold increase in static pressure that will cost you a NINE-fold increase in horsepower! This fan law says adding 1/2 horsepower and a bigger impeller to a 1.5 HP 1100 CFM blower nets you only 100 CFM in additional airflow! The wrong pipe size, leaks, fittings that change the air to abruptly, overly long runs, an inefficient separator, and a poorly designed cyclone can each cost far more CFM loss. Every time you force air to make a sharp direction change you lose lots of efficiency. Between use of the very inefficient flex hose, too small of a diameter pipe, and too many sharp angled fittings in their ducting, most hobbyist woodworkers severely kill the potential airflow needed for good dust collection. **These practical suggestions can help you to first address the inefficiencies before having to pay for expensive motors, bigger blowers, and more electricity.**

3. **Layout & Ducting Design**

Ducting layout is not that difficult, but the details must be done right to ensure a good working system. Unfortunately, most of the popular woodworking sites, dust collection vendors, and even dust collection books recommend large shop **traditional graduated ducting designs that will not work safely with typical small shop dust collectors and cyclone systems.** Although we all enjoy having bragging rights and a shop full of all different sizes of ducting looks incredible, for these impressive looking ducting designs to work in our small shops we would need monster sized blowers able to collect from all our tools working at the same time. These blowers would cost a fortune to buy, install, maintain, and run. Instead, our small shop blowers only move enough air to collect from a single machine running at once. With just one ducting run at a time open, we need much simpler ducting designs than the commonly recommended graduated ducting designs that collect from all tools working at the same time.

A good working system must move the amounts of air we want for good collection and ensure the air speed in the ducts keeps the dust entrained, meaning kept airborne in both the mains and the down drops. At dust collection pressures air is more like water and will barely compress at all so any restriction or smaller duct acts like a water valve and kills our flow. This means duct sizes must be much larger for a good fine dust collection system because these systems must move lots more air. This also means with our dust collectors and cyclones only able to collect from one tool at a time, we must design our ducting with all the down drops the same size and horizontal mains of that same size or at most one size larger. An undersized down drop immediately limits our airflow. Too little airflow plugs vertical runs and builds piles grow in height then grow longer and longer in horizontal runs. These piles and plugs pose a serious hazard as any spark can quickly get blown into a ducting fire. Also, when plugs and piles break loose they slam down our duct so hard they blow apart our joints, run through our separators, ruin our blowers, and destroy our expensive filters.

Our smaller blowers also require us to use properly sized duct with long sweeping big radius curves or 90-degree joints broken up with a straight run between two 45-degree joints. All wye (Y type) takeoffs need narrow angles. We always must avoid any sharp turns, harsh reductions and undersized duct, undersized flanges, small tool ports, etc. because these also kill air flow. At the machine the down drop duct may split into two collection pipes for two collection points so long as the overall cross sectional area is the same or only slightly larger than the down drop, but otherwise our ducting remains very simple. Additionally, duct itself adds resistance that can also seriously hurt our flows, so a good ducting design uses all the right sized ducting components and provides the shortest straightest runs possible with minimal sharp bends or joints. If your dust collection system is properly sized it can go anywhere in your shop, but most use smaller dust collectors and cyclones, so these should be placed as closes as possible to your tools that require the most CFM for good dust collection.

Below is a drawing of a well designed small shop duct layout. Note this system uses a 3+ hp blower needed to support an 8" diameter main with only 6" down drops. Moreover, the down drops all exit horizontally and go for a while before turning downward. This makes sure that stuff does not build up in down drops with closed gates to create plugging. Also, for maximum efficiency, particularly with a cyclone, this layout keeps a straight run that is at least 4' or longer going into the inlet. This keeps the incoming air very smooth making for far better material separation and improved efficiency as

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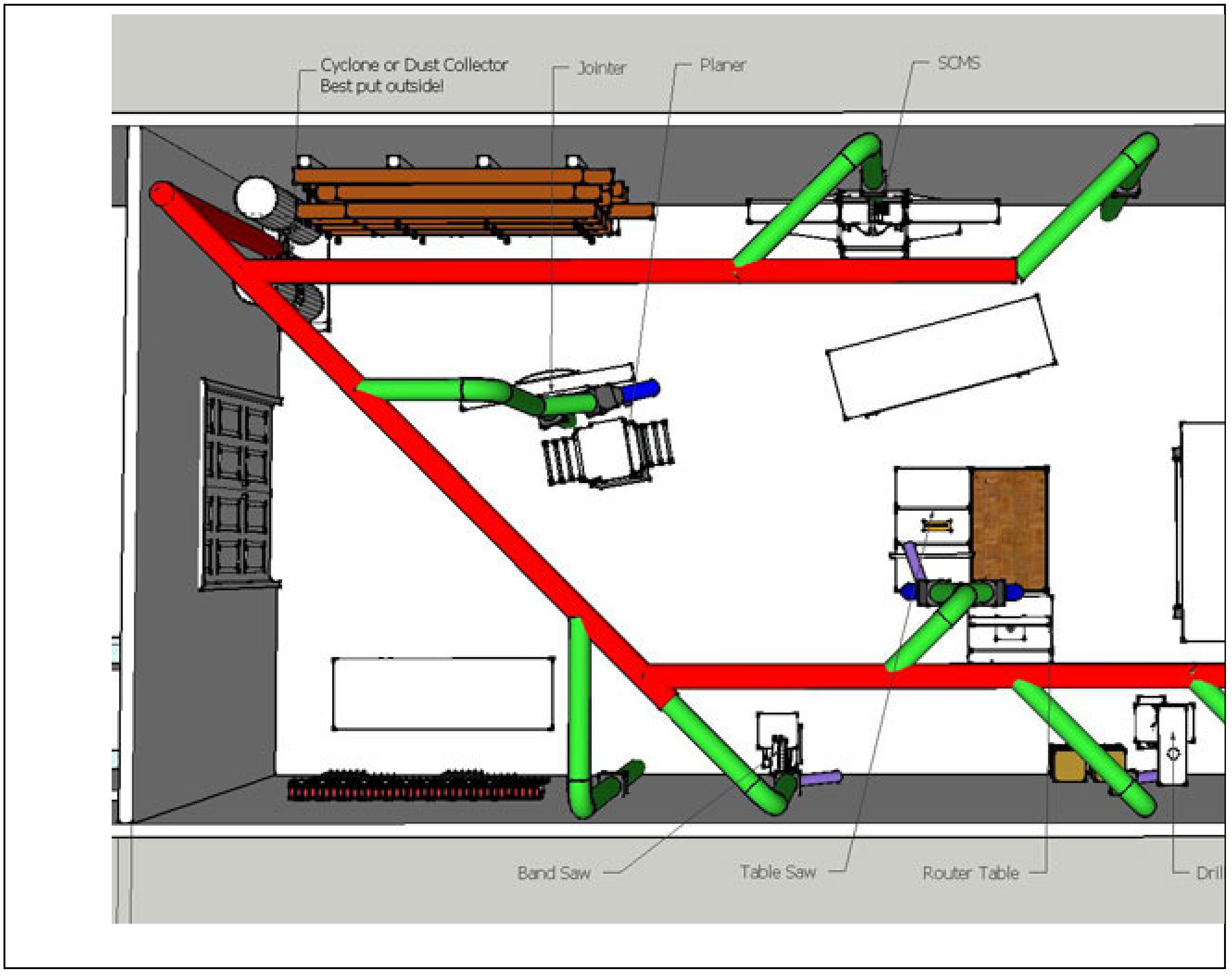


1. **Fire Safety**

   You need to set up your dust collection in a way that will **protect against fires!** If you have a unit where material can directly hit the impeller, then rocks and pieces of metal can hit that impeller, cause small sparks and those sparks fall into your sawdust and slowly grow into a disaster, often many hours after you leave your shop. If you have this kind of set up, you should never clean your shop floor or other areas that might have metal or stone bits with your dust collector. For this reason, most agree that dust collection bins should be metal. I used a 30-gallon metal trashcan on one unit and a 40-gallon metal trash can on the other, both with metal lids and metal flex duct going to them from my cyclone. That makes the dust more awkward to empty, but safer and the metal flex duct is much less expensive. With a two-stage unit using a separator or a cyclone before the blower this becomes less critical.

2. **Pipe Size**

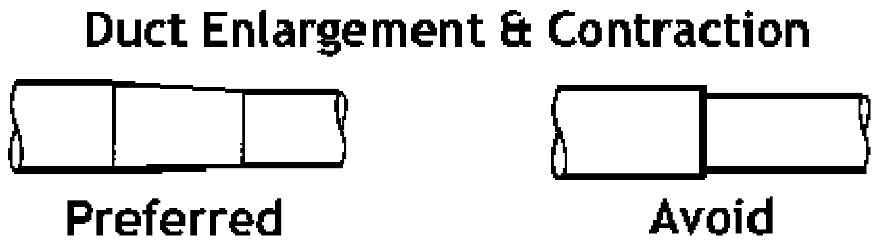
   Always use the largest diameter duct that your blower can use with the least number of restrictions. If your ducting is too small, then it instead of your blower defines the CFM that your system can provide at your machines to pick up the dust. If your ducting is too large you might not maintain the airspeed needed to keep sawdust and chips from building up and blocking your ducting. You need about 3000 feet per minute (FPM) airspeed to keep light sawdust moving horizontally and about 3800 FPM to move it vertically. Air engineers target their designs to maintain about 4000 FPM to keep the dust entrained (moving). FPM is simply CFM divided by the area of the duct in square feet instead of inches (144/sq. in.). If you do the math for the 1000 CFM we need at our larger tools and the 4000 FPM airspeed we need to keep our vertical runs clear, most small shops should run at least 7" duct. This sized duct is rare and the more commonly available 8" duct is so large we end up with the airspeed falling so low our vertical runs plug. My personal solution has been to use 6" duct which will normally only carry about 790 CFM, and to get that to over 1000 CFM by using an oversized impeller of at least 15" diameter running at 3450 RPM. This makes for more noise but results in great fine dust collection. It also means my whole system of mains and down drops ends up using 6" duct.

3. **Ducting Resistance**

   Ducting resistance is known as static pressure. Even a short run of duct that is too small for a blower will cut the airflow down to the highest speed that pipe can sustain. The impact on most hobbyist blowers is terrible. A 3/4 HP blower with a maximum airflow of about 600 CFM will rarely provide more than about 300 CFM real air flow when connected to a 4" pipe. On that same 4" ducting a 1 HP unit that gives 650 CFM maximum rarely will maintain 350 CFM. A 1.5 HP rated at 1100 CFM barely gives 350 CFM. And a 2 HP capable of 1200 CFM is lucky to provide 450 CFM. Bumping up to 5" pipe adds about 100 CFM to each of these configurations. Bumping up to 6" pipe causes problems for the under 1.5 HP units because the air speed (FPM) can fall too far and make dust block the pipes, but with this bigger pipe, the bigger units end up going to 800 and 900 CFM. As a result, you need to use at least 5" duct for any hobbyist blower rated up to 1100 CFM and 6" or larger duct for blowers rated 1100 CFM to 1800 CFM.

4. **Ducting Reductions**

   Unlike big industrial sites, most hobbyists should run the same sized ducting, fittings and hose right up to their machines. Don't do like many and run a 6" or 8" main trunk line then come off with smaller duct or flex hose. The smaller pipe will kill the airflow needed to keep the air in the mains moving fast enough to avoid plugging and building up dust piles. You have to keep three 3" ports open at once or two 4" ports to avoid the plugging a 6" main and even more open for larger mains. Having so much open often kills the airflow needed to collect the fine dust. If you use standard hoods you should still convert over to 6" ports. Even reducing ducting size right at the machine for the shortest possible distance to a small 4" port will still kill system performance. The smaller ducting, flex hose, and small ports limit the maximum airflow just like we proved in that little air test sucking experiment! If you do change size ducting, use a big enough blower to support opening multiple blast gates and appropriate connections for enlarging and reducing:



My friend Sugi found a better way to do ducting reduction and expansion. His mixed combination of Imperial and Metric sized ports on his tools required lots of different reducers and expanders to work with his 6" mains. He found a very elegant solution that gives far better airflow than we get with even the nice tapered reducers shown above. Kanaflex makes a polypropylene rigid duct hose they call Kanaduct with interlock construction which allows the inside diameter to be changed by twisting the hose. This duct starts off as a flat strip rolled into a spiral. On one side of the strip is a male rib and on the other a female socket very similar to zip-lock bags. Depending upon direction of twist this duct either expands or contracts in diameter up to about 50%. This results in very smooth clean transitions without all the nonsense of expensive transitions.

The retail price per meter is abot $24 which is cheaper than having to buy metal reducers and flexible hose. We can easily make long transitions that very effectively reduce pressure loss.

5. **Ducting Material**

The next most important aspect of building a good ducting system is which type of ducting material you will use. We need to be careful when buying either dust collection ducting or HVAC metal pipe. We can easily spend a small fortune and still not end up with a nice leak free system. Also, most "official" dust collection pipe uses proprietary connectors and sizes that often limit your expansion to working with just that firm. With special tools required to make junctions, you also end up generally paying for a number of custom made parts. Likewise, HVAC metal ducting thickness and size can vary considerably, but most recommend getting at least 26 gauge pipe. Most "snap lock" ducting in the larger home centers comes in light 30-gauge or heavier 26 gauge galvanized steel. Unfortunately, if you make your duct pipes or cyclone out of the thinner metal, you could collapse your cyclone and long metal duct runs if you have a large blower and should leave all the blast gates closed. The fittings even in the light metal have enough support they are not at risk of collapsing. Another inexpensive option is building square or rectangular ducts from Melamine coated particleboard. Particleboard ducts can be quite inexpensive and are very efficient. Unfortunately, **many alternative ducting materials are flammable so are totally inappropriate for use anywhere except in plain sight**. Putting a flammable duct material in a ceiling area or enclosed attic can create an unacceptable risk of fire.

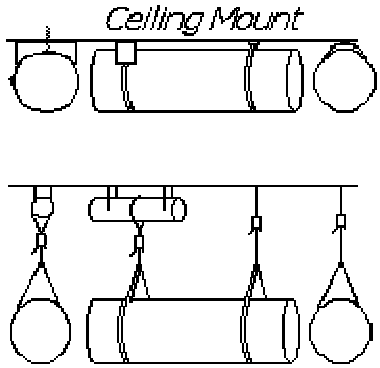
Although I am a fan of and personally use the higher end steel snap lock type ducting that is very pricey, I started off using HVAC pipe which worked well, then shifted to use of the thinner PVC pipe that is readily available in my area due to all the agricultural irrigation. Today with the price of oil driving PVC pipe costs crazy, if cost was a major concern I would use HVAC pipe. I suspect most of my pipe and fittings would come from one of the large box stores with my wyes and longer radius bends coming from a local ducting supplier. Use of two 45 degree fittings with a short segment would work in place of these long radius bends almost as well if those are not available locally.

Ideally we need the smoothest pipe we can get to minimize resistance and still ensure the level of safety in our shops. To minimize resistance, the interior of the pipe needs to be as smooth as possible and you need long smooth sweeping smooth joints on all your fittings.

There are lots of ducting choices and often we slip into a mode where we think if something costs less it is not as good. The smoothest walls that make for the least resistance come with using plastic coated pipe and fittings such as PVC pipe or plastic coated metal or wood duct. The next best is smooth walled laser welded steel pipe followed by a tossup between top quality metal spiral dust collection ducting and fittings and HVAC metal ducting, followed at a far distance by corrugated metal pipe and flex hose. The low cost S&D PVC (plastic) pipe (see my PVC site if you want to do "magic" with fitting PVC into your ducting.) is generally one of the best small shop dust collection material choices because it is smooth, far stronger than most HVAC metal pipe or spiral pipe, costs less, and fittings are a fraction of the price. Airflow depends upon ducting friction. Here are the Hazen/Williams friction factors for various duct types (a higher C number is better).

