Cyclone Plan

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A. Foreword

This web page provides general information on cyclone design, a detailed dimensioned drawing you can use to build your own cyclone from my plans, a spreadsheet that will let you design larger and smaller cyclones of this same design, and some of the details that led to developing this cyclone design. The following Build Cyclone web page provides more detail on the steps to build this cyclone. I believe most woodworkers can use these plans and building instructions to end up with not only the most affordable to install, but also the best fine dust collection system available today. Thousands have already built their cyclones from these plans and building instructions. Many have provided their suggestions, feedback, and questions to help improve these pages enough that most can build their cyclones without needing to contact me for additional help during the building process. With no sheet metal experience, most can build their cyclone in less than ten hours work, their blower in about six hours work, and their entire system with a full shop of ducting in under forty hours of work. If you don't want to take the time to build your own cyclone and blower, then you should seriously consider buying a kit cyclone from my son.

B. Introduction

One of my most frequently emailed questions is why should I use your cyclone design when virtually every other small shop cyclone gets high magazine ratings and praise? The simple answer is my cyclone design moves more air, uses less power, and provides over five times better fine dust separation which is what we need if we are going to use filters fine enough to protect our health.

I admit initially contributing to the misinformation about cyclones. Like most others I stupidly threw money at my dust collection problem installing the top magazine rated cyclone with vendor designed and supplied ducting, plus vendor recommended fine filter upgrade. I had so much invested in this unit that I gave it praise on the Internet when in fact I should have just thrown this system away immediately. This system collected far worse than my existing dust collector which cost a fraction as much. Its filter clogged constantly making for a nasty filter cleaning chore that left me and my shop covered in the very dust I bought this system to avoid. The vendor designed and supplied ducting regularly clogged as there was not enough airflow to keep the vertical runs from plugging and the horizontal runs from building up huge dust piles that posed a serious fire danger.

Even with all that nonsense I still supported and recommended this system and vendor until this most expensive poorly performing cyclone system landed me in the hospital. My heart went into congestive heart failure because it could not get enough oxygen. My emergency room doctors and consulting respiratory physician determined I was having a severe allergic reaction. I refused to believe that diagnosis until allergy testing proved that was what was happening. By the time I got over all the damage this fine dust did, I lost 42% of my respiratory capacity and required full time supplemental oxygen.

Unlike most, my engineering background allowed me to do some serious testing then come up with my own far better fine dust separating cyclone design. The airflow testing showed my expensive magazine top rated cyclone moved less than half its advertized air volume and its actual flow was far less than my dust collector it replaced. It is no wonder that my ducts plugged constantly. Particle testing showed that this expensive top rated cyclone separated no better than a $25 trashcan separator lid. This of course meant all of the fine dust separation was left up to the filters. Digging into the engineering charts showed at typical dust loading and dust collection airflows my vendor used less than one quarter of the minimum filter surface area required. This clearly explained why my filter clogged constantly. Worse, this same vendor designed ducting was not even high school quality as the vendor misused a free computer ducting design program which used pipe so restrictive in size it killed the airflow needed to keep the vertical runs from plugging. The particle testing showed the expensive filter upgrade I purchased freely passed the invisible 10-micron and smaller invisible dust particles known to cause the most health damage. This inspired me to come up with a better solution. I designed a cyclone that moves more air with less power and provides more than five times better fine dust separation which is what we need to protect our fine filters that respiratory physicians recommend.

Since I did that work in early 2000, our small shop market continues to be dominated by the same high budget advertisers whose focus is to sell equipment not provide health protection. I oversaw the testing of every major brand and size of small shop cyclone during 2007 and 2008. None except my cyclone provides much better separation than the inexpensive trashcan separator lids. Most continue to advertize and sell fine filters that freely pass the fine invisible unhealthiest dust. And, the vendor dominated magazine testing continues to ignore cyclone separation and keeps focusing on maximum airflows rather than what kind of airflows we really get with ducting and tools hooked up and a filter that is no longer brand new. Finally, our small shop forums are filled with vendor paid shills and forum administrators who get paid to recommend the same poorly performing cyclone. Likewise, these same forums are filled with first time cyclone buyers that are still convinced that because they spent so much, they got a great product. Clearly, you should not believe most available cyclone testing and recommendations.

Since 1999 over ten thousand small shop users have built or purchased my cyclone design. First time cyclone user letters and emails greatly praise this design. More importantly, the hundreds who like me abandoned other cyclones in favor of my design, also provide very positive review praising airflow, separation efficiency and recommended filtering. These experienced cyclone users consistently reported their 3 hp and smaller cyclones moved too little air. Those with particle counters such as the inexpensive 0.5-micron meter sold by Dylos Products report that if they also upgrade tool ports and hoods as I recommend, my cyclone design keeps their shop air cleaner than found outside.

For instance, D.B. Hayes wrote, *"I use my large shop vacuum as my dust collector when turning batches of pens. Knowing I use many toxic woods I upgraded my vacuum with a good HEPA filter. Although this filter works great, when turning I have to constantly take the vacuum outside to clean that HEPA filter because it plugs very quickly. Tired of the filter cleaning disrupting my turning I bought an XXX brand cone type cyclone that sat before my vacuum. This substantial expensive cyclone separator simply moved the chips and sawdust to its collection bin with no noticeable improvement in keeping my fine filter clean. I searched the Internet woodworking forums for help. Many said they got very good results with your mini cyclone, so I bought a 6" diameter cyclone of your design. The results are incredible. Almost all the fine dust ends up in the cyclone bin and I can go at least five times longer between the HEPA filter cleanings. Thank you for sharing such an incredible design!"*

Similarly, J. Wang wrote, *"Like you I bought a 3 hp top magazine rated cyclone and it did not collect the fine dust as well as my 1.5 hp dust collector it replaced. Worse, I borrowed a friend's Dylos air quality meter and discovered that this cyclone came with such an open filter it saved up and filled my shop with the fine dust I wanted to avoid every time I turned on my cyclone. I built one of your cyclones and upgraded to the much finer filters you recommend. I also did lots of work to improve my tool hoods and ports. Now the air quality in my shop consistently tests better than the excellent air quality we have outside here on California's northern coast. Thank you so much for your sharing and hard work!"*