Duct Material	H/W
Corrugated Steel Duct	60
Spiral Duct	90-100
Laser Welded Steel Duct	110-125
PVC	146

Notice that corrugated duct is so restrictive it should never be used! The same is also true of flex hose that has a rough interior. Also notice that in spite of some vendor claims, these values show that PVC moves more air with less friction than even equal sized spiral ducting. I recommend the PVC ASTM 2729 "Sewer and Drain (S&D)" pipe for most small shop woodworkers. The 2729 PVC pipe and fittings cost far less than metal or standard schedule



40 PVC, are much stronger, don't leak like metal pipe, and have a much lower coefficient of friction than even spiral metal ductwork. The 2729 PVC is rated for many times the pressure that even large industrial blowers generate. I've seen no flex with my PVC pipe even when doing testing on 10 hp blowers driving a 16" impeller. Alternatively, you can use either the more expensive but less efficient heavier spiral pipe or the 26 gauge snap lock HVAC pipe.

6. **Ducting Cost**

It is best to buy your dust collection pipe, fittings and flex hose from either a firm with free shipping or from a local supplier, otherwise you can easily pay nearly as much for shipping as for the cost of the ducting.

7. **Ducting Connections**

Making your dust collection connections can be done with glue, screws, special duct sealant, and many other things, but most find that slipping all together works best. This is especially true if you buy the S&D PVC for your main runs with the built in seals. They only cost a little more and make tight joints that normally don't need anything more to hold them in place. Most agree that not gluing is by far the preferred way to go, as you may change your mind on your shop arrangement, and you will for sure eventually catch something that clogs requiring you to take one or more joints apart. The best way to seal leaking temporary joints is with standard 2" aluminum duct tape found in home and HVAC stores. Be careful when handling his tape as it is very sharp! Permanent joints are better sealed with either duct sealing compound or polyurethane caulk.

Although the Kanaduct shared above in Transitions works well for joining different materials and diameters, this can be a little pricey and requires mail ordering. John Koster reminded me that standard plumbing neoprene "no-hub" connectors provide a good less expensive locally available solution for those who need to connect dissimilar pipe materials. These "no-hub" connectors come sized to mate Cast Iron/PVC, Steel/PVC, and PVC/PVC. These connectors are easily placed and removed for access, provide a good seal on an adjustable range of diameters, and act as good "dampeners" for vibration and noise transmission.

8. **Duct Hanging**

There are lots of ways to mount your ducting to the ceiling or wall.

1. **Nylon Cable Ties**

   I found at an electronics outlet some nice screw-in mounts designed to be used in electronic cabinets. These mounts work well to hold heavy nylon cable ties right to the ceiling or wall. I snapped a chalk line then put in one of these every other stud held in place with a 2" deck screw. To use just thread a nylon tie (took me using two linked together) and leave in a loop. Insert the 6" duct and then pull the ties up tight. A good metal cable tie gun will cinch these up tight enough even heavy PVC pipe will not slip down a wall.

2. **Band Clamps**

   Another approach is to mount blocks with regular stainless steel band clamps. The clamp threads through a thin slot I cut in the side of the block. I then secure that block to a stud with a deck screw. That screw also secures the open edge of the block and squeezes down on the clamp to hold the clamp in place. This same approach works equally well with the nylon cable ties.

3. **Wire**

   The traditional approach to have hanging ducts from a high ceiling simply uses heavy galvanized steel wire or plumbers strapping screwed to the ceiling or looped around a pipe. This works well, but is difficult to adjust without a lot of practice.

4. **Wire Rope**

   Another solution for hanging duct is to use stranded metal cable (called wire rope) with special clamps that let you adjust the length. A number of firms make and sell different types of cable connectors. The simplest are the "8" shaped metal ferrules that you squeeze onto the cable with a crimping tool. Most boat supply stores sell both the cable and ferrules, or you can get them from a cable supply store. I bought a large spool and a pound of ferrules for what it would have cost me to buy just a few pieces from a boat store.

5. **Suspension System**

   A far more elegant and expensive solution for hanging duct is to use wire rope with special adjustable fittings that allow you to quickly do the installs and set the pipe height. Just about all HVAC supply stores and ducting supply firms offer one or more of these types of systems. One of the better known that many woodworkers have used successfully is the Gripple System.

9. **Pipe Under Floor**

   Although most prefer to hang their ducting from the ceiling, there are also lots of ways to put your dust collection pipe under your floor.

   0. **Subfloor**

      For those who have a shop that sits on a heavy subfloor, it can be very convenient to run your ducting under the floor. I like a wooden sub floor in a shop because it is much easier on the legs. Both of my two larger shops had nice sub floors and I ran most of the ducting under those floors. For my first, I carefully designed and put every hole just where it needed to be. That worked for about two weeks until I bought a few more machines and ended up having to crawl back under the floor and redo all. For my second shop I put a fitting every six feet along the walls and down the center of the shop. Each had a plug and was covered by a piece of tile, so when I needed to make a change, I just had to lift the tile, remove the plug and put in a flex hose to the machine. That worked pretty well.

1. **Concrete Slab**

   Cost and convenience often end up with many shops having a concrete slab floor. If you are fortunate enough to be building your shop from scratch, you can build in some trenches. I've helped build one of these type shops and did most right, but also learned a few lessons the hard way.

   1. Because I included both a sink and small shower, I ran water and drains in dug trenches, plus another trench to bring in power. Living right on the edge of an industrial area, I was fortunate enough to be able to bring in three-phase power. The floor I built was put over those utilities on well-tamped ground covered in 4" of crushed rock then a vapor barrier.
   2. I also tapered each of my trenches with just a little grade and put drains at the end of each trench. The mistake I made with those drains was sharing them with the sewer drain without a water trap to kill any odors. I ended up having to reconnect them to my yard drains instead.
   3. I built my trench with a lip that will hold a 2x8 flush with the rest of the floor. That let me cover up the trench and not create problems moving around my equipment and tables that were on rollers. If I were to do this again today, I would make the trench sized with a lip to use the surplus aluminum raised computer room floor tiles. These are much stronger than the 2x6 and much easier to install and remove for access.
   4. Into my trench went the ducting, compressed air, and power. I protected the power by putting it in well-sealed PVC coax. Had I used that raised computer room flooring my trench would have been big enough to also include lines for my shop vacuum, drainage, and possibly water if permitted by my building codes.
   5. I carefully framed in the trench to make a nice rectangular pour. Even with rebar sides, my straight walled trench cracked. Those cracks made for a moisture problem that was not compatible with my galvanized ducting. A far better way to go is to make a nice smooth pour as shown in the picture.
2. **Computer Floor**

   We are in an interesting time right now where the computer world is changing so fast that this leaves an opportunity for woodworkers. There are huge quantities of surplus very well made raised computer floor that provides a raised floor of 8" to 12" to permit running electrical, communications, cables, etc. under the floor using easily removed tiles mounted on stands. These surplus computer floor squares and uprights are readily available for little cost. They create a floor that is nothing short of incredible for woodworking. You can put in your ducting, power, water, and whatever else you need or want to run under that floor, then have easy access to make changes.

4. **Ducting Components**

1. **Ducting Accessories**

   There are many nice accessories that you can use with your dust collection, but realize that even with these accessories a dust collection system does some functions poorly.

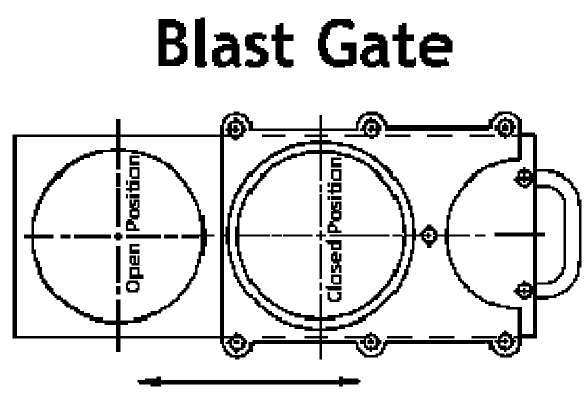
   0. My first accessory mistake was buying a transition that mated my 4" dust collection hoses to the tiny 1.25" port on my band saw. So little air was moved I went back to using my powerful shop vacuum on all tools with small ports. I also bought the 5" Delta replacement port for my band saw lower port, plus used Lockline adjustable pick up duct with hood pick up above by the table attached to my strong shop vacuum. The rule is never hook a dust collector or cyclone to any size pipe less than 3" in diameter.
   1. My dust collector came with an upper and lower filter bag that worked poorly and required constant emptying because I made lots of dust from preparing rough stock. My next mistake was buying a metal trashcan and trashcan separator lid. The trashcan separator reduced the fire risks and saved on emptying the dust collector. When I bought a set of air gauges and did some testing, I realized that my trashcan separator was not good news at all. It pulled the real 1100 CFM I got from my dust collector through a 6" test pipe to under 450 CFM.
   2. My next mistake was replacing the dust collector bags with an easy to empty lower plastic bag and fine oversized fine upper filter bag. but I still constantly struggled with the new upper filter bag getting so full of dust it felt like cement and would barely pass air. Every filter cleaning left me and my shop covered in the fine dust I bought that fine bag to avoid. I later learned during the medical air quality testing done on my shop that my so called filter was a sieve that freely passed most of the finest unhealthiest invisible dust.
   3. I made my next mistake buying a "best" hobbyist cyclone system. It moved less air than my dust collector, just about half of what the vendor claimed in the advertising. That cyclone killed the airflow below about 450 CFM, plus did not move enough air to keep the ducting clear. After digging into the engineering behind cyclones, I realized that almost all small shop cyclones were copies of the same original design. That design was never made to be used inside with fine filters, so I designed my own more efficient cyclone. It works well to power my downdraft table, collect chips from my router table and larger tools, and pick up the leaves that constantly get blown into my garage shop. It also is a huge help in cleaning my shop when used with a ShopSmith vacuum attachment. **Do not use a dust collector as a vacuum because any steel screw or nail picked up hits the impeller and can put a spark in the collection bin.** Also, most dust collectors make poor vacuums because the airspeed is too low for good pick up. My cyclone moved more air and also separated off the material before it got to the impeller so worked well with my new floor sweep. I hot melt glued in big neodymium super magnets on the front of that sweep to collect nails and screws before they get sucked up.
   4. Even with a good cyclone and vacuum, I found some tools still spray dust. When using them I wear my mask, open up the side door and garage doors and then run a big fan in the side door to keep that dust blowing outside. For quick cleanup after using these dusty tools I wear my mask, open all up with the fan running, and use my big compressor or leaf blower to quickly blow out the whole shop then turn on and leave on my ceiling mounted air cleaner.

Blast Gates

You close the airflow to a machine with a blast gate. There are many different types of blast gates including many that can be opened automatically through electric motors, air pressure, and even hydraulics. **The best place to put your blast gates is next to the wyes off your main line up high.** The more open pipe or hose you leave exposed between the main run and the blast gate, the more resistance it causes. Also, if that pipe fills too much, opening the gate will cause all that material in the down drop to slam into the impeller potentially ruining motor bearings and even breaking impellers. It then goes into the filters potentially poking holes and greatly reducing filter life by requiring far more cleanings.

Many buy or make poorly designed blast gates and get very frustrated. Many of these gates, including expensive metal commercial gates, leak badly and we can make this problem worse by installing them backward. These gates come with a screw that pushes down on the slide portion of the gate to lock that slide in place. Many install these gates backward so the screw pushes the slide away from the vacuum source creating a noisy air leak. One system I tested had so many leaks from installing the gates backward that he had less than half the total airflow that we got after reversing the gates so they sealed well.

Also, many of even the expensive gates get clogged with sawdust that prevents them from closing fully. Most used a slide that slips out of the way leaving an open track that will pick up sawdust even if the gate is set with the slide pointing down. Every time you close a gate like this it jams sawdust into that track. Eventually you pack in the dust so tightly that the gate will not fully close, will jam, and can even split. **You need to install the gates so the slide opens downward, but this often causes the slide to fall out on poorly made gates, so with these we need to clean often. I found a heavy paperclip and shop vacuum works wonders, but need to clean every few months. A much better design is shown here where the portion that closes goes all the way through ensuring there is no place for the sawdust to clog.**



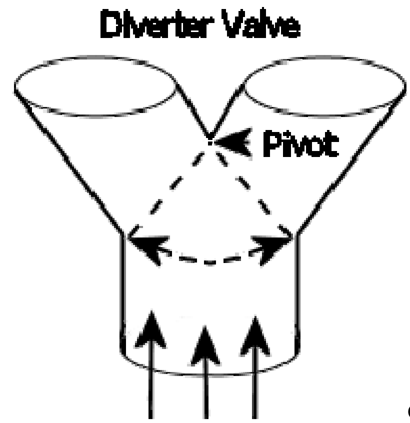
The only retail carrier I've found who that sells these types of "self cleaning" blast gates in 6" for an affordable price is Lee Valley Tools (search on blast gate). Otherwise buying this type of blast gate is difficult without a commercial license to buy from a wholesaler.

Because there was no available source when I needed my gates, I found Phil Bumbalough's

Building a Blast Gate provides an excellent set of well pictured directions on how to make these types of gates. Making your own similar gate is fairly easy. The only changes to Phil's design that I recommend are using a split female PVC connector instead of pipe on the gates. The couplings let me connect directly and tightly to my PVC and metal ducting without leaks or having to use another often expensive and for sure bulky fitting. On a few of my gates that end up next to my machines and get connected with flex hose I instead use a short length of PVC pipe for the lower portion of the gate outlet. I prepare that pipe before gluing by first cutting six 2" long slits in the end made by my band saw in three cuts then wrapping that pipe with a heavy wire in a spiral that I hold in place with glue. This creates a threaded taper that lets me screw on my flex hose onto the pipe for an easy tight fit and no need for another expensive clamp. The result is tight enough that a piece of tape is ample to make a good seal.

There are many who are interested in having automated blast gates that open when you turn your machine on and close when you turn your machine off. This will help make sure you get good collection, but I don't recommend you turn your dust collection system on and off as too many on off cycles will soon ruin your motor. Not only does turning our blower motors on and off use up lots of extra electricity, the top motor makers recommend no more than six on off cycles an hour or our motors will get too hot and burn up. Regardless, you can make excellent automated blast gates. Two of my friends have built nice automated blast gates and shared how they were built and how to use them. The first was Jim Halbert in 1995 and shares on a YouTube video at (click here). The second is Alan Schaffter and he shares his information at (click here).

Blast gates work great if placed between your tools and cyclone, but work poorly for changing your air stream between filters and venting outside. You can use a couple of blast gates on the outlet side of your blower but they will leak badly. To not have these leaks you need a different kind of gate or valve. Nomal gates do not leak because the suction pulls the flat portion down tight to make a good air seal. With a gate on the blower outlet the air is blowing on the gate, so air pressure opens the gap in the gate and can spray fine dust all over. For these it is better to make a diverter valve as pictured below that will swing to make the air close tightly on one side or the other. The first is a wye fitting with a valve and these are easier bought than made because getting a tight seal is tough. The second is a simple box with a throw.