C. Cyclone Modifications

I spent considerable wasted time researching, changing, and testing my existing expensive cyclone to try and improve its airflow and separation efficiency. In addition to gathering up changes recommended by other woodworkers I also spent considerable time in the cyclone research literature. One of the best sources of information was the work done on the Cotton Site that shares research and testing of various cyclone designs. After gathering this information I then built, tested and in many cases improved the various modifications. The best improvement in airflow came from adding Jim Halbert's "neutral vane" which reduced horsepower needs by reducing the cyclone internal turbulence. When all was said and done I changed the cyclone dust chute outlet on the bottom of the cone, changed the cone angle, changed the cyclone diameter, changed the inlet size, changed to a rectangular inlet, changed the blower sizing and design, added a filter stack with lower cleanout, and changed the cyclone outlet tube to a more efficient size. Before these improvements roughly one full horsepower of a 1.5 horsepower cyclone blower went into nothing but turning the air inside the cyclone. All of the major small shop vendors today now use variations of my modified cyclone design that I shared and put on my Cyclone Modifications web pages. Thanks to these efforts these cyclones move more air with less horsepower, are easier to empty, and it is far easier to clean the cyclone filters. **Regardless, of these improvements the bottom line is separation efficiency on that basic cyclone design that all still use remains little better than a $25 plastic trashcan separator lid.** This poor separation creates serious filter problems. When used with fine filters these cyclones put out so much fine dust the filters clog very quickly. That clogging kills the airflow we need for good fine dust collection and quickly destroys our filters because the higher pressures force the fine sharp particles to cut and tear their way through the filters. Cleaning does the same thing but faster. This why I only recommend using these units without filters vented directly outside. It is also what inspired me to build a better separating cyclone.

D. Alternative Cyclone

With a choice of giving up on a forty plus year woodworking hobby, I chose to spend my recovery time putting my three engineering degrees to work. I needed a solution that reduced how much dust went into the filter. Wearing a mask was not good enough because the fine dust lingers for months and would continue to get tracked into my home, office, and vehicles. I needed to capture the fine dust as it was made then get rid of that dust. I found some excellent small commercial cyclones and dust collectors from Felder, AAF, Torit-Donaldson, Dust Vent, etc. All of the more affordable units required putting them outside. The ones setup for indoor use cost far more than my budget, plus required quarterly changing of many expensive cartridge filters. Most also used large commercial three phase motors that my home electrical service would not support. This pushed me into doing more research on basic separation theory and cyclone design. My research convinced me that a cyclone was the best solution, but none of the seven fairly well studied cyclone designs offered a combination of fine separation with minimal power usage.

I went back to the basic swirl tube separation physics and cyclone design theory to come up with my own cyclone separator design. It took me a couple of years to design then build, test, and refine my design into its current configuration. The following shares some of that process. Although this is probably not that interesting to most, knowing much of this information will make the difference between your having a shop that looks clean and a shop whose air protects your health and the health of those close to you. Rather than cover this information more than once, you can read it over on my Dust Collection Basics web pages.

E. Cyclone Design

Some university sites offer cyclone design optimization spreadsheets. To use one of these spreadsheets you need to know the airspeed and air volume we will be working with, the amount of material to be separated, and the sizing of this material. These cyclone spreadsheet calculators will then compute the overall resistance for each of the different cyclone types along with expected separation efficiency.

1. Airspeed

Airspeed measured in feet per minute (FPM) defines what size and weight of chip we can pickup. Because woodworking makes a range of chip sizes we normally pick the airspeed for the largest type of material we use. During normal woodworking we make fairly large chips all the way down to very fine dust particles that are so small they are invisible. Major blower makers that provide equipment to use air and ducting to transport different types of material provide charts that tell us how much airspeed and the minimum pressures needed to transport various types of material. For fine wood dust such as created when using fine sandpaper we only need about 50 FPM airspeed to overcome normal room air currents and move this dust. For typical sawdust we need to move the air at about 3800 FPM and for larger chips we need to move the air at about 4500 FPM. Ideally **we should move right at 4500 FPM airspeed for picking up the normal range of wood chips**. Many air engineers design instead at 4000 FPM because this airspeed is ample to pickup the material most fire marshals consider dangerous.

2. Air Volume

Air volume measured in cubic feet per minute (CFM) defines how big of an area we can collect over. Air speed and air volume are tightly related by the air formula where FPM = CFM/Area where area is in square feet. In short if we know what air speed we need and the size of the area we need to cover we can compute how many CFM we need. To just collect the same sawdust and chips we would otherwise sweep up with a broom, known as “chip collection”, most large stationary small shop tools can use existing hoods and tool ports and get good “chip collection” with about 350 CFM. Tool makers like Fein and Festool have shown us we can get excellent fine dust collection with a big shop vacuum. To do so our tools must be built from the ground up to totally contain the dust. Unfortunately, most large stationary tools found in small shops are older designs that only have good “chip collection” built in. Air engineers have spent decades figuring out how to fix our older tools to get good fine dust collection. To collect the fine dust on our typical older tool designs we must upgrade hoods, often provide larger dust collection ports, and provide a bubble of air around the working areas of the tools that pulls in the fine dust. Although that bubble only needs the air moving at 50 FPM and faster to overcome normal room air currents and pull in the fine dust, the size of this bubble is large. This large area is bad news because airspeed for sucked air drops at about the same rate as the surface area of a sphere expands so we end up needing to move lots more air for good fine dust collection than is required for “chip collection”. The airspeed falls at roughly four times Pi times the distance squared which is the surface area for a sphere. We already know the effect of this decrease in airspeed from using our shop vacuums. They only pick up right next to the end of a nozzle. Air engineers calculated the minimum airflows at each size and type of large stationary tool then refined these values over decades of experience. They provide CFM requirement tables for each size and type of tool. These tables show our larger stationary small shop tools need to move about 800 CFM to meet the OSHA air quality standards, about 900 CFM to meet the five times tougher ACGIH standards, and only about 1000 CFM to meet the fifty times tougher standards set by the EPA and medical experts.

3. Ducting Size

Ducting size is easily calculated once we know the FPM airspeed and CFM air volume requirements. A 4” diameter duct is near the ideal ducting size for our 350

CFM needed for good “chip collection”. A 5” diameter duct is just about perfect for carrying 550 CFM and a 6” diameter is near ideal for 800 CFM. We need a 7” for the ideal size to carry 1000 CFM. If we are willing to use an oversized impeller and a little stronger motor we can trade some loss in ducting efficiency to let us move more air in a smaller diameter duct. Knowing that 6” duct is readily available and inexpensive, I targeted my design to move a real 1000 CFM in a 6” diameter duct.

4. Static Pressure

Static Pressure is how much overhead we need our blower to overcome to work in our shop. Every length of duct, duct fitting, tool hood, tool port, and filter will add some resistance. This is a well studied area and we can use a good static calculator such as the one provided on my pages here to get a good working estimate of the lowest and highest potential resistance or static pressure in our system. That highest resistance is going to be our longest ducting run plus the highest resistance we expect from our filters.