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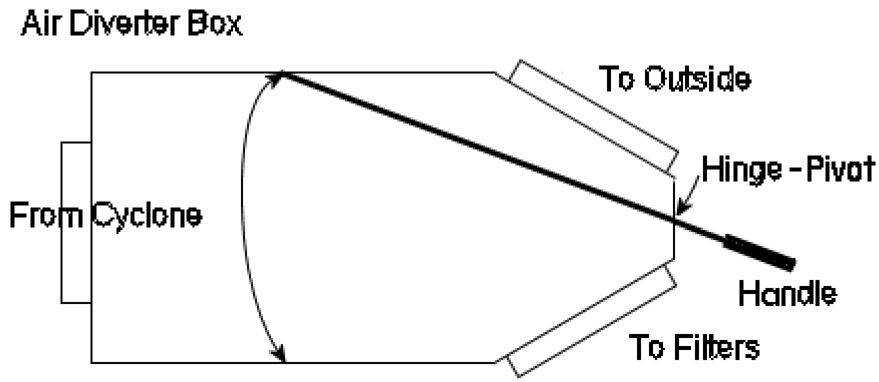


One other important note is don't go with the cutesy HVAC metal flanges on your blast gates that I see popping up on woodworking forums as a recommended way to make these gates. They do look pretty but greatly increase the cost of your gates, don't seal well, are razor sharp so will cut with even a small touch, and unless modified don't fit either standard dust collection pipe or even 2729 S&D PVC.

2. **Flex Hose & Hose Clamps**

   The internal ridges on rough or poorly made flex hose can create as much as nine times more resistance than smooth walled pipe of the same diameter. Even good smooth walled flex will increase resistance three or more times over straight duct. This resistance kills airflow, so when you use flex hose, always use minimum lengths and only use flex hose with smooth interior walls to get the best possible airflow from your blower. Additionally, there are flex hoses available with plastic reinforcement ribs, but these plastic ribs provide poor crush resistance and make this type of hose generate so much static electricity that it is not permitted in commercial shops subject to fire marshal inspections. Finding 6" smooth walled flex hose with metal reinforced ribs that can be grounded can be a price shock. Good flex hose costs considerably more than the bulk rough interior walled 4" stuff that many buy only to eventually learn that small diameter will not support the airflow required. I found Amazon.com, Wynn Environmental, and Northern Tool sell very good quality larger diameter smooth walled flex hose. Wynn continues to have the best pricing on hose if you buy 25' lengths. Lesser quality hose with rougher ribs can be purchased through Grizzly.

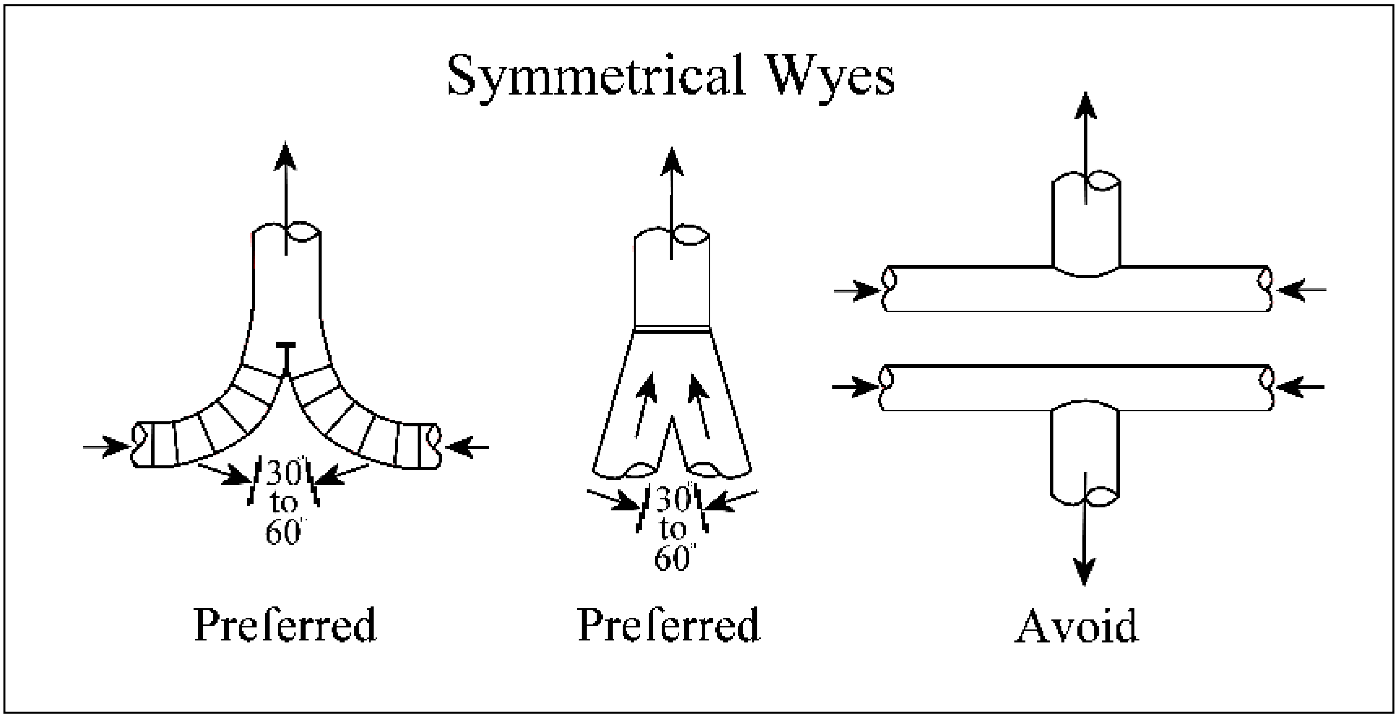
Although most buy stainless metal band screw type clamps for securing their flex hose, **standard stainless steel band clamps work poorly**. When we use normal clamps the hose reinforcement ribs create a gap which keeps the hoses from sealing tightly all the way around, so the joints leak air and fine dust. A bridge or wire hose clamp provides a much better seal as these clamps bridge over the ducting reinforcement rib to create a good seal all the way around. Amazon.com sells expensive good wire clamp that bridge over the ribs. Wynn Environmental and Lee Valley sell the best stainless steel bridged band clamps, but you need to buy these in either left or right handed versions to match the spiral on your hose.

3. **Fittings**

   Types: Many choose to run to their local box store and buy HVAC (heating ventilation and air conditioning) fittings. For the most part these are a poor choice just as they are for ducting. Unlike the thinner 30 gauge ducting pipes these fittings will not collapse, but if you look closely many fittings are all made for the air to flow away from the blower. The result is every joint is backward where the air ends up jamming against an interior lip which causes extra resistance and can pick up debris. Most fittings can just be turned around, but some like wyes require changing the gender on each of end to keep from trapping sawdust and strings. I use a roller to flatten all the male ends and a crimper to convert the female ends to male. Moreover, few of these fittings seal real well or are that smooth inside. Many also have very tight angles and bends. The result in terms of efficiency is not too bad for each joint, but unless you are careful the total can add up to terrible performance. Many choose to avoid the work needed to clean up the HVAC joints by buying or making PVC fittings or using actual dust collection fittings that are smooth walled without the joint reversal problems.

   0. **Wyes**

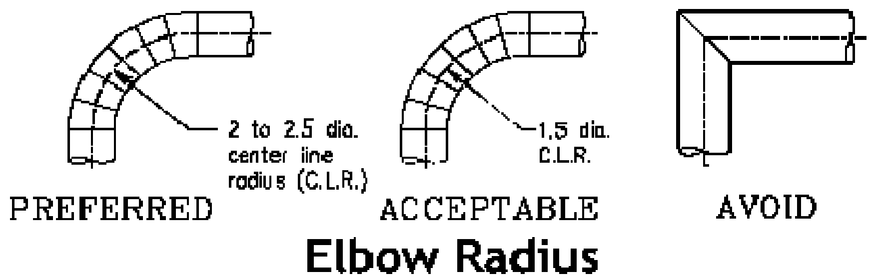
      You come off your main run with Wyes. There are many different types of wyes, but the best are going to be those that are smooth and either the most gentle angle or longest radius. Many choose to use the inexpensive sheet metal HVAC wyes found in home centers, but these have far more resistance and potential to cause plugging than what is appropriate for dust collection. As shown some configurations are far better than others.



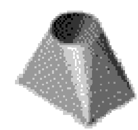
We often use wyes on our down drops to split the flow to mate with two or more ports on a single machine. For instance the collection to my table saw starts with a 6" down drop that goes into a 6" blast gate, then a wye with one leg going to a 4" diameter port on the saw Shark Guard blade guard port and the other leg of the wye going to a 5" port on the table saw cabinet that I upgraded from its original 4" port size. In small shop systems when we calculate the overall static pressure we normally just add up the resistance levels for each piece starting with our tool hood, then ducting with fittings, then separator if used followed by filter resistance. Because both both legs of our wye are open at the same time past the blast gate we calculate the static pressure for these a little differently. We calculate the static pressure for one leg including tool hood then calculate the static pressure for the other leg with tool hood followed by dividing that total by two. If there are three ports such as on my band saw, we need to calculate all three legs separately, sum them up and divide by three. If we don't do this we get unreasonably high static pressures that do not occur in real use. If you want to make it easy on yourself and still get a workable number, just pretend that there is no wye and calculate static pressure based on having a single length of flex hose the same diameter as the down drop with a length the same as the longest leg after the wye.

1. **Elbows**

You change ducting direction with elbows. As with wyes, there are many different types and the best are going to be those that are smooth and have the longest radius. As with wyes the inexpensive sheet metal HVAC units found in home centers have far more resistance and potential to plug. As shown some configurations are far better than others.



2. **Homemade Fittings**

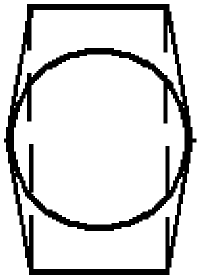
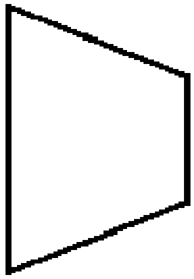
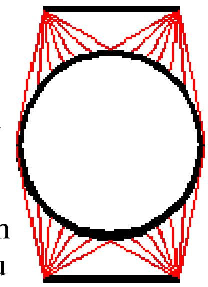


With the cost of both HVAC and PVC fittings so high, many choose to make their own fittings. I made quite a few of my own both in sheet metal and in PVC. At first I used a free sheet metal transition program I found on the Internet that let me print out full sized patterns and then cut out my own patterns in either PVC or metal remembering to add for the PVC extra thickness. Lots of work with my metal sheers and soldering torch or heat gun and PVC cement created whatever custom fitting I wanted. Eventually I changed to two different approaches after realizing I was mostly making 45 degree wye fittings in 6" PVC. I set up my lathe with a 6" piece of PVC made into a sanding drum by slotting then wrapping tightly in heavy sandpaper. The slot keeps the final drum diameter with sandpaper the same as the rest of the pipes. I use a protractor to set the angle at 45 degrees with a jig to move pipe into that piece. I also have a stubby precut pipe piece that I lay on other pipe where I want to mark a hole that gets cut with a saber saw. Just a little hand sanding on the hole leaves a near perfect joint. The other nicer approach I use is a little more work and takes far more skill, but makes better joints and allows using longer pipes. For this one I also mark where I am going to cut my hole in the pipe, but make the cut 1" all the way around too small. I then heat the pipe with a pair of heat guns and use a custom made wooden mandrel that I slip into the hole from the inside pushing out a perfect female fitting that when cool can be used to join a pipe.

Stan Harder developed a resource to help woodworkers save money when building their PVC dust collection transitions. His free online software program Harder Pipe Joint Template Software creates templates to assist in cutting PVC pipes that can be joined together at different angles to let us have joints without needing to buy expensive pipe fittings. He has had good success using the thicker CA glues used by wood turners to make PVC joints and they look really good. I would strongly recommend adding inside and out on his joints a strip of the 2" stick on aluminum duct tape for grounding. Additionally, for my similar joints I wrap and CA glue some heavy copper grounding wire around the PVC joint that we can use to screw in flex hose creating a solid joint that seals well with an inexpensive hose clamp. Thanks for sharing Stan!

4. **Transitions**

You need a way to go from your 6" round ducting to your filters, your blower, your cyclone, and some tools that have square or rectangular duct. These pieces are called transitions. There are three relatively straightforward approaches to getting a transition. The best is to build a

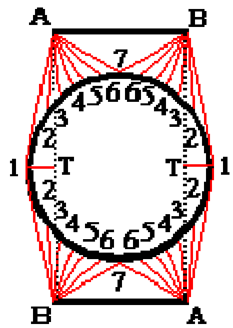
transition that makes a perfect fit. Next best is to buy an HVAC fitting that is close then modify it to work. It turns out a 4" x 10" to 6" round HVAC heating register fitting easily changes to be a 4.5" x 9" to 6" transition. Likewise, I found by measuring the perimeter of the blower outlet that it just so happens that each of my designs is a perfect fit with one of the various sized round transitions when you compute the circumference. Least best is to change your tool or other unit to fit a standard transition. You can follow the below information to make your own transition. If you would like to learn more on making a transition and have a spreadsheet to calculate all of the specific distances, please see Joe Emenaker's Transition Page.

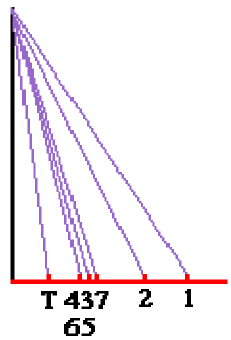
There is a fairly simple but lengthy way to build a transition. Sheet metal workers call this an evolution. Because my plans are scalable, your evolutions will change based on cyclone and blower sizes. I've done one by hand for a 13.5" and another for an 18" cyclone.

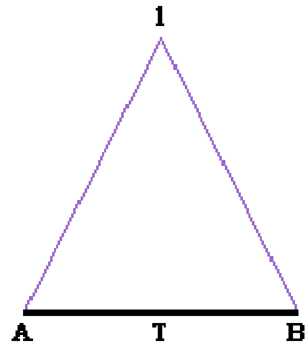
Ronald Scalise shared an easier jig technique he learned from a friend to quickly layout a transition for metalworking. Ronald said he is more used to working in thousandths of an inch and was amazed at this technique because it comes out just right every time. Ronald says, "You need three things, a wood dowel a round disc the size of your incoming duct and a wooden rectangle the size of your inlet. Find the center of both the disc and rectangle then drill a hole through each and connect them using a dowel. The dowel needs to be exactly the length of the desired transition. Place the jig on the sheet metal and carefully roll it around using the jig as a ruler to mark your lines on the sheet metal. The result after marking all four sides of the rectangle is a perfect layout that only needs cut and formed to be done.

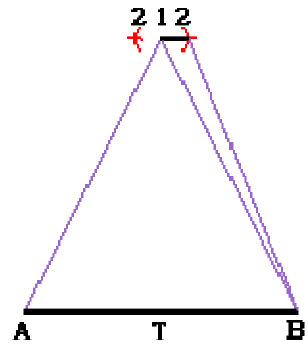
My friend who has done this for years made this look too easy. I ended up with way too many lines on the sheet metal my first try. Although it turns out to be easy, I do recommend starting with some practice paper to get the technique down. It only takes a few tries to get it down pat. I learned to start with the longest side and draw a line then follow the circle around as I turn the disc."

5. The traditional way to build a transition is fairly simple and also works well, but takes more time. By drawing a view of that fitting looking down at the circular inlet you can see a circle and the rectangle that it joins.
6.
7. Add to that drawing the fold lines used to transition from the circle to the rectangle. The fold lines in this view are red. Looking at these fold lines from the circle inlet gives us the actual length of a base of right triangle whose height will be the length of the fitting.
8.

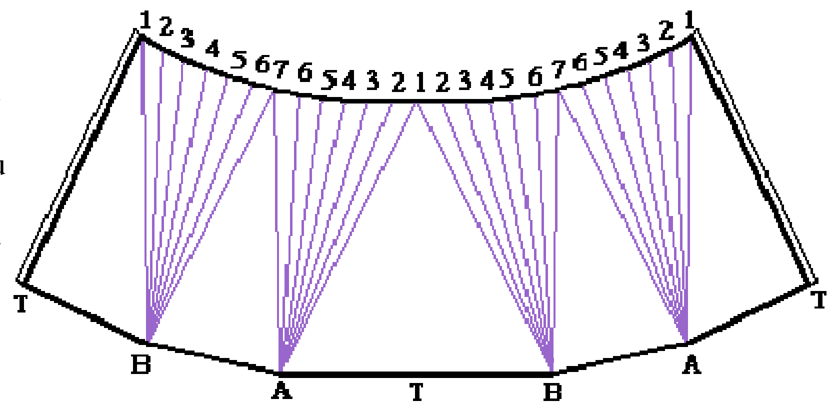








9. The diagonal for each of these right triangles is the actual length of the line used to layout the metal cutting/folding diagram. You can either use math to calculate the lengths of these fold lines or you can get them by drawing a right angle. This angle forms a right triangle as tall as the height of the fitting and base taken with a set of dividers from that view picture. You can then use dividers to go from the top to the base to get the diagonal. The more fold lines, the smoother your circle. Most metal workers find it is easiest to divide a circle into 24 parts making for 24 fold lines. Draw a fold line from each corner to the seven closest circle divisions. This means the first and seventh line each end up going to two corners. Once you have the lengths of the seven fold lines that go from each corner, you have all it takes to layout your cutting diagram.



10. This is all the information you need to actually draw your layout for your cutting diagram. Start by drawing with a horizontal line that is the length of the longest side of the fitting rectangle. Use a compass to set the length of line one. Swing arcs from either end of that horizontal line to set the top of that triangle. I used a second compass that is set to the length of an arc that is 1/24th of a circle. To get that length I drew a full sized circle, then divided the circle into sixths, then twelfths, then twenty-fourths. If you don't know how to do this, you have to look it up yourself. (Radius will give you sixths, splitting any angle will give you 12ths, then one more split for twenty-fourths.)
11.

12. Carefully in order add the lines that go to that corner joining the first two to make a triangle. Each successive line makes another triangle whose base equals the length of a segment that is 24th of a circle.
13.

14. After drawing seven lines, the eighth line starts from where the seventh ended and creates a triangle whose base is the shorter rectangle size.
15. Anyhow when it is all said and done, the result plus 3/8" of soldering tabs gives the transition duct. I only showed the soldering tabs for the sides. You also need them for both the circular part and the rectangular part. I used those extra tabs to solder a 2" ring onto the circular part to mate with my PVC.

16. **Tool Ducting**

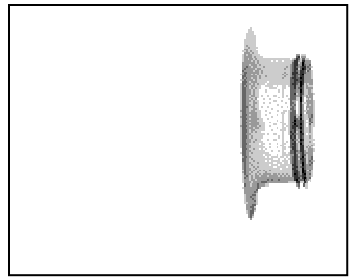
Each machine needs the dust collection to protect, control and deliver good fine dust collection. Each machine requires appropriate hoods to keep the airflow from our blades, bits, cutters, belts, motor fans, etc. from launching the fine dust before it can be collected. These hoods need to control the dust and then deliver it right to the dust port for collection. Sadly, most small shop tools come with internal ducting, hoods, and ports far too small and too restrictive to effectively protect, control, and deliver the fine dust. That means we almost always have to do extensive tool modifications. In some cases we cannot amply fix our tools, so we must use them with a powerful downdraft table. Some even a downdraft table cannot help, so these either need used outside or replaced.

1. **Dust Ports**

   The connection from your machine to your ducting is often a problem with hobbyist equipment. In looking at the CFM requirements table it is clear that most stationary small shop tools with a single port connection need that port enlarged to a 6" port. Most with the need for two collection ports should have a larger 5' port and a smaller 3.5" port. Often we cannot get the 3.5" ducting, but using a 5" with a 4" on two port machines still works well. The total area of the ports should closely match the area of our ducting. If that total area is too small we kill our airflow needed for good fine dust collection and can create dangerous dust piles in our ducting. If the combined area is too large we lose the airspeed needed to pull in the dust and keep all moving in our ducting. Because the small shop industry remains in the "dark ages" of chip collection in terms of only going after the same dust we otherwise sweep up with a broom, most small shop users will have to upgrade their machine dust ports themselves. It is a real shame to buy a top notch piece of equipment and suddenly have to make a big 5" or 6" hole in it. Although many use HVAC connections it is far better to use actual dust collection ports that at least leave a good looking smooth strong port. I like the Lindab and Nordfab smooth walled laser welded steel take off flanges plus they and have a built in gasket.

   I heard from Steven Thompson that a good source for these parts and other DC ducting components is Mechanical Equipment in Georgia at (770) 963-6226. He said they have great prices and are willing to ship UPS.

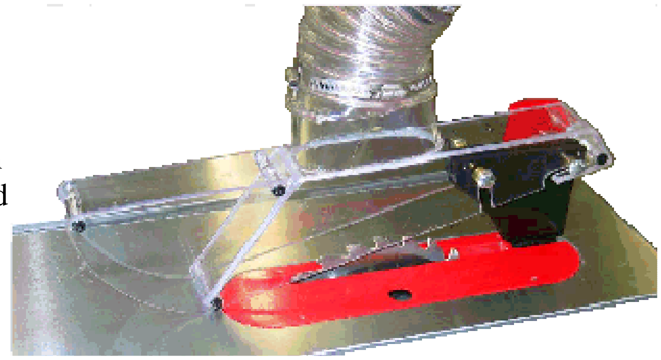
2. **Dust Hoods**



Dust collection hoods and pick ups are one of the least explored areas in small shop dust collection, yet one of the most important. Although many vendors would like us to believe good fine dust collection is all brand new and about as complicated as rocket science, the reality is we have decades of air engineering experience that show just what we need in terms of our hoods and airflow. A good hood must do the following things:

0. **Safety** - A good hood needs to provide a reasonable measure of safety. This means it helps us keep away from our blades, bits and cutters while also protecting us from kickback and flying debris. For saw blades I strongly recommend use of hoods that incorporate at least a splitter or riving knives plus use anti-kickback pawls. Our hoods also need to be made of something strong enough that if things go flying we get good protection. I strongly recommend hoods be made of either metal or the polycarbonate plastic used in safety glasses, bulletproof windows, etc. I made the side of a blower from this type of material to see when it was time to clean the impeller. One of my test impellers exploded inside my blower. That 1/8" thick polycarbonate plastic held up better than the metal parts.
1. **Visibility** - A good hood also in my opinion needs to let us see what we are doing. Strangely, some saw blade and router guards are smoky or solid steel like the one that came with my European saw. I admit my saw guard soon got removed and ignored because taking it on and off to ensure my cuts were aligned correctly was too much trouble. I strongly prefer a clear polycarbonate plastic saw guard because it gives excellent visibility and minimizes a buildup of static adhered dust so we don't have to do a lot of cleaning.
2. **Chip Collection** - A hood also must provide good chip collection meaning collect the same sawdust and chips that we would otherwise sweep up with a broom. It is real simple. Our saw blade tips along with many of our other blades, bits and cutters launch dust at over 100 miles an hour. Even a powerful cyclone like my design only moves air at about 60 miles an hour. Unless our hoods block the fast moving airflows, we lose and are going to have sawdust and chips all over.
3. **Fine Dust Collection** - For those who want good fine dust collection, a good hood must also move enough air in the right places. If our tools are made from the ground up to totally trap all the sawdust and chips we make then a good shop vacuum will provide excellent dust collection. Because most of us use do not use tools built from the ground up for good fine dust collection we need to instead use a different approach. What decades of air engineering found works with our older tool designs is having hoods that block the fast moving streams. These hoods then also must move a large volume of air around the working areas of our tools. We know that the slightest breath can move the fine airborne particles, so to keep the fine dust from being blown all over our shops, we need to surround the working areas of our tools with air moving fast enough to overcome normal room air currents. Again the research followed by decades of refinement show what we need in terms of hoods and what is needed in terms of total airflow. It only takes about 50 feet per minute airspeed to overcome normal room air currents, but we have to provide that airspeed over such a large area that we need about three times more total airflow for good fine dust collection as we do for good "chip collection". Because air at dust collection pressures will barely compress at all, any undersized hose, duct, or port will restrict our flow. This means

almost all of our typical 4" tool ports and ports on our 4" hoods must be need increased to 6" to carry ample air. For tools with two ports, we generally need a 6" down drop that ideally splits into a 5" and 3.5" separate hoods. Since the 3.5" ports and ducting is near impossible to find, we still can go fairly well using a 4" instead. I originally thought I could get by with using my existing 2.5" port on my splitter mounted blade guard on my table saw. The CFM Requirements chart showed I needed at least 350 CFM, but testing the airflow with that smaller port showed only 183 CFM. In short, for good fine dust collection we almost always have to rebuild our hoods and use larger ports.



I recently did air quality testing all over the State of California. One of these tests was at an engineer friend's shop with the testing coming out worse than ugly. He carefully followed my instructions from these pages building his own cyclone from my plans, upgraded to a big 16" blower impeller and built one of the prettiest carefully laid out metal ducting systems I've seen. Without doing any woodworking at all, our just moving around in his very clean looking shop stirred up enough of the fine invisible dust that his shop failed the EPA, medical and European air quality standards. I saw the problem but rather than tell him what was wrong we then did a standard test. We started using his table saw to cut 54 linear feet of Â¾" thick MDF. Within seconds his shop air quality went well over fifty times worse to exceed the OSHA air quality maximum. I showed him what was wrong while his big exhaust fan and cyclone rapidly made the air quality safe.

The problem was the normal. Decades of air engineering show that if we do not capture the fine dust as it is made, we are going to fail the air quality test. **The only way to capture the fine dust as it is made is to start with hoods that block the fast moving air streams.** His dust problem was simple. His big new over arm blade guard was wide open in front so launched the dust off the tip of the saw blade right out under his guard. A 3450 RPM blade speed with a 10" diameter blade creates a 102 miles an hour air stream. His saw pulleys increase the blade speed closer to 4000 RPM so the blade tips launched the dust even faster. A typical dust collector or cyclone only moves air at about 40 miles an hour. With the hot rod oversized impeller on his cyclone, he was got 60 mile per hour air speed which had zero chance of capturing the well over 100 mile an hour dust stream. To effectively control the fine dust as it is made **we must have hoods that mechanically block all the fast moving air streams or there is zero chance of effectively capturing the fine dust before it escapes collection.**

Shark Guard - My friend suffers from a common engineer disease meaning he is a touch obsessive sort of like a mule is a touch stubborn. He was really upset at that air quality test and soon called me back ordering me to give his shop a retest. In place of the blade guard that came with his over arm blade guard system my friend added a pretty amazing product. He replaced his over arm saw guard with a new Shark Guard pictured here made by Lee Styron. That guard rested on the wood and blocked the fast moving airstream that was spraying the fine dust all over. The bottom line is we again tested his shop and with that guard in place he got none of the dust that sprayed out all over in front of his saw and his air continued to test clean. Frankly, I was so impressed that I contacted Lee and ordered up the works for myself including his 4" dust port, tail gate, and special splitter with anti-kickback pawls that fits my European saw plus chose to have the metal parts in a bight easy to see safety red.

In addition to having good collection over the saw blade, it is even more important to have good collection below the blade because **most of the dust from table saw use gets sent downward**. Cabinet saws enclose the lower portion of the saw and generally come with a 4" port in the cabinet. A 4" port will only support about 350 CFM, but the airflow charts say we need 550 CFM for good fine dust collection. This means we need to open the port below our saws to a full 5".

Contractor saws also need good collection below the blade, but most lack the enclosures needed to control the dust sprayed below the blade. This makes collecting the dust from cabinet saws one of the more difficult dust collection challenges. Some have successfully used large magnet signage material to seal up the holes, but the bottom line is the only way to get a contractor saw controlled in terms of fine dust is to use a good blade guard like the Shark Guard mentioned above plus use coverings to enclose the saw base with a port for your dust connection. There used to be excellent magnetic attachments that did this but that firm is no longer in production so I recommend that you make your own coverings out of either metal or thick plastic.

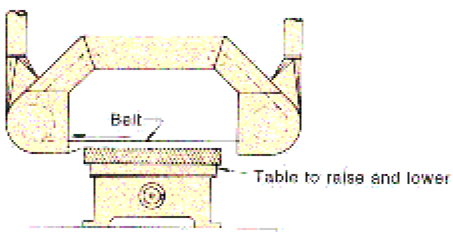
Our chop saws, miter saws, sliding compound miter saws and radial arm saws all pose one of the more difficult fine dust collection challenges. The traditional solution sets up the blade guard connected to one leg of a down drop and the second down drop leg connected to a hood that sits behind the saw. This solution only works if you have a saw with a big blade guard port or can modify your blade guard to handle at least a 3" and preferably 3.5" or larger port. Most of these saws only come with a small vacuum sized port that cannot be easily modified. The best way to tame tools with small ports is to use a strong shop vacuum attached to the small port and connect your dust collection system to a large separate hood. Both need to run at the same time to get good fine dust collection. Nothing short of a strong vacuum generates the pressure needed to pull the air through a small blade guard port. We need preferably a 6" port on a rear hood to pull in the spray plus the fine dust.

I personally made my own shell out of a large plastic wash tub that only cost a few dollars. I cut a hole in the back bottom that was 4" in diameter then warmed up that plastic with my heat gun. Once it was a bit soft I worked a slightly tapered wooden form I made on my lathe to make a rear port that a flex hose would slide over. I also mounted my square wash tub to the rotating portion of my saw so when the blade rotates the tub stays centered behind the blade. Pictured to the right is a commercial Rosseau hood that does the same job. I wish it had a 6" instead of just a 4" port.