5. Filter Resistance

Filter resistance will change considerably over the life of a filter. A clean brand new filter passes the most air and has the least resistance. As a filter gets dirty the resistance goes up. Over time filters “season” meaning they build up a cake of fine dust in the filter pores that does not come out with normal machine shaking type cleaning. A seasoned filter will often filter ten to twenty times better than a brand new filter, but it will have a much higher resistance.

6. Filter Monitoring

Filter monitoring is done with a pressure gauge and recording the filter resistance after every cleaning. This fine dust trapped in our filter pores is made up of small sharp particles that will cut and tear their way through the filter matrix. As the filter dirties the air pressure increases forcing these particles through faster speeding up this damage. Cleaning our filters forces these fine particles through the filter but even faster, so cleaning also quickly breaks down our filters. Filters that get too dirty quickly fail and so do filters that are cleaned too often, plus most small shop woodworkers tend to over clean our filters causing them to fail even faster. This is why most large commercial installations use a pressure gauge and record the air pressure after every cleaning. That pressure will steadily rise as the filter “seasons” then fall off as the filter breaks down. They must replace filters when the pressure drops too low because the filter is no longer working well.

7. Filter Rating

Filter rating> is done in a variety of ways, but ASHRAE writes the rules for rating indoor filters designed to protect our health. ASHRAE requires indoor filters to be rated when clean and new which is when they pass the most air and the most fine dust. Otherwise we would be using our lungs to filter the air in the sometimes up to two years it takes a small shop cyclone filter to fully season. Filter material makers also provide a filter rating that gives the expected level of filtering once the filter is fully seasoned, plus the resistance level for a fully seasoned filter. This resistance level is then used as part of the static calculations used to size the dust collection system.

8. Filter Sizing

Filter sizing is generally done based on recommendations from the filter makers based upon the fineness of the filter, the amount of airflow and amount of dust to be filtered. The medical experts recommend we filter wood dust to at least 0.5-microns unless we have a known allergy or other respiratory problem then we should filter to HEPA filtering level which is using filters individually certified to provide 99.97% efficiency in filtering off particles 0.3-microns and larger. The main filter makers say the 0.5-micron polyester cellulose blended filters need a minimum of one square foot of filtering area for every 2 CFM of air carrying this much fine dust. The thicker all spun bond material 0.5-micron filter material can get by with one square foot of filter area for every four CFM. If you read further the filter material makers further recommend using double the minimum filter area because that will reduce static pressure filter resistance four fold, extend filter life four fold, and reduce cleaning cycles four fold. Typical small shop dust collectors with bag type filters generally have less than 50 square feet of filter area when with their claimed 1000 CFM of airflow actually need about 250 square feet of these spun bond bag type filter area whether in a bag or cartridge. Most small shop cyclones claim 1000 CFM airflow and come with the poly cellulose blended cartridge filters that are typically under 250 square feet in area when they really need a minimum of at least 500 square feet of filter area.

9. Stock Filters

Stock filters supplied by most small shop vendors end up being a mess of confused advertising and performance numbers. Most small shop vendors advertise their filtering level not when clean and new as required by ASHRAE, but instead based on a fully seasoned filtering level which leaves our lungs doing the filtering for sometimes two years and more while the filter seasons. Most size their bag and cartridge filters based on clean and new air resistance which can be one tenth and less the actual working resistance of our filters when they fully season. This combination ends up with their providing far too small filters that quickly load up killing airflow and soon leaving us with filters that quickly fail and no longer provide us with good fine dust protection. Although this may make for more filter sales, it is not a very good way to care for their customers and invariably ends up using filters with far too much airflow robbing resistance.

10. Fan Tables

Fan Tables let us use our calculated high and low resistance levels in combination with our required airflow to choose a blower housing that is the right size, an impeller (fan) sized to meet our airflow needs, and the right size motor. Good fan tables also tell us the correct diameter for our blower opening which is also the same size we should use for our ducting main.

11. Cyclone Sizing

Cyclone Sizing is then done by then feeding in our CFM, FPM, dust loading, dust weight, resistance, etc. into one of the cyclone calculators. The good ones like the ESSCO cyclone calculator will show the sizing and estimate the efficiency of each of the major well known kinds of cyclones. We don't really need a fancy calculator because once we know our ducting size from our fan table we can multiply that by three to get the diameter of our cyclone. All the major cyclones then use this diameter dimension (D) to let us compute the sizes for all the other features of our cyclone. Feeding the ESSCO cyclone our values for an 800 CFM airflow and 4000 FPM airspeed, plus normal range of wood dust sizes shows we need a 13.5 inch diameter cyclone powered by a 7.5 hp motor turning a 16 inch diameter impeller.

12. Cyclone efficiency

Cyclone Efficiency is something that these calculators will predict, but almost all typical woodworking cyclones that we see outside almost every large woodworking facility provide a 99.9% separation efficiency on wood dust particles sized 30-microns and larger. A 30-micron particle is roughly one third the thickness of a coarse human hair. The woodworking industry considers particles sized under 30-microns to be airborne dust because when blown outside they will quickly dissipate with no trace. Virtually all woodworking cyclones provide exactly this same 30-micron separation and are designed to simply drop the heavier sawdust and chips into a collection bin while blowing the fine dust away outside. This is also almost exactly the same separation efficiency found in trash can separator lids, except the trashcan separators need huge trashcans at the much larger airflows needed for good fine dust collection. Cyclones can handle much larger air volumes in a smaller size.

Although this 30-micron separation may be ideal efficiency for a woodworking cyclone that blows the fine dust away outside, it is a very poor choice for running our air through fine filters. Roughly 15% of all wood dust by weight is made up of these 30-micron and smaller airborne dust particles. The problem is wood dust contains far too much of this fine airborne dust. This dust ends up quickly plugging our filters killing the needed airflow, requiring constant cleaning, and leaves greatly reduced filter lives.

So in conclusion we need a cyclone that minimizes air resistance and maximizes how much of the fine dust it separates. When I did my research there were no such cyclone designs available for woodworking and no other kinds of cyclones provided the needed airflow and separation efficiencies without using greatly oversized motors and blowers.

F. Cyclone Options

Applying what I learned to the available small shop and even most larger facility cyclones showed woodworking fine dust collection is a mess. Only a couple of the largest dust collection vendors that actually certify and regularly test their customer air quality after installing a dust collection system provide good fine dust collection.