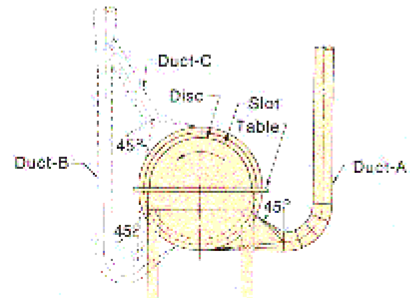
If we don't have good hoods on all our tools that control the fast moving airflows and move enough air, there is no chance of getting good fine dust collection. Fortunately, the better air engineering firms who certify that their customer shops will pass the air quality tests have been kind enough along with the EPA to share different hood designs that we know work well. Each of these hoods does a good job catching the fast moving heavier sawdust and chips, plus mechanically blocks the fast moving air streams. Even with good hoods, that still leaves most small shop dust collector and cyclone users in trouble because our vendors sell us equipment that moves about half of the maximum airflows they advertise. These lower airflows leave us with a bad false sense of security, meaning clean looking shops that tend to build up dangerously high amounts of fine invisible dust. AAF was kind enough to let me share one of their publications with their designs for dust collection hoods. I also have slowly been adding other hood designs that work well:

Exhaust Hoods

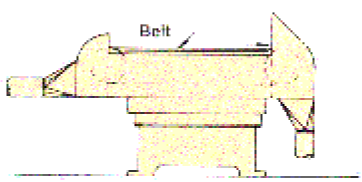
RECOMMENDED DESIGNS FOR VARIOUS EQUIPMENT



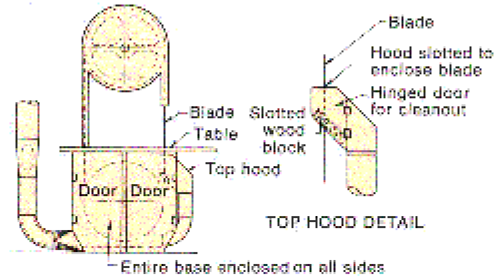
BELT SANDER



DISC SANDER



HORIZONTAL BELT SANDERS



BAND SAW

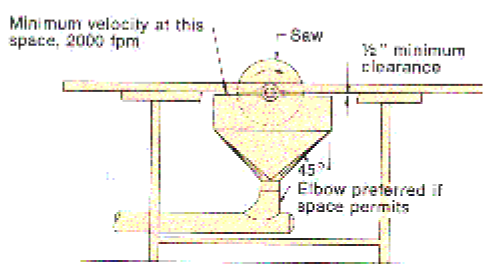
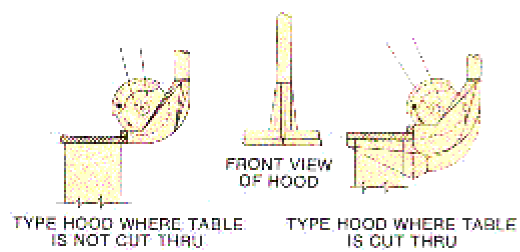
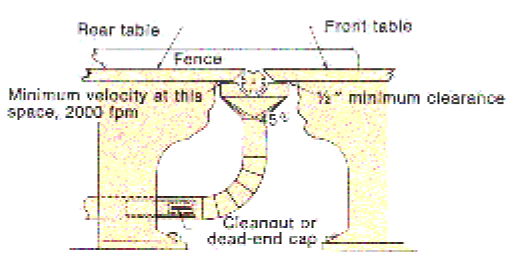


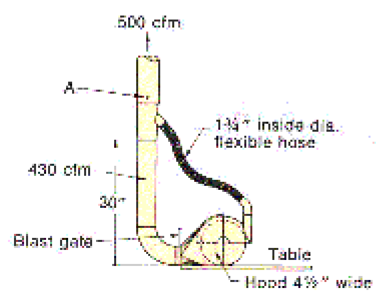
TABLE SAW



SWING SAW



JOINTER



RADIAL SAW

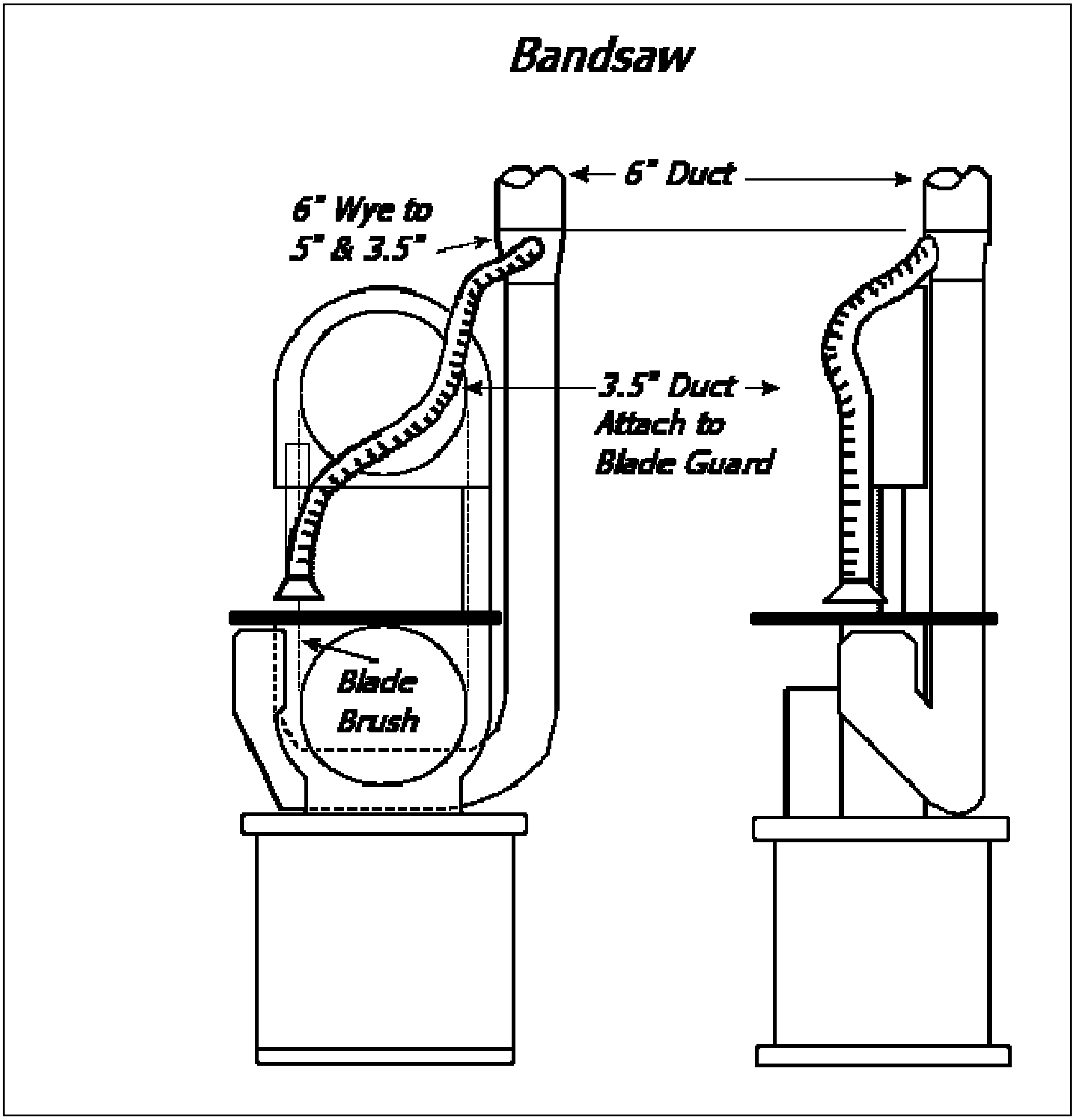
Provided by **AFF**:

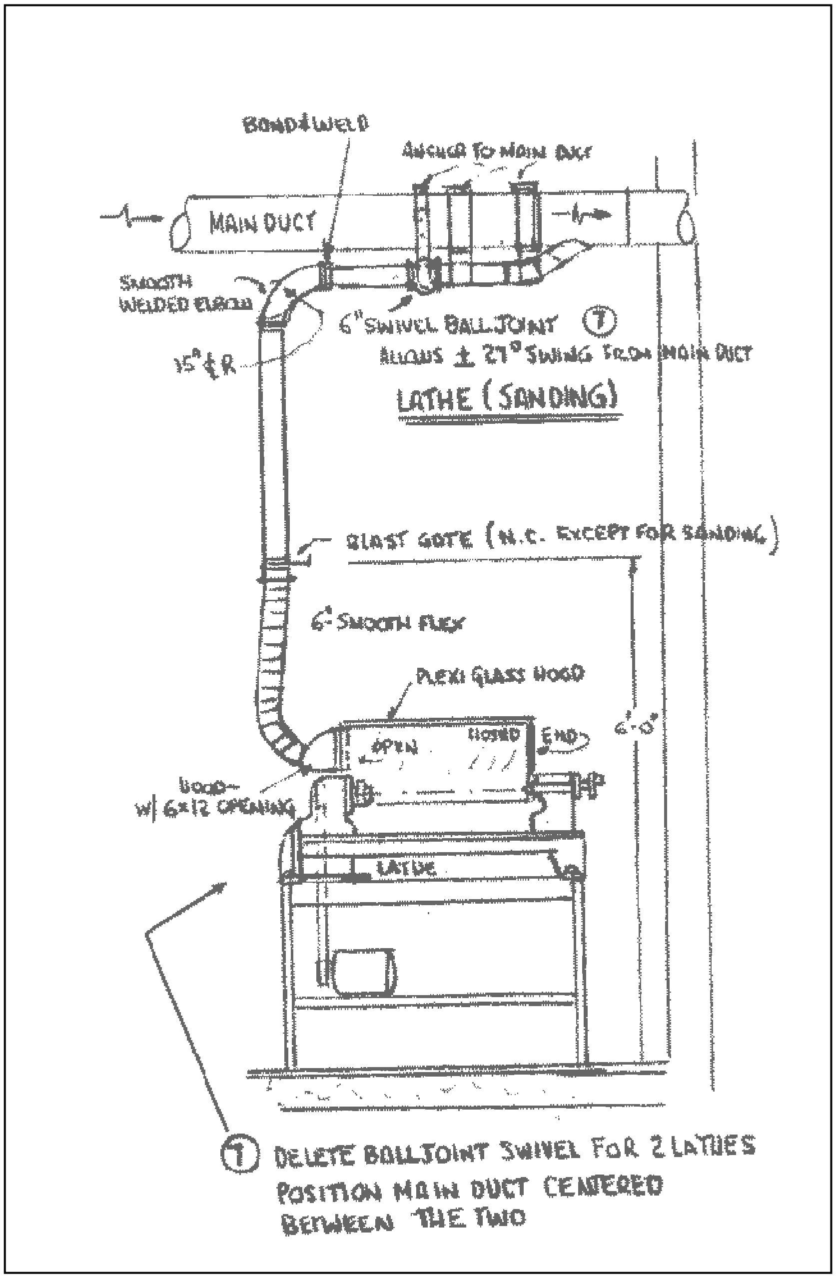
Chris O'Connor, APC Sales Manager

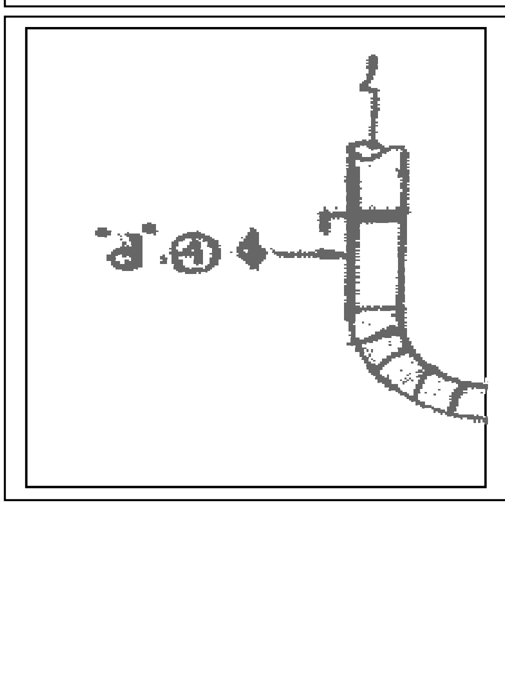
http://www.aafintl.com/ep_home.htm

AAF Hood Design suggestions

Other professional hood designs:
(Note: 3.5" ducting is difficult to find so you can substitute 4")


Bandsaw
6" Duct
6" Wye to
5" & 3.5"
3.5" Duct
Attach to
Blade Guard
Blade
Brush


BOND & WELD
ANCHOR TO MAIN DUCT
MAIN DUCT
SMOOTH WELDED ELBOW
6" SWIVEL BALLJOINT ⑦
ALLOWS ± 27° SWING FROM MAIN DUCT
15° ₵R
LATHE (SANDING)
BLAST GATE (N.C. EXCEPT FOR SANDING)
6" SMOOTH FLEX
PLEXI GLASS HOOD
OPEN
HOSED
END
6'-0"
HOOD W/ 6x12 OPENING
LATHE
⑦ DELETE BALLJOINT SWIVEL FOR 2 LATHES
POSITION MAIN DUCT CENTERED
BETWEEN THE TWO


"a" ④

Radial Arm Saws (RAS) & Compound Sliding Miter Saws (CSMS)

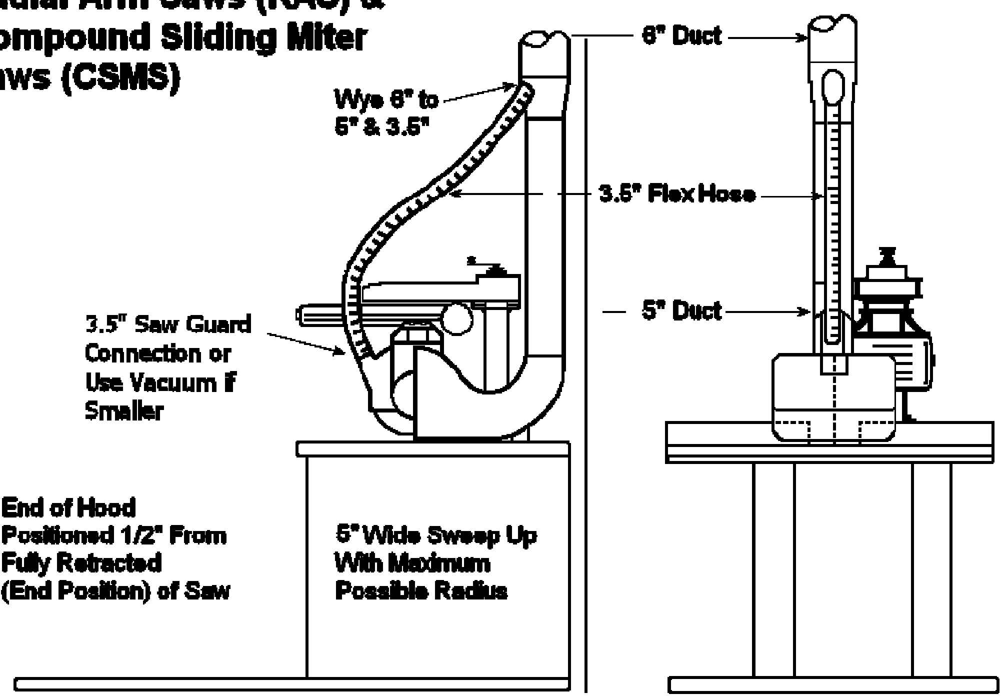
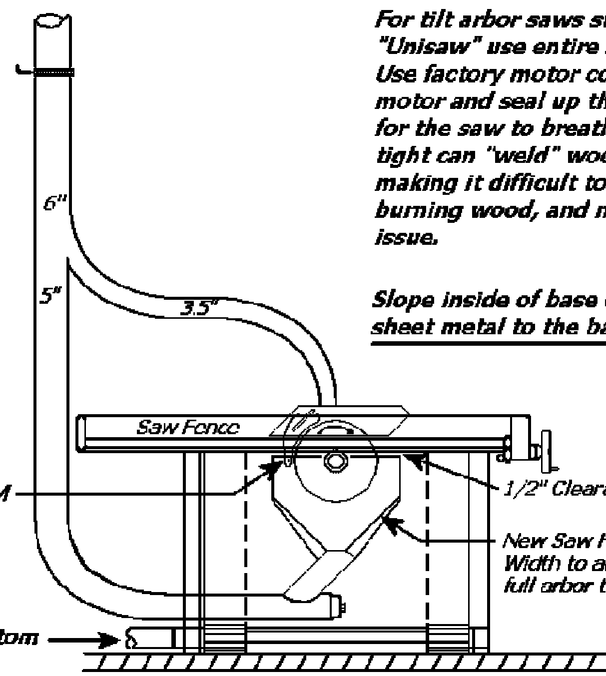