Most instead provide cyclones that provide terrible separation, blowers that move far too little air, filters that filter so poorly the air should not be returned indoors, ducting that will not begin to move the airflows shown by decades of air engineering as the minimums needed for good fine dust collection, plus most don't even pay lip service to the key requirement of having to start with upgrading most tool hoods and ports. This really did not make sense at all until I got deeper into the literature and discovered that dust collection is a strongly contested war between a few well meaning medical experts versus our fourth largest group of employers in the country. These folks continue to spend big dollars to purchase the best studies that money can buy which prove woodworking makes no fine dust, the fine dust made by woodworking has no negative health effects, and the exposure levels are so tiny as to be of no importance. These interests delayed the OSHA air quality standard for woodworking for nearly thirty years and forced this standard to be fifty times easier than recommended by the medical experts. These same interests successfully challenged that easy OSHA standard before it even went fully into effect. In short, dust collection today for woodworking is almost entirely up to the customers to decide and then trust that the vendors will provide what they claim in their advertising. In small shop dust collection this situation is so dismal that the "best" magazine rated cyclone vendor puts out a cyclone that actually increases our airborne dust level in our shops to far higher than if we just worked with a fan running in an open doorway.

In summary small and large shop dust collection in the U.S. is a mess. My personal testing of every major brand and size of small shop dust collector and cyclone found only the 3 hp and larger dust collectors and the 5 hp and larger cyclones moved enough air to even meet the relatively easy OSHA air quality requirements. I found most small shop cyclones now use portions of my earlier design shared on my Cyclone Modifications web pages, but all continue make serious design compromises to make them easier to build, to use a much less expensive and powerful motor, and to force fit them under an eight foot tall ceiling. Not one of these units as of my testing done in 2006 provided a cyclone filter that when clean and new provided even 10-micron filtering. All small shop vendor dust collector and cyclone vendors advertised maximum airflows that were more than double the airflows these systems provided in real use. All small shop dust collector and cyclone filters ranged from five to twenty times too small for their claimed filtering level, and were even too small for their actual filtering levels. In short, small shop dust collection remains the same dismal mess it was when I got inspired in 1999 to come up with better solutions to help small shop workers better protect our health.

G. My Cyclone Solution

The problems with small shop cyclones were even worse in 1999 when the unit I installed to protect my health landed me in the hospital. These design problems helped me define what I wanted in a better cyclone. I still wanted a cyclone that protected the blower impeller and filter from material hits. I wanted a unit that still fit under a typical eight foot ceiling that is 96" high. I wanted this cyclone to provide much better fine dust separation to permit using smaller and more affordable fine filters. I also wanted to power this cyclone with an affordable motor that would run on normal household current.

Many of these design goals appeared mutually contradictory. Reducing the cyclone height to fit it under an eight foot tall ceiling forces use of a prohibitively large motor. Increasing the cyclone size enough to use a smaller motor kills separation efficiency and keeps us from fitting the unit under an eight foot tall ceiling. Using a shorter cone length causes the cone to plug when processing larger chips and to suck the fine dust right out of the dust bin and put it into our filters. The cone needs designed to reverse airflow direction so the natural air reversal point is just right to let the dust, chips and shavings fall while the cleaned air escapes upward. The cyclone research models all say the best fine dust separation occurs when the cone length is 3 times the upper cylinder diameter again creating a too tall cyclone. I tried modifying the traditional cyclone design that all still sell, but nothing ended up with much better fine dust separation without creating a cyclone that was either too tall or needed too big of a motor.

This pushed me back into the basic separation physics literature of which a cyclone is a special case of a "swirl tube". This information was not of that much help either because the traditional approach to getting better dust separation is to move the air faster. The faster the air moves the more particles that a cyclone will spin out of that airstream. Unfortunately, my calculations showed I needed a 12.5 hp motor to double the fine dust separation.

This moved my thinking to looking at other options to get better separation. Almost all cyclones start with an inlet that comes in straight from the side. This causes the air to spin and relies upon gravity to pull down and drop the dust. Minimizing the internal turbulence inside the cyclone lets the same airflow get rid of far more fine particles. Aiming that incoming airflow to push the dust down toward the dust bin further improves separation but creates a new set of problems. Since the bin and connection to the bottom of the cyclone is sealed, that downward moving spiral of air is going to reverse direction and head up and out the cyclone exit. I needed to get that inlet aimed just right to minimize turbulence and adjust the cone sizing so the airflow reversed direction in just the right place. The traditional cyclone designs had already shown that making the cone dust chute outlet the same size as the cyclone inlet and making that cone three times as long as the cyclone diameter created the best fine dust separation for a cyclone with a perpendicular inlet. For a tilted inlet I needed to calculate an ideal reversal point based upon my inlet angle and air speed. Unfortunately, the airspeed is not a constant but is near zero on the cyclone walls that are carrying the fine dust out and climbs close to the initial velocity from the inlet. It was not easy as too high causes the cyclone to plug when processing larger chips and too low sucks the fine dust right out of the bin. Each different design and airspeed needs a different cone length. I found for my optimized design the ideal reversal point occurs 1.64 times that upper cyclone outer cylinder diameter. This creates a cyclone that will move a real 1000 CFM and will just barely fit under an 8' ceiling with a small dust bin.

This design minimizes internal turbulence decreasing cyclone overall resistance from the roughly 3.5" typical of my modifications of the original 4.5" resistance cyclones down to only 2.25". This much cleaner airflow allows this cyclone to provide a five times better fine dust separation efficiency. This means we can use smaller filters which is good news because good fine filters are expensive. It also means we are going to get many times the filter life and go far longer between filter cleaning cycles. It also means that I can power this cyclone with a 5 hp motor and get better airflow and separation than other designs can get with far larger cyclones and motors. Moreover, when teamed up with an oversized impeller, this high efficiency allows using all 6" diameter ducting instead of needing to use 7" or in some cases even 8" ducts for good fine dust collection. The additional pressure generated by this larger impeller also minimizes our hood and port changes to our tools.