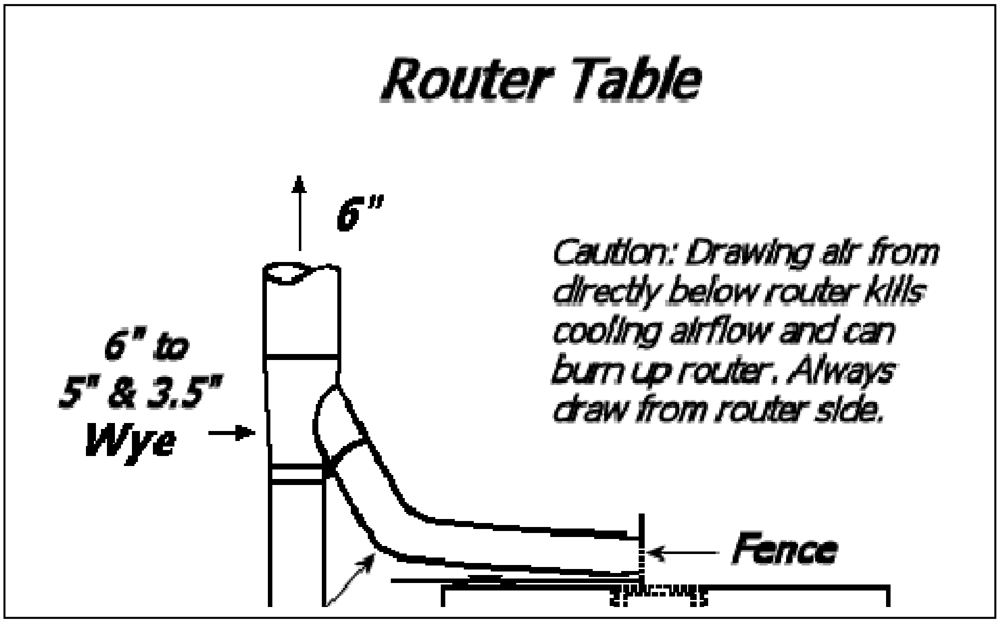
Table Saw

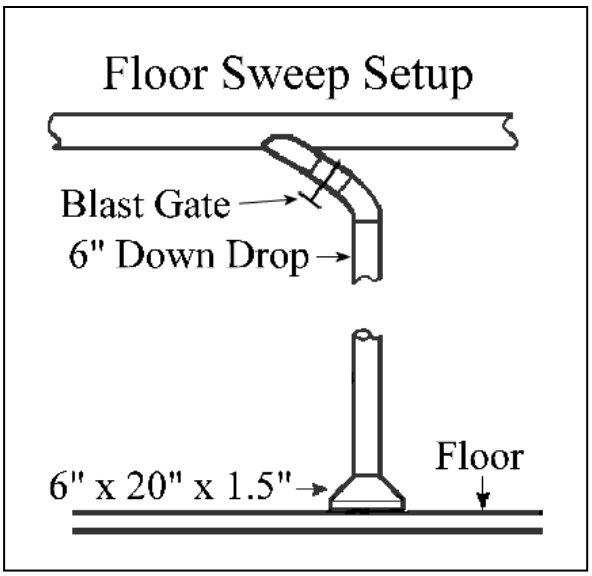
For tilt arbor saws such as the Delta "Unisaw" use entire saw base as hood. Use factory motor cover to protect the motor and seal up the base. Leave room for the saw to breathe as making all air-tight can "weld" wood to the table top making it difficult to push, potentially burning wood, and may create a safety issue.

Slope inside of base on three sides with sheet metal to the back bottom outlet.



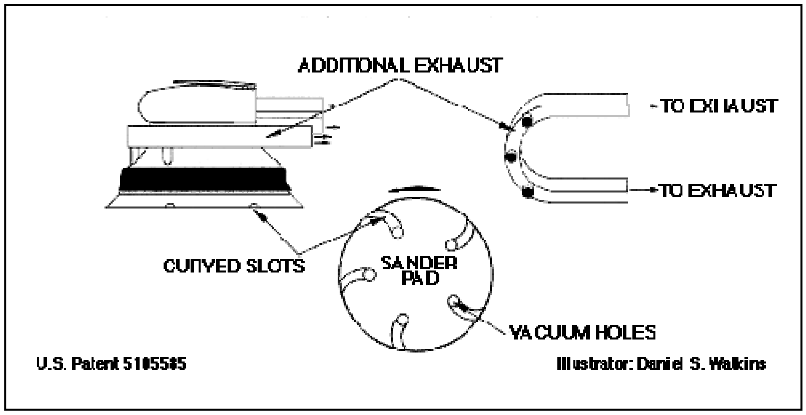
For saws having partial hood and chutes to rectangular sqwdust discharge, connect as in Joiner Detail.


Router Table
6"
Caution: Drawing air from directly below router kills cooling airflow and can burn up router. Always draw from router side.
6" to 5" & 3.5" Wye
Fence


Floor Sweep Setup
Blast Gate
6" Down Drop
Floor
6" x 20" x 1.5"


Floor Sweep
Woodworkers Supply
6"
1 1/2"
20"
Model 816-707

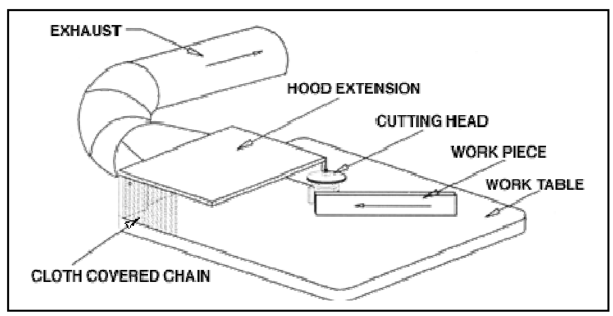
Random Orbital Sanders NIOSH Recommendation



The dust generated by random orbital sanders is sometimes controlled by a vacuum in combination with a perforated sanding pad. The vacuum draws wood dust up through holes in the sanding pad. It was found that, in spite of this control, large amounts of wood dust were still emitted into the workroom. Adding more suction to these units causes the sanding pad to be pulled to the work surface making the tool difficult to use and potentially damaging the piece being sanded.

To alleviate this problem a slotted sanding pad provides up to 90% better fine dust control. Cutting curved slots into the sanding pad as shown relieves the pressure caused by the extra suction and provides additional dust control at the pad edges. This change does not interfere with the operator, requires no special maintenance and is inexpensive to make. This dust control device is not currently commercially available, but is patented so you can make these changes for your own unit but cannot go into commercial production.

Shaper NIOSH Recommendation



Wood shaper emissions are usually controlled by an exhaust hood located at the back edge of the work table which allows the operator to freely move the work piece over the table. Placing the exhaust hood nearer the cutting head would maximize dust collection; however, this would restrict the operator's freedom to move the work piece.

To overcome this problem, a hood extension with a flexible face opening is added. The flexible face opening consists of cloth-covered chains that allow the wood to pass through, but stops the wood dust particles. The extension also increases the hood face velocity by minimizing the open face area.

17. **Static Electricity**

There is always someone who will bring up the concerns about duct static potentially causing an explosion when you use PVC pipe. PVC pipe is an excellent insulator that will build up a static charge, particularly in a dry cold climate. Although that charge can shock you, the experts say it is not ample to cause an explosion in hobbyist based systems. Dr. Rod Cole wrote an excellent article in Fine Woodworking that debunked the static myth with PVC pipe. He also posted that article on a woodworking forum and gave me permission to include a link to his article. If you are still concerned, go read his information. Dr. Rod Cole has some excellent additional information on grounding PVC on his site: Dr. Rod Cole on Grounding PVC (Click here).

Explosion or not, getting a good zap while next to a sharp blade or cutter can be plenty dangerous, so if you live in a dry climate and chose to use PVC, you might want to seriously consider grounding your ducting. Running a single grounded wire around the outside of your PVC that also attaches to the metal coil spring inside your flex hose helps if you ground that wire both at your machine and your blower. However in dry climates, static can be a real pain around tools and doing a better job of grounding your dust collection piping is worth doing. As I said before most grounding approaches do not work well at all and often lead to plugged pipes. Here is a workable solution shared by one of the many contributors to this site. Thanks for sharing Brent!

Brent Dugan was the Maintenance Supervisor/Plant Engineer for a large 'Meltblown' polypropylene manufacturer (oil sorbents) for 9 years. He shared his way to eliminate those nasty static shocks, "Our product was plastic and our conveying systems both air and mechanical were plastic. Polypropylene fibers traveling through 3" or 4" PVC piping creates massive amounts of static electricity. Our problem was so severe that we had sparks jumping 1 1/4" from our piping that would leave burn marks on your skin. Our employees dreaded working with the equipment. We tried all of the available methods you proposed and more; e.g., wire inside, wire outside, wrapped wire outside, etc. We spent quite a bit of my company's money to try and solve the problem with consultants and experts all to no avail.

I finally came up with a solution. It was so simple and inexpensive that you will not believe it. As you stated, static means electrons building on the surface of an object. Well, I solved the problem by sticking 2" wide aluminum foil tape to the outside and inside of the PVC piping and then grounding that tape. It is easy to just stick the tape on the outside of the pipe. Unfortunately that was not enough and I also had to put a strip of tape on the inside of the duct.

Putting the tape on the inside was an interesting challenge. I wanted my tape inside and tape outside to end up right next to each other with just the PVC in between so I could use a screw and nut to ground the two layers together. I was only able to make the aluminum tape with a backing like double-sided tape work on the inside. To do so I started by sticking the aluminum tape to the bottom edge of the PVC pipe. Slightly peel the backing and adhere the aluminum tape to the end of a piece of 1/2" EMT, conduit pipe, or other long rod. Feed the aluminum tape through the pipe as you unroll it from the roll. When you have the tape through the PVC, stick the aluminum tape to the end of the PVC pipe. Now 'tape' the backing to the rod then stretch the aluminum tape tightly angling it towards the top of the PVC piping (12 o'clock position). This keeps it from sticking prematurely. Now gently pull the rod out of the PVC that also removes the 'backing strip' off as you go. Keeping the aluminum tape stretched tightly lower it to the bottom side of the PVC pipe. To smooth it onto the inside I slipped in a longer piece of PVC and simply rolled that pipe inside to "iron" the aluminum tape down.

Having the tape back to back made grounding easy. I drilled a hole near each pipe end through both layers of foil, inserted a 1/4-20 screw from the inside of the pipe, put on a nut to make a good circuit, then connected each section using 14 gauge wire. I connected each end with alligator clips to another strip of the aluminum tape adhered to the concrete floor. That totally eliminated the massive static electrical discharges and earned me a bonus!"

Some have had problems with this technique. Here is what I did and it worked well to help me install my aluminum duct tape inside my duct. I put my pipe on my workbench oriented with where I want the tape on top. I then attach the tape end sticky side up to a long 2x2 and feed that board through the pipe while unwinding the tape. When it is all the way through stick the tape to the inside top of the pipe using a tennis ball to smooth it down as far as I can reach. From the other end pull the tape fairly tight without tearing. Now take a tight ball of rags and push it through the pipe from that well secured end. This will get the tape stuck. To smooth the tape and stick it well, rotate the pipe down then using a tennis ball on the end of the 2x2 smooth and press the tape down well.

18. **Noise Control**

One of the most difficult parts of dust collection is having enough airflow without so much noise that it drives you out of your shop. The difference between an air raid siren and a blower is impeller speed and clearance between the blades and impeller housing. Much of this noise is lower in frequency, so not too bothersome, but it is important to address noise throughout your dust collection and ducting efforts. I measured almost every major brand of small shop cyclone through 2003 and all put out between 85 to 95 dB measured at blower height at 5 feet distance by a calibrated digital dB sound meter. Sadly, the vendor ads strongly disagree with my measurements because most choose to measure at different heights and much further distances. My own galvanized steel cyclone measured 92 dB. I found that by making a few minor changes I could cut the overall noise created by my cyclone from 92 dB to 73 dB, meaning a quarter as noisy. Remember that the dB scale is a log scale so every 10 dB saved halves the overall noise.

Quieting my cyclone involved a lot of work. On the test bench my cyclone was over 100 db. I hung the whole set up using shock mounts and dropped it to about 92 dB. I used a big home-made muffler that pulled it down a few more dB. I put a piece of neoprene foam between the blower and cyclone to isolate the blower and keep the cyclone from being a sounding board, plus sprayed the inside of the cyclone with rubberized (not asphalt) automotive undercoating saving another few dB. I also tried spray coating the cyclone outside, but that did not seem to help any more than just spraying the inside. Spraying the outside metal sides of the blower helped some, but wrapping the outside of the entire blower except for the motor in heavy foam rubber foam helped more. Using a PVC pipe from the blower to the muffler wrapped with pipe wrap helped a little. Using MDF instead of my original plywood top on my cyclone and blower helped some. I also tried putting the cyclone outside, but it was way too close to my wife's study/craft room and it quickly found itself back inside. Probably the biggest help was building a new cyclone that was far more carefully finished so the airflow was very clean. Here is more detail on some of the things I did.

1. Locate your dust collector or cyclone so it does not impact on other parts of your home.
2. If you bolt directly to your framing, most of the noise is fairly low frequency so like a subwoofer will go all over your shop and house if they are attached. I know as 12" of well-insulated plenum between my and my teen's room still let me hear the bass. You need to change over the mounting to use a floor mount or use shock mounts so the low frequency

stuff does not make your shop and or home walls into sounding boards. Grainger's carries them (search under vibration hanger), but pick a set that is sized near the overall weight as heavier mounts provide little vibration protection. Using springs, heavy rubber cords, or nylon straps instead of metal bolts for mounting will help keep the noise from transferring into your shop or home framing.

3. Ducting can make considerable noise and often serves as a transmitter or even speaker cone to spread noise all over your shop and into your adjacent home. Using PVC pipe instead of dust collector spiral pipe or thick HVAC pipe helps considerably as you don't hear nearly as much sawdust rattling in the pipes. If you use a small section of flex hose between your ducting and your blower and cyclone that will also make a huge difference. The flex hose absorbs the vibrations. Using a piece of insulated HVAC flexible duct on the exhaust part of your blower will also help.
4. Muffling the exhaust side of your blower is a huge help because that is the source of most of the noise. You can do this with a muffler or a long length of heavily insulated HVAC flex hose. Larry Adcock, creator of the WoodSucker, told me that using a length of fiberglass insulated HVAC flex duct instead of building a muffler is easier and costs far less. He is right, but it takes a fairly long length to be as efficient. PSI sells an inexpensive muffler that saves about 10 dB, but it only fits a 5" outlet that is too small. We really should use 8" exhaust ports on our cyclones and that requires a muffler with an 8" center tube. Quite a few have made their own mufflers out of perforated pipe wrapped with screen then with fiberglass followed by being slipped into a larger tube. I tried making one using PVC pipe because PVC helps dampen the noise, but found sliding the outer pipe onto the insulated inner was difficult. Take a look at my Muffler Page for more details on how to build your own muffler.

   I did a little testing on the various forums of mufflers. On my cyclone with its biggest blower, a 15.5" diameter impeller powered by a 5 hp motor, my galvanized metal cyclone measured 96 db with the blower just going directly into the filter through metal duct. Trading the metal duct from the blower to the filters for PVC dropped it to 92 dB. Adding my homemade muffler in place of that duct dropped it to 88 dB. Using 8' of insulated HVAC duct in place of the muffler dropped it to 87 dB. Using insulated HVAC duct and my own homemade muffler it went down to 82 dB. **These test results will vary considerably depending upon how you made your blower, your choice of impeller, motor choice, any coatings or insulation you use, and depending if you use anti-vibration mounts.**
5. Use one of the rubberized automotive under coatings (not oil or tar based) sprayed inside of your cyclone. This protects wear areas and makes a huge difference in noise. You can get better results by taking your cyclone to a truck bed liner retailer and have them spray the inside with the heavy bed liner spray which works even better. You can also use compounds such as Dip-It or a plastic based coating. Be careful as the odors from some of these coatings can be terrible.
6. Adding the baffling and sound deadening materials around the blower and blower outlet helps considerably. Don't cover the motor as that needs to be open for cooling. Also, I suggest using something that is covered so it does not becoming a place for dust to gather.
7. Yitah R. Wu says: "With regards to cyclone noise, I work in automotive and one product which probably be good for reducing cyclone noise is what we call peel and stick mastic. It's usually in 8x10 sheets and is basically a 1/16" sheet of asphalt and recycled rubber with adhesive on it. This thick material adds both mass and damping for sound deadening of the cyclone itself. Auto parts and auto stereo stores typically carry it, some brands are Evercoat Q-Pads and Dynamat."