H. My Cyclone Sizing

Another very positive benefit of this design is it ends up being scalable. Innumerable people have built and purchased little 6" diameter cyclones to use with their 2.5" heavy duty shop vacuums. The medical school testing on these smaller units ends up being just as impressive than the separation on the larger units. These small 6" versions provide 99.9% separation efficiency on particles sized under 5-microns versus the closest competitor providing only 99.9% separation on 25-micron and larger particles. The real proof is in the results that woodworkers get with these in real use. Even shops that make multiple 55-gallon drums of MDF dust daily find they can go six months and still see almost no fine dust in their filters. The same is also true in terms of scaling this design to much larger. I designed one of these for a huge cement processing facility and they went from having to replace filters monthly to every five to six months, plus were able to use a much smaller horsepower motor. The owner of that facility said his cost savings in energy and filters pays him back more than he spent to build this unit every three months. I've heard similar reports from a plastics maker, a coffee bean roasting firm, and innumerable woodworkers. Many have even built these units with oversized cyclones to permit them to use smaller motors. Although I don't particularly like this idea because too much fine dust is not captured if the blower does not move enough air and separation efficiency goes way down, many successfully power my cyclone design with 1.5 hp motors. Instead of building my recommended 18" diameter cyclone, those with 3 hp motors should make 20" diameter cyclones and those with 2 and even 1.5 hp motors should use 22" diameter cyclones. Often these bigger diameters end up requiring mounting the blower to the side as the result would be too tall with a top mounted blower, but regardless they still work very well. If you need a more powerful than 5 hp cyclone, have medical problems, or need to collect from more than one machine at a time, I recommend you seek professional engineering advice.

I. Cyclone Materials

You might want to carefully consider your cyclone materials. We need to use a material that will wear well. Most commercial wood working cyclones tend to fail from wet abrasive dust causing rust out and wearing a hole on the inside of the cyclone where the dust and air first hits. Apparently the wood hits hard enough to lose some moisture and generate heat. This creates a fast corrosion process aided by the sand blasting from the high silica content in sawdust and other materials sucked in. Most industrial cyclones are made from coated heavy steel to keep the cost down. Because our small shop cyclones are generally much smaller we can make the whole unit of stainless steel, one of the new very tough plastics as the Clear Vue Cyclones used to use, or coat the contact area inside your cyclone. It costs more than double to build one of these cyclones in a tough plastic like Clear Vue Cyclone used and about $40 more to build from stainless steel. To work plastic or weld stainless, you do need specials tools, so most end up building from galvanized steel. If you make your cyclone from steel or stainless steel then you should use a replaceable rubber blast plate that sits right where the air first hits inside the cyclone to minimize the sandblasting wear. My cyclone has a rubber sheet (from some old cupboard liner) glued on with polyester caulk where the material hits to provide a little extra protection.

Alf Toy does some work with making signs and suggests using the tough and long lasting sandblast resist sheets he uses in sign making to protect the inside wear spot on our cyclones. He says, "We use this resist to mask off areas on sandblasted cedar signs and the same material is used with the even heavier sandblasting used to make granite gravestone markers. This tough adhesive backed rubberized material is easy to apply, holds up well and sticks tight enough that the high pressure air from a sandblaster does not pull it loose. Just about any opening or having that material come loose can quickly ruin a job allowing the sand to etch granite sometimes up to a 1/4 inch deep. The adhesive on the resist is the same as used on the vinyl material that sign makers use to make decals for automobile lettering which can last for 7 or more years. You should go to a gravestone store and ask for a foot square piece of resist or whatever size you need. Shouldn't be more than $10 or free if they have scraps."

J. Blower Sourcing

Many just buy a small shop dust collector blower and use it to power their cyclone, but this is actually a very poor idea. We size our blower to work against the expected pressure range. For our small shop cyclones this is typically from a low of about 4" of static pressure to a high of about 12". In short, the best way thing is to first start by sizing our blower then go looking for what makes the most sense. For a cyclone what makes the most sense is an oversized blower housing and impeller attached to a good motor.

1. Fans

I get a few people every week who want to power a cyclone with a typical air movement fan in the form of a big squirrel caged impeller, an inline duct fan, or a some kind of bladed fan. HVAC fans, evaporative water cooler fans and all different kinds of other bladed fans can easily move the 1000 CFM I recommend. Unfortunately, they also need to move this much air at a real 4" to 12" of pressure to do any good with a cyclone. I engineered a special airfoil impeller that will provide up to about 8" of pressure which is just about the minimum for a one car garage sized shop. Although these airfoils and other caged impellers are far more efficient, they are just plain not safe to use with woodworking dust. Woodworking makes long stringy curls and shavings that can get caught on any of the impellers that are not self cleaning. Material handling blowers are built to be self cleaning and are the correct type of impeller for us to use. Likewise, with these being one of the less efficient impellers we need a big enough motor and large enough impeller to drive the air at the pressures we want. My testing showed nothing less than a 14" diameter impeller will really move enough air. Over the normal pressure range in our shops the motor turning this sized impeller will pull as much as 3.5 hp. With motors coming in 1, 1.5, 2, 3 and 5 hp, I strongly recommend getting a good quality 5 hp motor. Although we can get 3 hp motors that have an extended service factor allowing them to produce 3.45 hp, it seems stupid to me to buy a motor that is straining for our most heavily used motor in our shop. In short I recommend a real 5 hp motor which lets us turn a real 15" diameter material handling wheel with the backward curved (BC) blades needed to minimize noise.

2. Dust Collectors

It seems only reasonable that the dust collector makers would sell just their motor blower units and maybe even sell a blower motor combination that was ideal for our cyclone sizing. Most say they sell blowers separately, but only a few do, and those charge as much if not more than buying a whole dust collector. Jet, Wilke Machinery, PSI, RBI and Laguna Tools all sell motor blowers without having to buy a whole dust collector, but prices are high and the impellers are too small until you get into their larger units which come with more motor than most need. The 3 hp dust collectors with a 14" impeller provides a 1900 maximum CFM and these are the best compromise I could find. Unable to find what I wanted, I worked with a few vendors to provide the right sized blower wheels and motors to work best with my cyclone design. More detail is on my Cyclone Building page.

In addition to not offering very efficient blowers, you need to know most hobbyist blower vendors advertise extremes, not practical working efficiencies for motor horsepower and cubic feet per minute (CFM) output.

Most dust collector and cyclone makers use what are known as compressor duty motors. Sadly, many of our small shop vendors rate their compressor motors like their shop vacuum motors based on how much they pull during startup. A typical small shop 5 hp compressor motor is really a 3 hp motor when running but is designed to start a heavy load so will have a heavy duty starting circuit typical of a 5 hp motor. We need this heavy starting circuit to handle the high load while starting up our heavy impeller wheels. I gave up on the traditional small shop motor suppliers after having too many motors burn out and shifted recommending the Leeson American made real 5 hp compressor motors that can handle the heavy startup current and then run with a full 5 hp of capacity.

CFM is a similar case of what you see advertised by the small shop vendors is not what you are going to get. Current truth in advertising allows anyone to claim whatever they can show if even for only an instant. With clever inlets and no filters or cyclones, small shop vendors have figured out a way to rate their blowers at just about double what they can do for real in a working environment.

The reality is something very simple that sadly many small shop vendors don't understand themselves. **Performance for small shop blowers almost always comes down to one simple thing, the diameter of the impeller.** The reasons for this are:

1. Most dust collector motors turn at 3450 RPM;
2. Most have to use simple material movement impellers that are built like tanks to handle material hits from pieces of wood. Whenever our cyclone dust bins get full, all goes right through the impeller, so don’t get sucked into buying an aluminum impeller that can explode when hit with a wood knot;
3. Most use material movement impellers with backward curved blades because these provide the most efficiency with the least noise;
4. Experiments show that changing blade height over about one third the diameter of the impeller has little impact on impeller efficiency because each blade shadows following blades;
5. Experiments further show that blade length which establishes the diameter of the impeller is almost totally responsible for establishing impeller efficiency; so,
6. These facts let you make an informed decision on what a blower can really produce instead of having to rely on totally useless sales claim information. With all virtually identical in performance, you can look at a good ACMA certified fan curve table for an industrial blower with the same size impeller running at 3450 RPM. That table will instantly let you know not only the expected CFM at different resistances, but also the needed horsepower to drive an impeller at that load, and even the size of the inlet needed by that impeller. If the sales claims don't match, please don't be surprised as many of today's hobbyist blowers appear to look pretty but their designs are so bad that almost any hobbyist with just a few minutes time can build a far better performer using the same impeller.

Dust collector makers have to protect their motors from burning up when allowed to run wide open with no airflow restrictions. PSI, Grizzly, and Delta are known to build in restriction into some of their dust collector inlets to prevent this problem, but others put a caution in very fine print that says the warranty is void if the unit is used with no ducting or oversized ducting. Strangely, air at typical dust collection volumes and pressures is more like water. It will barely compress at all, so even a little restrictive opening can kill airflow. Using a small blower inlet may save the dust collector motors, but kills the airflow we need to power our cyclones and still collect the fine dust. Most other vendors more appropriately limit maximum airflow by choosing smaller diameter impellers. In either case, if you put the overhead of ducting, filter, and cyclone on top of the manufacturer limiting airflow, you are going to be lucky to get one third of the dust maker's maximum CFM rating at your machine. Just like a water hose size limiting how much water can flow, the size of your ducting is critical to airflow. Standard hobbyist 4" ducting and hose supports the up to 350 CFM we need to get the same dust we get with a broom, but for the 800 to 1000 CFM needed to capture the finest most dangerous dust we need either a huge blower or all 6" or larger ducting and flex hose.

Things just get worse when you add a separator. A cyclone can add between 2.25" and 7" of resistance and a garbage can separator can add 4.5” of resistance. It takes at least 3/4 more horsepower and about 1.5" of extra impeller wheel size to overcome that resistance. This means the smallest viable cyclone that is moved from machine to machine with no ducting needs to be a 3.5 horsepower motor turning a 14" impeller. Our induction motors normally only come in 3 or 5 horsepower sizes and 3 hp is too small. This is why I consistently recommend using a 5 hp. That extra horsepower lets us turn a 15" diameter impeller which means we move more air and that makes our system more effective. Adding almost any ducting or even a dirty filter leaves a smaller unit badly air starved. Air starved means the impeller and motor are loafing unable to get the air they need to work at full efficiency. In terms of dollars and sense it is faster, easier and less costly to buy the right impeller and motor for your cyclone plus either build or buy a good blower housing. Most find they really need a full 5 hp motor turning a 15" impeller to power a cyclone and take care of a typical two car garage sized shop and get really good fine dust collection.

3. Build a Blower:

Building a blower is not too difficult and actually costs less than buying a far less powerful dust collector or commercial blower. You still do want to take the time and care to make one that will hold up and be safe to operate. The two keys are making it solid enough and ensuring your motor does not overheat from trying to push too much air. I've built many blowers for myself and other woodworkers, plus have had lots of help from people who visited this site and offered suggestions. One of the easiest to make uses a couple of pieces of plywood or MDF as a sandwich that holds a metal spiral. By using thin insulation in grooves on your MDF and long bolts on the outside of that metal, you end up with a very solid blower housing that is easy to make, easy to take apart, very safe, and relatively quiet because the wood dampens the sound. For detailed step-by-step instructions for making your own blower you can go to my Building a Blower (click here) page with pictures (takes a while to load for slow connections).

4. Motor & Impeller Sources:

After enough requests, I got serious about finding an impeller maker willing to supply top quality direct drive impellers that we can use to more optimally power our cyclones. I tried a number of firms with varying degrees of success. The aluminum impellers I got from the top blower maker in the U.S. had problems sliding down shafts and breaking when hit with stuff. The first couple of impeller makers I tried did not exercise good care in making their impellers, plus their preparation for shipping was dismal. Too many impellers arrived out of balance and with shipping damage. I share various suppliers for motors, impellers, and filters. Electric Motor Warehouse also provides these same motors at excellent prices. My cousin and I did considerable testing and settled on recommending a 15" diameter impeller driven by a 5 hp Leeson motor for one and two car garage sized shops and a 16" impeller for the larger shops that only use one tool at a time.

K. Construction

I've received so many questions on every detail of how to build the cyclone that I finally gave in and put up a detailed set of Cyclone Building Instructions - click here.

L. Construction Alternatives

A local sheet metal firm agreed to build the cyclone body in 24 gauge galvanized steel for $78, plus the cost of the steel. I had to make my own inlet so ended up spending about $150. Another sheet metal firm agreed to build the whole unit in welded 22-gauge stainless for $230. A local welding shop quoted $320 for all welded seams in 18-gauge stainless steel. I hired a professional metal engineering firm to cut out kits using my design. My son sold those kits for a few years until he left to attend school out of state in 2003. I do not have the health to run another business, so turned that kit business over. That firm and its successor both talked a good story, but their work was sloppy and caused so many problems I finally closed down those efforts in early 2004. I do not have or sell anything. My son does offer cyclone and blower kits along with impellers.

Too many keep requesting me to help them build a unit. Physically my health makes that impossible.