8. I have not tried an enclosure myself, but I know a few of the folks who have. They consistently said it did little to no good in terms of reducing the noise. Since those early comments, others have responded with solutions that apparently do work. They have built enclosures with enough room to access the cyclone using either two layers of sheetrock inside and a third outside or sheetrock outside and a 3M construction sound deadening board inside. They also recommended mounting the cyclone on a wall with isolation dampers to keep the wall from being used as a sounding board.

19. **PVC Confusion**

Let's see if I can help with the confusion on PVC caused by many mixed up terms and names that often refer to the same kind of pipe. There are many, many different classes of piping/tubing used for many different applications and have different characteristics. Many of these pipes are used for irrigation and would be suitable, but most limit their looking to one of the three most commonly found classes of PVC pipes. When it is all said and done, most end up going to an irrigation supplier and buying S&D PVC pipe for their dust collectors. It works well, is plenty strong, is easy to shape, and it costs 1/3 or less the cost of the other forms of pipe.

1. In readily available 4" and 6" PVC pipe there are two regularly used classes of "drain piping", this includes DWV (drain waste, vent) and PVC schedule 40. These are "thick wall" relatively expensive products that are normally used inside the house and buildings for carrying clean water. The cost to use this material often exceeds the cost to use inexpensive metal ducts.
2. In areas where we need to install drainage or that do lots of irrigation for agriculture, we often have some other less expensive thinner walled pipe options. The least expensive is rarely found today which is styrene plastic used to work with standard yard drain perforated pipe. Although that 6" pipe is rare and useless for ducting because of its very rough interior, the inexpensive styrene fittings that work with it are about half the price of better quality PVC fittings. Most end up instead having to use a little better and much more expensive sewer and drain pipes known as SDR-35. SDR-35 is the "common name" for the 4" and 6" range of this product that has thinner walls than normal schedule 40. The standards, fittings, and details are specified in the ASTM D-3034 standard. Sadly, almost all of these standards which were initially free on the Internet are now publications we must purchase from A href="http://webstore.ansi.org/" target="_new">American National Standards Organization (ANSI). Many choose to use this class of pipe because it is readily available in or can be ordered by some of the larger hardware stores.
3. There is a less costly PVC option that is priced between styrene and SDR-35 pipe. It comes in light weight 6" and 8" pipe commonly known as just "Sewer and Drain Pipe" or S&D. The standards, fittings, and details are specified in the ASTM D-2729 Standard. Personally, if you cannot afford nice spiral smooth interior walled ducting and smooth snap on fittings, this is my next favorite choice. I like it not only for cost reasons, but because you can work with some effort standard 6" HVAC fittings into the pipe. That gives you tight instant connections, the ability to quickly change out ports on your machines, and a variety of fittings that can let you make a floor sweep, hoods, and just about anything else you would want including transitions to my cyclone from off-the-shelf parts.
4. Both SDR-35 and S&D come in solvent weld systems and fittings with built in gaskets. Both SDR-35 and S&D are available at the home hardware stores in 4". The amount of 6" is limited there, but generally found in most irrigation and farm supply stores that carry pipes. These two pipe standards are by far the least expensive and have the least expensive fittings. Many say they are best way to go when building ducting for your shop. Because it is thinner

walled it is relatively easy to work, you also can minimize the use of connectors (See working with PVC).

20. **Frequently Asked Ducting Questions**

1. I'm at that nice place in life where money is important, but not going to drive my ducting decision. After retiring I fell in love with woodworking, have just finished building a large shop, and am slowly adding one machine after another. It seems that every time I add another machine, I have to move at least one or more of the existing machines. What ducting would you recommend for someone who wants minimum upset and trouble to do the install and later move things around?

   I am also in a fairly similar place, except I have kind of been there and done that with all the different types of ducting. The simple answer to your question is with time instead of money being a driving force in my world, I would install high end laser welded duct with the built in seals and snap lock fittings. Airflow is great because the seams are so smooth you can hardly tell where the pieces were joined. I also am an admitted tool junkie who keeps adding tools, so has to constantly reconfigure my ducting and shop layout. The airtight seals and clamps allow quick installation and even faster reconfiguration. To reconfigure just release the clamps, make the changes and then reclose the clamps. Plus, with my now in retirement and thinking about a downsized new home with a separate shop, this system would allow for easy disassembly and reassembly. If finances preclude that expensive duct then I would go for all PVC. I think the spiral pipe and HVAC ducting solutions work well, but they are a bloody pain to install and even more difficult to later change.

   Back as a hobbyist when PVC pipe was cheap I built a nice ducting system from the agricultural PVC that is readily available in this area. It worked really well, was not a constant blood letting to install, was fairly easy and cheap to change, and once I learned the trick of putting a 2" wide strip of aluminum tape inside and outside the pipe to drain the static, static electricity stopped being an annoyance. I am still a big fan of PVC ducting because of its ease of installation and making changes, plus it moves the air with less resistance. At the same time using PVC poses a serious fire danger for those who use a tiny blower and large PVC pipe. That combination creates piles of dust in the ducting just waiting for a spark for the duct airflow to quickly blow into a fire that the PVC will make worse. Shops subject to commercial fire marshal inspections are not allowed to use plastic duct. The big issue with PVC is cost. Since I originally wrote these pages the cost for petroleum based products like PVC has gone through the roof. The last couple of ducting systems I helped friends build ended up using steel HVAC and spiral pipe solutions because they cost far less than PVC today.

   The two main firms that make the laser welded steel duct are Lindab and Nordfab, but this duct is resold by many other vendors. By the time you add additional markups for wholesaler, distributor, and retailer this laser welded duct gets ridiculously expensive. Worse, most of the firms that resell this duct strongly dislike getting involved in hobbyist and small woodworking shops. Most are no where near ready to pay the high cost for this type of duct. Worse, it takes far longer sales and air engineering time to help a small shop owner as it does to help a large shop owner. They invariably have to share why we need bigger duct to move enough air and few small shop owners take kindly to being told they are going to have to remake most of their tool hoods and ports for the result to be effective.

If you want this kind of duct, it is best to get it directly from one of the manufacturer's main distributors. Only two large distributors have come forward willing to work directly with hobbyists and small shop owners, Duct Incorporated 877-BUY-DUCT and Air Cleaning Specialists Inc. (866) 455-2130. These two are with the largest manufacturers (Lindab and Nordfab) and offer top quality all USA made smooth seam laser welded steel ducting with clamp connections. They keep all the wyes, bends, dampers, reducing cones, branch pieces, fittings, etc. in stock. Both have excellent reputations and enjoy working with hobbyists and small shop owners, plus have worked out fast affordable shipping for our orders.

If you're interested in Nordfab Laser Welded Clamp Together Ducting my friends at Air Cleaning Specialists Inc. (ACS) (866) 455-2130 are happy to work with hobbyist and small shop owners interested in a clamp together duct system. They provide detailed CAD/PDF drawings, parts list, and engineering recommendations for the low cost of $13.00 per drop. Click here to view more information about the ACS ducting design service. If you purchase the ductwork the drawings are free. Everything is made to order and ships within 5 working days. They maintain plants on both the east and west coasts for faster less expensive shipping.

After installing both HVAC and with spiral pipe ducting, I picked up a bit of knowledge, some unfortunately from making dumb mistakes. I put my HVAC ducting in the attic above my shop roof where local building codes require metal. I got a big surprise when my heavy blower collapsed the light HVAC pipe. It turns out our box stores sell two gauges of their snap lock pipe and I bought the really light stuff but should have used the heavier 26-gauge metal or instead used real steel spiral pipe made for dust collection where its ribs make it much stronger. I also learned many vendors offer spiral pipe ducting solutions and quite a few local vendors make their own pipe and fittings saving lots on shipping. You want to do your homework carefully before buying. Hidden costs like for shipping can really add up. Shipping ducting is tough because it is so bulky it gets shipped with heavier items. All it takes is a heavy box to slide into or get stacked on top of our ducting and fittings to ruin them. That is why you only want to buy from a firm that either will replace anything that does not arrive intact or buy locally. Even buying locally poses some challenges. The same $6 elbow I could buy at the local box store cost $25 from my dust collection ducting firm, $12 from my local HVAC firm, and with shipping $18 mail order. I had multiple sales people tell me their elbows were only for dust collection. That's silly, flipping an HVAC elbow end for end makes it identical to a duct collection elbow. The only time the dust collection elbows are more important is if you do things right and buy the more expensive large radius elbows. That is not the case on reducers and wyes. For those you need a good roller crimper to change the end genders, or spend the larger amounts needed to buy actual dust collection fittings.

If you have an established shop with little need to relocate tools I favor the use of spiral pipe with real large radius dust collection fittings. You can buy and install spiral pipe yourself, but most choose to have a local firm do the installation. Although these work well, the inside of the spiral pipe is pretty rough and adds considerably to the overall resistance of the ducting. Additionally spiral pipe ducting is a pain in the tail to change. Personally, I put a spiral pipe system under the floor of one of my shops. Even with a 4' tall crawlway under the floor installation was a pain. By the time I sold that shop two years later the floor looked like a prairie dog village with patched holes everywhere. My tools kept moving because I kept adding more tools. Anyhow to avoid that whole mess, I strongly recommend overhead ducting. If you want a spiral pipe system and keep the costs down by doing your own install because shipping is so high, you should check out your local suppliers. I have also heard many are pleased with the spiral pipe from:

SPIRAmir Corp. 6780 Sierra Court, Unit "M" Dublin, CA 94568 Phone: (925) 803-8444 Fax : (925) 803-8448	Air-Duct Mfg., Inc. 920 N. Lombard Road Lombard, IL 60148 Phone: (630) 620-9866 Fax: (630) 620-9878	Die Stamped Products, Inc. 1230 S. Manufacturers Row Trenton, TN 38382 Phone: (731)855-0040 Fax: (731)855-0460

2. These firms are known for offering good quality spiral duct, elbows, fittings, and other sheet metal products for about 1/4 the cost of some of the "dust collection ducting" vendors. (Thanks Amer from Amer's Woodworking)

   I also heard Spiral Manufacturing offers good quality metal ducting. They sell directly to individuals, make their stuff from the better heavier 20 gauge, and have OK pricing. (Thanks Grant Erwin!)
3. Does a 4" connection at the machine negate the benefit of the 6" duct going right to that machine? Yes, it kills the dust collection performance. At typical airspeeds and pressures for dust collection, air is virtually incompressible. Air can speed up some to get around a short obstruction, but just like a water valve, closing down the opening greatly restricts flow. The standard 4" connections on our larger hobbyist machines kill the CFM below what we need to collect the fine dust. We pretty much have to replace all the 4" ports on our larger machines if we are going to collect the fine dust at the source.

   The other part of your question is what is the impact on airflow when using a 4" drop attached to a 6" line? My engineer friends at Dwyer Instruments that build most of the air measurement meters say roughly 10 diameters of pipe will both stabilize the airflow and set that airflow to about the same duct speed as your main. Most air engineers that are just interested in getting sawdust build systems targeted to get an airspeed of 4000 FPM in the main. That 4000 FPM when pulled through more than about 40" of 4" diameter duct will end up with a total air volume of 350 CFM. That is plenty for good chip collection at most small shop stationary machines, but far short of the 1000 CFM I recommend for good fine dust collection. The bad news is that roughly 350 CFM ends up with our main only having an total airflow of about 1782 FPM. That is way short of the minimum 2800 FPM needed to keep a horizontal main clear. The result is the main ends up building up first the larger chips then finer dust. It will continue to build up this dust until the duct is sufficiently restricted that the airflow is again fast enough to keep the remaining area clear.

   So, putting that 4" diameter down drop on 6" diameter is bad news. These ducting piles are a serious fire hazard. When airflow is restored from open more area these piles go slamming down the ducting. This slamming ruins blower impellers, blower motors, knocks the ducting joints loose and destroys filters. Worse, when these piles break loose they create one of the few times that small shops end up with a potentially explosive dust to air ratio. The slightest spark say from a nail hitting a steel blower housing is enough to cause a serious problem. Plus, it is unpleasant to listen to this dust rumble around in the ducts.

   We can easily do the math to understand why that 4" diameter is just too small to be used with a 6" duct unless we open up more airflow downstream. From the area formula A=r*r*Pi we know the area of our circles more formally known as the cross sectional area of a piece of duct. For 4" this is 2*2*Pi =4*Pi and for 6" ducting this is 3*3*Pi=9*Pi. The difference is the 6" duct has 125% more area and the 4" duct only has 4/9ths the area of a 6". Not only will this cause piles in the horizontal runs, if we have any vertical runs there is a good chance that we will develop plugging because we need at least 3800 FPM going up to keep the heavier stuff moving. That 1782 FPM is less than half of the 3800 FPM minimum we need to keep the dust from plugging in the vertical runs.

I know of four solutions and there may be more, but I only recommend the first:

0. Use all 6" duct right to your tools. For tools that have two ports like a table saw, use a 5" duct to the larger cabinet port and a 4" to the smaller blade guard port. Cutting into my precious tools to put on big enough ports was one of the toughest things I had to do, but the result made a huge difference. Some tools have internal ducting that requires use of two 4" ports. This will work but not nearly as well as a 5" and a 4". It is all a matter of trying to keep the areas as close to the down drop pipe as possible.
1. Go with overhead ducting so you don't have to pull dust up at the end of the run by the blower. This works only if the difference between main and down drop is minimal. That more than double 4" to 6" area is just not going to work.
2. Stay with all 6" and just use a tapered wye on the end with the extra pipe going to a dust hood to help with upper collection. People do this all the time and it sort of works. I tried it and measured the airflow. That 6" to 4" taper cost me about a third of my total airflow.
3. Build at the end of your main as far from the dust collection system as possible a weighted door that opens a little whenever the pressure in the line becomes too large. This will keep up the main airflow ample to ensure no plugging but you kill the total airflow needed for fine dust collection and often don't end up even with good "chip collection". I had to do this with my airfoil impeller as it will stall if I let the pressure get too high.

4. You commented at one point about the possibility of using melamine coated particle board to build solid ductwork, rather than using pipes. But I could not find anything to advise the pros and cons of this approach.

   Is there any problem with static buildup, as there is in PVC? Assuming that I'm careful with building smooth and tight joints, would melamine provide as high flow efficiency as PVC or metal? Would melamine be quieter? I'd like to keep the noise down to a reasonable level, since it's in the basement, right under the kitchen and dining room. Are there any other concerns that you can think of, with using melamine?

   Would a combination of melamine and flat sheet metal be even better? Just like your blower design; sandwiching sheet metal in a groove between two plates of melamine?

   I'm just in the preliminary stages of planning a cyclone dust collector based on your airfoil blower. I already got a price quote from Paul, and I see that the Delta motors are still available via eBay. I'm planning on having a weighted duct opening at the end of the duct to eliminate the stall condition.

   Melamine works fine except for the normal concerns for rectangular ducting building up piles in the corners, plus some concern about flammability. You really do have to ensure ample airflow in the ducts and use long smooth radius turns with this to keep them clear always. Melamine does not normally present a static problem. And, it does help to dampen the noise considerably. With a basement shop, make sure your blower is not attached to a ceiling or wall and that you go from the blower to the melamine with flex hose to dampen blower noise. If you do have to attach the blower to the ceiling or wall, use good shock mounts to keep from sending the noise upstairs. Also a couple layers of heavy foam above the blower will absorb quite a bit of the noise going upward.

The only cons for using melamine are you have to size the ducts properly and make sure you make cleanouts at the end of each run. It is near impossible to take apart that duct later in case of a plug, particularly if you use the preferred RooGlue melamine glue. The cost for the hardware bolts would be far more to sandwich sheet metal between melamine halves, so would not go that way.