M. Cyclone Cutting Layout

My plan is in the form of a scalable Microsoft Excel spreadsheet that redraws and re-dimensions the plan except for cone angle and adapter to go from the ducting to the cyclone air inlet. You get to choose the cone multiplier to create an overall height that will fit under your ceiling. With typical 6" ducting I recommend making an 18" diameter cyclone with a 1.64 cone length. Depending upon how powerful your blower, you can tweak the diameter downward or upward. Alternatively, if you have a low horsepower motor and smaller impeller, you can save lots of resistance by going to a 20" or 22" cyclone. I really do not recommend using anything smaller than a 3 hp motor, but many do and are pleased with their cyclone performance. The tradeoff is they get much less good fine dust protection so must depend more on their respirator masks for protection and must regularly clean out their shops to keep from building up large amounts of the unhealthiest fine invisible dust. I used to provide pictures of a few of the plan iterations, but those with slow connections said it made using this site to get information painfully slow to load, so I've removed those pictures. I also used to post a complete cutting diagram on this page along with a DFX CAD file. That picture got so big that I had to compress it to the point you could not read it. Even then, it makes loading this page very slow for those without faster connections. The CAD drawing frankly upset me considerably because I found people all over the world making and selling my cyclone design without permission. All are welcome to make and use this design for their own use, but making these for sale is not something allowed. I now only keep these pictures as excel cyclone sizing spreadsheet files that you can download.

Most current Cyclone Sizing Spread sheet thanks to A. Cortida with integrated Imperial and Metric versions: Click here if you have MS Excel setup to work with MS Internet Explorer and want to download the latest version with a dimensioned picture. This automated spreadsheet design will work from 2.25" vacuum hoses to a 10 hp motor. It will also calculate much larger cyclones but you need to contact me to get help setting it up to do so.

If you want the spreadsheet to calculate the cyclone sizing to your duct size, then clear the "Fixed Cyclone Diameter - D Fixed" cell. I do make changes as suggestions come my way, often repairing the spreadsheet before updating the site, so make sure you do the download before getting ready to build to ensure you have the most current version.

The below spreadsheet images are provided for those who want to look at the plans and do not have a current copy of Microsoft Excel. Please use the spreadsheet for the most current plans.

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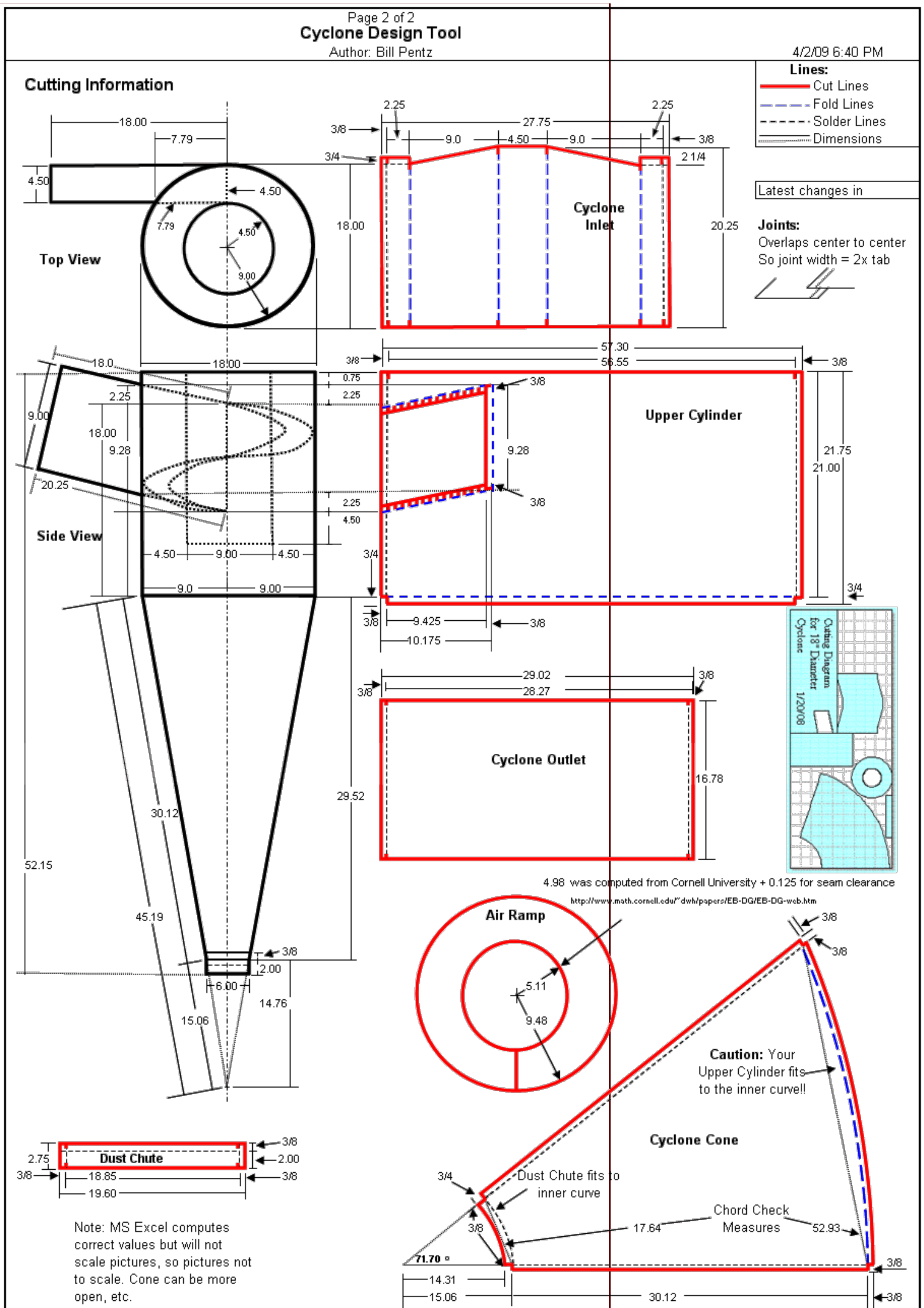
Cyclone Design Tool

Imperial Version

Author: Bill Pentz

Site always in progress, so be patient and check back often..