Making your ducting from Melamine creates rectangular ducting. The corners in rectangular duct reduce airflow. You need some different sizing with rectangular duct to provide the same airflow as we would get with round duct. This web page will give you the information you need to calculate sizing that will overcome that extra resistance: Rectangular Duct Calculator

5. You seem to say that 4" ducting, categorically, is not sufficient. Why? Sadly, this is not what I am saying. There is nothing wrong with 4" or even smaller sized duct if it is ample to carry the volume of air needed for good collection at your machines and you have made sure that you open enough ducts to preclude plugging in your larger main duct runs.

   My problem with 4" diameter duct is most don't understand the impact that ducting size has on our total air volume and air speed. The normal blowers used with dust collection systems generate about 7" of working pressure meaning enough pressure to push or pull a column of water about 7" high. That's why we measure blower performance in water column inches abbreviated W.C. At this typical pressure a 4" duct will only move 350 CFM with an internal ducting speed of around 4000 FPM. This FPM airspeed is very important because when it drops below about 3800 FPM it is not fast enough to pull heavier material upward in vertical duct so we get plugging. When the airspeed inside our duct falls below about 2800 FPM then even our horizontal runs begin to plug with piles. These piles pose a serious fire hazard as any spark can quickly get fanned into a dangerous ducting fire. When airflow gets restored these piles slam large enough volumes of dust down our ducting that it can blow apart our joints, ruin our blowers, and destroy our filters. Smaller duct poses a big airspeed problem when we feed a main with just one smaller duct open. For instance, our 4" duct moving 350 CFM at 4000 FPM in a down drops suddenly cuts the airspeed in a 6" main to 1783 FPM creating instant plugging in our larger mains. That same airflow only provides 1310 FPM in a 7" main and 1003 FPM in an 8" main. This is why I am so hard on the popular cyclone maker whose graduated ducting designs use 8" mains with lots of 4" down drops on their systems that can only support one machine running at a time.

   Adding to the airspeed in our ducts needing to be ample to keep the ducts clear, 4" diameter duct gets us all tangled up in the continuing problem where small shop vendors continue to mix "chip collection" and fine dust collection standards. Good "chip collection" collects the same sawdust that we get with a broom, and good fine dust collection provides good "chip collection" plus also collects the fine dust ample to keep our air quality below one of the different air quality standards. Most firms who guarantee customer air quality recommend and provide at least 1000 CFM airflow at our **larger** woodworking machines to collect the fine unhealthiest dust at its source. Because air at typical dust collection pressures is incompressible, normal dust collection blower pressures will only pull about 875 CFM through a 6" diameter duct. This means most dust collection systems need all 7" diameter and larger duct. I get around this problem with the cyclone systems I designed by building a more powerful blower that generates a much higher working pressure able to pull over 1200 CFM through a 6" diameter duct. And yes, many of my 6" down drops split into 5" and 4" sized duct, so I do use lots of 4" duct in my ducting designs.

6. I'm having a serious case of sticker shock after trying to follow your advice and only use 6" ducting and 6" flex hose! OUCH! Where did you get good 4, 5, and 6" flex hose? You are not alone in this sticker shock. I have 6" clear, smooth walled flex hose from Amazon, Jet, Wynn Environmental, and Northern Tool. All was over triple what I paid for good quality smooth walled 4" flex hose, but that was not big enough for some of my needs. I found the best prices at Wynn Environmental (thanks Jack Diemer) and next best from Amazon. It was a bear to find on Amazon and often not in stock (search for "jet hose"). Grizzly, PSI and others also carry 6" flex in a few different grades as do most local hosing suppliers. The record cost I found was a heavy multiple layer rubber 6" flex hose that sold for $26 a linear foot, minimum 10'. Wynn Environmental carries affordable clear good quality 6" PVC hose and would recommend going with them in 25' lengths. I now only use 6" duct for the runs to all my machines then split after the blast gates for two pick up type machines. This is not cheapest, but saves having to balance everything, open extra ports when using small machines, and it hurts nothing to move more air than needed. For sound deadening I used insulated HVAC duct on the outlet side of my blower going to my filters thanks to a tip from Larry Adcock with WoodSucker. Most HVAC shops will let you buy a short piece of this insulated duct inexpensively.
7. There are all kinds of different PVC pipes out there. What do you use and what do your recommend? I've had a commercial shop that used all 4" spiral pipe installed by a commercial contractor. It was terrible and barely gave any dust collection at all. My next shop was 6" mains going to 4" and 5" drops. It was better, mostly because it used a much bigger motor and impeller in the blower that powered it, but was still terrible. My current shop is in my garage and up until recently was also a mix of 6" mains and smaller down drops. When I let my first prototype cyclone follow a friend home he also got that ducting, so I again started over. This time I used all 6" Sewer and Drain 2729 PVC because it is inexpensive, has the least resistance, and the fittings slide tightly onto 6" HVAC fittings.
8. I see your shop is as messy as mine and see quite a bit of big pieces of PVC in the back. Is this what you recommend and used for your shop ducting? You have a lot of nerve! *Laughing* I recommend smooth interior walled ducting and smooth interior walled flex hose. If you have a traditional blower then you need all 7" or larger diameter duct and hose to move a real 1000 CFM. With my oversized blowers you can use 6" diameter to each of our larger machines. I've used spiral pipe, 24 gauge HVAC pipe, S&D PVC, and smooth interior walled flex hose with good success. The key is long straight runs, no sharp bends, no right angle fittings, no rough or ribbed hose, on and on.. Don't use anything but large smooth interior walled flex hose to your larger machines.
9. I'm laying out a shop right now, have already used your AAF CFM requirements tables, worked through your ducting resistance calculator, and am convinced I do need all 6" to each of my tools when using one of your higher pressure blower designs. I bought a bunch of HVAC parts and am copying forum advice you gave others. My question is I want to put my ducting buried under a concrete slab. What are your thoughts on doing this and can you share any hints? First, I would rather see ducting on the ceiling simply because things change and in floor ducting is not easy to modify, plus long sweeping turns on the ceiling are easy versus

hard to form in the floor. Also, over time junk will go into those pipes and they will be a nightmare to clean or replace. If you have to or want to use floor ducting, I strongly recommend making concrete trenches instead of just buried under the slab.

Steve Cater built his shop and put his 4" ducting under the floor, but not in channels. When he hooked up his dust collector there was not enough airflow. He sent me a long email and again verified for the umpteenth time that anything less than 6" is going to almost cut in half the airflow from your dust collector or cyclone. We went through all kinds gyrations to come up with a fix for him and were finally successful. It came down to having to use a monster motor driving a huge impeller to overcome that resistance and get enough airflow.

You might want to look at Steve's Solution and some of his discussion or even contact him before going too far. If you want some independent confirmation on the need and advantages of using only 6" duct and 6" hose, there are now dozens of hobbyists on most of the larger woodworking forums who I am sure would be happy to verify what a bid difference it made for them.

Also, one of my friends locally put his ducting under a slab floor. Not too long ago his shop apron that was hanging on a hook near the open floor sweep tried to commit suicide. It almost made it, but his metal calipers got turned sideways at the second bend and jammed in so hard it locked in place. With no clean out, you would not believe what we had to do to get that apron unstuck. You need to use Y's with one end going to a clean out for each buried run. This is another reason to go with the trenches.

We have those kinds of trenches in our machine/woodshop at the university. They carry a copper airline, a water line, additional 110, 220 & 440 power, and the dust collection mains. We covered each trench with surplus computer room raised flooring tiles and on top of the whole shop floor we have interlocking horse stall mats. That makes for an incredibly comfortable shop that is easy on the legs and was not too hard on the pocket book.

Finally, make sure you run two PVC 2" pipes in the same runs with heavy poly-rope inside and a few T outlets that come out next to your machines for future goodies like more power, remote switches, on and on.

10. I need your help with **transitions**. I made your cyclone and low cost blower for $167 from your Build Budget Blower web page using a 14" Jet impeller and HF 5 hp motor. It moves an incredible amount of air! At your recommendation I purchased the 6" flex hose, bought and made some 6" blast gates, and have a mess! Your blower design has a rectangular outlet that will not fit anything! A couple of my machines are European and use a dust port that won't fit anything. All of my other machines use anything from 4" down to 1 1/2" dust ports. My expensive new commercial blast gates won't fit my PVC duct. How do I make all these transitions? Good for you on that construction! My twin to yours measures out at a real 1800+ CFM before connecting cyclone, ducting, or filters then the bad news is I only get 875 CFM through that 6" duct. The problem is that 14" diameter blower wheel does not generate enough pressure to move more air through a 6" diameter duct. I had to upgrade my 14" diameter impeller to a 15" and eventually again upgraded to a 16" diameter with bigger blower housing. If you are just starting I recommend going right to the 16" impeller and skipping these air volume problems.

    You are not alone with your **connection problems**. Many of us end up with confusion and problems in trying to hook up our dust collection systems. Machine outlets don't match our sized duct or flex hose. We use a combination of metal, flex and duct that will not fit our blast gates, etc.

In terms of the **transition** to the blower, you can go to my Transitions section above and see how to build a sheet metal transition that will go from either round or square to either round or square. That approach works and is kind of fun, but very labor intensive. It also is unforgiving if you are not real careful in your measurements and cutting.

Alternatively, what I've been doing lately is measuring both the size and perimeter of the outlet then making a run to my local orange box store (Home Deport or Lowe's for me). There I go through the HVAC transitions until I find a rectangular or circular one that is either right on or just a little bigger that mates on the other side with a 6" round fitting. Most of these are held together with either rivets or metal stamps that kind of push a little circle through adjacent pieces then mushroom the top a little. I drill out those connections, then use a piece of angle iron and hammer to square up the corners with the top and bottom set at the width of the outlet I want it to mate with. Slot each corner and bend the top and bottom at 90 degrees to be screwed onto the blower MDF. The sides I leave straight and use aluminum tape to hold to the metal sides of the blower.

Mating the PVC together is mostly a matter of staying with the same series. I only use the 6" (remember 4" and 5" are too small for our larger machines!!) S&D 2729 series and all from the same supplier. Different suppliers make pipe of different thickness so not all will fit together. The supplier I use is an industrial irrigation and plumbing supply firm and their product has an ID that is dead on at 6".

The reason I only use that type of pipe is that it also takes care of the problem of **mating with standard HVAC ducts** and transitions. You have to work at it hard, but the 6" HVAC fittings will just fit into that duct. They are tight enough that they don't fall apart. I seal them just in case with the aluminum tape. Also, after making sure all fits and before my final assembly into the PVC, I pull out my flux and solder the HVAC transition up so there are no air leaks.

If the **blast gates** you made don't fit, shame on you! If the gates you bought are normal, they will be too small! Shrinking PVC is a major pain that takes a mandrel, special heating arrangement, and big clamp similar to a piston ring compressor. Instead, as McGiver would do, whip out your Swiss Army knife and duct tape. Put a couple of Â½" wide turns on the inside of the flange. These first couple of turns create a taper making for a better fit. Follow that with enough turns so you get a good tight fit with your blast gate. I cut the end off a metal screw, drill a hole through the PVC and blast gate flange, and keep all held together with that screw. If your gate gets moved around or used a lot, then use two or three screws done the same way.

Mating your **flex hose to PVC** can be a real pain. The 6" flex hose I use is just a touch larger than 6" ID and will stretch a tiny bit. My PVC is about 6 1/4" in outside diameter. They don't fit! But, there is a fix. I take that PVC to my band saw with the thin kerf 3/32" blade. I then cut 2" deep in the end right down the center of the pipe, turn the pipe 60 degrees cut 2" deep again, then turn the pipe 60 degrees more and make a final 2" deep cut. (If you use a thick kerf blade only make two cuts!) This creates a pipe with six (or four) cuts that with a little squeezing becomes tapered losing just enough diameter to fit tightly into my flex hose. You can use a screw type band clamp and PVC glue to seal and make stronger, but I find that is not at all needed. The hose slips on enough to make a good seal.

Mating your **flex hose to metal pipes** can also be a real pain because they keep falling off. I beat this with a simple but nice solution building a simple thread into my pipes that the duct can screw onto. I drill a small hole near the front of the metal flange and one toward the end. That hole is sized to just fit a single strand of 12 gauge copper wire. I put the wire through the hole then wind tightly around the metal flange at about the same spacing as the coils in my flex hose. With a little solder that copper wire is there for life! Trim off the tags inside the flange and sand smooth. Now the flex hose just screws on. Sometimes, depending upon the hose I may need to use thicker wire, but in most cases the result is plenty tight enough that it does not even need a clamp to make a nice non-leaking seal! This also works well on my tapered PVC, but use super glue instead of solder to hold the wire in place.

Mating my pipes to my **European machines** is a whole different technique. Although heating PVC gives off very dangerous fumes that you need to protect yourself against, you can do magic with a heat gun or two and PVC. I documented my techniques and show some extreme examples of how much you can do on my How to Bend and Form PVC page. I was able in a few minutes to make some incredible joints that fit nice and snug on all those weird sized pipes.

Now with all that said, **is this the way to go?** Nope. Instead go to a real ducting supplier and buy their top quality laser welded standard 6" flanges that include a seal, and replace those often way too small inlets on all your larger machines.

That same heat gun technique will let you make most of your **long bends in your PVC** without using any joints or fittings at all. You have to have a couple of heat guns to get a large enough area hot at once, but the result is nothing short of amazing.

Finally, **reducers** for me are almost all 6" runs that start with a blast gate then come down to a wye with upper and lower collection hoses. One leg of the wye will connect to my machine dust port and the other goes to a movable hood, often with a super magnet to hold it in place. Woodcraft, Lee Valley, Rockler, Grizzly, etc. all carry fittings, but I mostly either use HVAC or make my own. Make sure you only get fittings with smooth joints and tapers, as tight corners and blockages kill airflow and performance.

21. **Disclaimer**

The reader assumes all responsibility and liability associated with the hazards of woodworking and dust collection. **Dust collection when improperly built, implemented, used, or maintained may cause serious injury or even death**, so **USE THIS INFORMATION AT YOUR OWN RISK!** The author has no control over how a reader will act as a result of obtaining information from these pages. Your actions are your responsibility, **VERIFY and CHECK** information out before proceeding, and don't attempt anything without the required skills. The author shall not be responsible for any errors or omissions that may be present on these pages. Accordingly, the author shall assume no liability for any action or inaction of a reader.

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These pages are directed toward a hobbyist and small shop woodworker audience and are not intended for application in a commercial, institutional, or industrial setting. Commercial woodshops are generally governed by a complex set of worker safety regulations, such as those mandated by OSHA. Satisfying the compliance of such regulations is beyond the scope of these web pages. **HIRE A PROFESSIONAL ENGINEER** to design, specify, test, and certify performance of any dust collection system if you have a commercial or an industrial application, allergies, other medical problems, people working for you, a large shop, work with hazardous materials, or are subject to regulatory oversight.

Unless you as a woodworker provide appropriate fine dust protections, most small shop owners put your health, the health of those close to you, and even the health of your pets at risk. Unfortunately particle testing by the author and hundreds of others all across the country shows those who vent inside even with very clean looking shops invariably have huge build ups of invisible dust. Government testing shows on average just one hour inside a small shop that vents its dust collection inside results in more fine dust exposure than large facility commercial workers receive in months of full time work. The difference is almost all large commercial facilities vent their dust collection systems outside, so they rarely build up the fine invisible fugitive dust that escapes collection. Even with venting outside, the peer reviewed medical research shows the more fine dust we take in the greater the short and long term health damage and this research also shows even with their much lower exposures almost all large facility woodworkers develop serious dust triggered health problems and significant loss of respiratory capacity. This should terrify small shop and hobbyist woodworkers because of our much higher exposures. Respiratory doctors who have read these pages share small shop woodworkers and their family members often have the worst respiratory problems. Please take the time to protect yourself and those close to you.