Version **09/01/07**	Bill's Site: http://billpentz.com/woodworking/cyclone/CyclonePlan.cfm			
	Last updated by B Pentz 4/2/09 6:40 PM	Enter only values in blue	Today's Date & Time: 4/2/2009 18:33	
		Improved the Ciclone Cone Botton diameter calculation based on the hose size		
mm/inch 25.4 **Pi (π)** 3.1415927	Ducting Size (≥ 6") (Used to Size Cyclone Only) **DS** 6	Impeller Type 0 if Regular or 1 if Airfoil **IT** 0	Motor Size in HP » 1.5 ≤ motor ≤ 5 (Zero if used with vaccum cleaner) **MS** 5.0	Wood Lid Thickness In Top of Cyclone **WT** 0.75
AirRamp **0=no 1=yes** **SAR** 1	For **Fixed Cyclone Diameter** Enter Width or Leave 0 for Auto **D Fixed** 0.0	For Fixed Inlet - Enter Width or Leave Zero for Auto **IW Fixed** 0.00	For Fixed Inlet - Enter Height or Leave Zero for Auto **IH Fixed** 0.00	Cone Length Ratio 3 - normal (1.64 for short) **CLK** 1.64
Tab Overlap **TW** 0.750	Calculated Minimal Inlet Width **CIW=(ICA/2)^½** 3.75	Calculated Minimal Inlet Height **CIH=IW*2** 7.50	Inlet Circle Area Rounded **ICA=pi*(DS/2)^2** 28.27	**Inlet Intercept** **IY=-IW** **IX=((D/2)^2-IY^2)^0.5** 7.794
				IL=(IW^2+IX^2)^0.5 9.000
Inlet	Inlet Width **IW=D/4** 4.50	Inlet Height **IH=IW*2** 9.00		**IS=(CR^2-(IL/2)^2)^0.5** 7.794
				IA=ATAN((IL/2)/IS) 9.425
Cyclone Size	Cyclone Cone Length **CL=CLK*D** 29.52	Total Cyclone Height (Including Wood Top) **CH=CL+H+DCH-TW/2** 52.15		**ID=(SARO^2+IH^2)^0.5** 9.277
Cyclone Upper Cylinder	Cyclone Diameter **D** 18	Cyclone Radius **CR=D/2** 9.00	Cyclone Upper Cylinder Height **H=WT+SARO+D** 21.00	Cyclone Upper Cylinder Circumference **C=D*pi** 56.549
Cyclone Outlet	Cyclone Outlet Dia **OD=D-2*DW** 9.00	Cyclone Outlet Radius **OR=OD/2** 4.50	Cyclone Outlet Height **OH=WT+SARO*2+ID+D/8** 16.78	Cyclone Outlet Circumference **OW=pi*OD** 28.274
Air Ramp	Air Ramp Helix Offset (from the top) **SARO=IH/4** 2.25		Air Ramp Annular Ring Inner Radius **ARI=1/((4*pi^2)*OR)/*(ID^2+(2*PI*OR)^2))+SC** 5.11	Air Ramp Annular Ring Outer Radius **ARO=ARI+D/4-SC** 9.484
			seam clearance (SC) =	1/8
Cyclone Cone	Cyclone Cone Bot Diameter **CCBD=hose Ø closest to (D/3)** 6.00	Cyclone Cone Bottom Radius **CBR=(CCBR^2+CCBH^2)^0.5** 15.06	Cyclone Cone Top Diameter **CTD=D** 18.00	Cyclone Cone Full Arc Length **CAL=(CCTH^2+CTR^2)^0.5** 45.185
	Cyclone Cone Bottom Radius **CCBR=CCBD/2** 3.00	Cyclone Arc Bot Length Degrees **CBL=CCBC/(PI*CBR*2)*360** 71.70	Cyclone Cone Top Radius **CTR=CTD/2** 9.00	Cyclone Arc Top Length Degrees **CTL=CCTC/(pi*CTR*2)*360** 71.705
	Cyclone Cone Circumference **CCBC=CCDB*pi** 18.85	Cyclone Cone Bot X Coordinate **CBX=cos(CBL/360*2*pi*CBR** 4.73	Cyclone Cone TCircumference **CCTC=CTD*pi** 56.55	Cyclone Cone Top X Coordinate **CTX=cos(CTL/360*2*pi)*CTR** 14.184
	Cyclone Cone Slope **CCS=(CT-CCBR)/CL** 0.20	Cyclone Cone Bot Y Coordinate **CBY=sin(CBL/360*2*pi)*CBR** 14.30	Cyclone Cone Top Slope **CCTS=(CTR/CCBR)/CL** 0.20	Cyclone Cone Top Y Coordinate **CTY=sin(CTL/360*2*pi)*CTR** 42.901
	Cyclone Cone Bottom Height **CCBH=CCBR/CCS** 14.76	Cyclone Chord Bottom Length **CSBL=((CBR-CBX)^2+(CBY)^2)^0.5** 17.64	Cyclone Cone Top Height **CCTH=(CTR-CCBR)/CCTS** 29.52	Cyclone Chord Top Length **CSTL=((CTR-CTX)^2+(CTY^2))^0.5** 52.930
Cyclone Dust Chute	Dust Chute Diameter **DCD=hose Ø closest to (D/3)** 6.00	Dust Chute Circumference **DCC=PI*D/3** 18.85	Dust Chute Width **DCW=DCC+TW** 19.60	Dust Chute Height **DCH** 2.000



N. Cyclone Orientation

We can build our cyclones from these plans with the inlet on either the left or right, but **you should build your cyclone for the best match with your impeller**. The direction the air turns inside the cyclone is set by the inlet. For motors smaller than 2 hp turning a smaller impeller you can put the inlet on either side because my testing only showed about 0.1 amp difference with no measurable airflow difference. When I upgraded from the smaller blower to the larger 5 hp with a larger impeller I was stunned at the difference. The bigger impellers with larger motors generate a really fast moving spiral of air that needs to be turning in the same direction as the impeller, or the impeller has to overcome that direction of spin. **This quickly spinning air when it hits the blower can cost up to 1 hp of overall performance if it is not turning in the same direction that the impeller is rotating.** With a big impeller, I found the blower moved as much as a 33% more total airflow if the impeller turned in the same direction as the air coming into the blower. You need to specify if you have a left or right handed cyclone to make sure you get optimum performance. A left handed cyclone is one where when facing the cyclone as it hangs we see the inlet pointing toward us on the left side. The cutout is the same for either orientation, we just change which side is up when we roll the metal or plastic to put the inlet on side we want. You must match the blower, impeller and motor to turn air in the direction if you want the best performance for your cyclone.

Disclaimer

The drawings, procedures and words shared on these pages are for information only. Your actions are your responsibility - **VERIFY and CHECK** information out before proceeding, and don't attempt anything without the required skills. Although I've taken every care to ensure what I have done and presented is safe, dust collection equipment uses electrical components and blowers that when improperly built, used, or maintained **may cause serious injury or even death**, so **USE THIS INFORMATION AT YOUR OWN RISK!** At the same time, unless you as a woodworker provide appropriate protections for the fine wood dust you make, you put your health, the health of those close to you, and even the health of your pets at risk. Long term exposure to fine wood dust eventually harms most woodworkers. Please take the time to protect yourself and those close to you. **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. Neither I (Bill Pentz) nor any other references or links on these pages will accept any liability for any damages or injury caused to people or property from the using of this information or from any associated links. No claims are expressed or implied as to the safety, usefulness, or accuracy of this information.

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