Design and Building Cost Analysis of a Powder Coating Ventilation System for the San Luis Obispo High School Welding Shop

By

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2013
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<table>
<thead>
<tr>
<th>TITLE</th>
<th>Design and Building Cost Analysis of a Powder Coating Ventilation System for the San Luis Obispo High School Welding Shop</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUTHOR</td>
<td>Miles Rutherford</td>
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<tr>
<td>DATE SUBMITTED</td>
<td>May 17\textsuperscript{th}, 2013</td>
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</tbody>
</table>

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Dr. Gary Weisenberger

Project Advisor

Signature

Date

Dr. Kenneth Solomon

Department Head

Signature

Date
ACKNOWLEDGEMENTS

First, I would like to express my appreciation of Mr. Tim Fay. Without his help and patience, I would not have accomplished this design. Mr. Fay was very helpful with ideas and the measurements and specifications of the shop area. I also appreciate his time; he made it very convenient to visit his shop when needed.

I also owe my gratitude to my advisor, Gary Weisenberger. I appreciate his donation of the fan, which helped save a considerable amount in expenses. Through his experience and knowledge, he was also able to provide guidance in the scope of the project.

I would also like to thank the BioResource and Agricultural Engineering Department for providing the computers and software necessary for this project. I spent many hours in the quiet and helpful environment of the BRAE lounge, where I was able to use AutoCAD and various other programs to design and complete my project.
This senior project includes the design and cost of a possible ventilation system for the powder coating operations of the San Luis Obispo High School welding shop. The aim of this project was to see if a suitable ventilation system could be built in the allocated shop area for the welding team at a reasonable expense of roughly $500. The available shop area was surveyed and a design was created for the site. A cost analysis was then conducted for the design to see if it would indeed be less expensive than purchasing a pre-manufactured system. The results indicate that the design would slightly exceed the budget. The total estimated cost for this design would be about $526.80, whereas a pre-manufactured system would cost approximately $2,000-$2,500.
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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIGNATURE PAGE</td>
<td>ii</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>iii</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>iv</td>
</tr>
<tr>
<td>DISCLAIMER STATEMENT</td>
<td>v</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td>vi</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>viii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>x</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>LITERATURE REVIEW</td>
<td>2</td>
</tr>
<tr>
<td>What is Powder Coating?</td>
<td>2</td>
</tr>
<tr>
<td>Why Powder Coat?</td>
<td>3</td>
</tr>
<tr>
<td>Ventilation System</td>
<td>3</td>
</tr>
<tr>
<td>Pre-Manufactured Booths</td>
<td>7</td>
</tr>
<tr>
<td>PROCEDURES AND METHODS</td>
<td>9</td>
</tr>
<tr>
<td>Shop Floor Area Survey</td>
<td>9</td>
</tr>
<tr>
<td>Research</td>
<td>9</td>
</tr>
<tr>
<td>Design Structures</td>
<td>9</td>
</tr>
<tr>
<td>Analysis</td>
<td>10</td>
</tr>
<tr>
<td>RESULTS</td>
<td>11</td>
</tr>
<tr>
<td>Main Priorities</td>
<td>11</td>
</tr>
<tr>
<td>Filter and Related Sections</td>
<td>11</td>
</tr>
<tr>
<td>Fan, Ducting, and Vent</td>
<td>12</td>
</tr>
<tr>
<td>Costs and Bill of Materials</td>
<td>12</td>
</tr>
<tr>
<td>DISCUSSION</td>
<td>14</td>
</tr>
<tr>
<td>Costs and Comparison</td>
<td>17</td>
</tr>
<tr>
<td>RECOMMENDATIONS</td>
<td>19</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>20</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1</td>
<td>A Tribo Charging Gun</td>
<td>2</td>
</tr>
<tr>
<td>Figure 2</td>
<td>Inside a Tribo Charging Gun Barrel</td>
<td>3</td>
</tr>
<tr>
<td>Figure 3</td>
<td>A Booth with a Rear Ventilation System</td>
<td>4</td>
</tr>
<tr>
<td>Figure 4</td>
<td>A Pair of Pocket Filters</td>
<td>5</td>
</tr>
<tr>
<td>Figure 5</td>
<td>The Selected Pocket Filter</td>
<td>5</td>
</tr>
<tr>
<td>Figure 6</td>
<td>Frame Assembly Example</td>
<td>6</td>
</tr>
<tr>
<td>Figure 7</td>
<td>Air Duct Piping</td>
<td>7</td>
</tr>
<tr>
<td>Figure 8</td>
<td>Funnel Pan</td>
<td>7</td>
</tr>
<tr>
<td>Figure 9</td>
<td>Small HCP Benchtop Booth</td>
<td>8</td>
</tr>
<tr>
<td>Figure 10</td>
<td>Large HCP Benchtop Booth</td>
<td>8</td>
</tr>
<tr>
<td>Figure 11</td>
<td>Layout of Available Shop Floor Space</td>
<td>9</td>
</tr>
<tr>
<td>Figure 12</td>
<td>3D Completed Isometric View</td>
<td>11</td>
</tr>
<tr>
<td>Figure 13</td>
<td>Filter Housing Hinges</td>
<td>12</td>
</tr>
<tr>
<td>Figure 14</td>
<td>Douglass Fir and Pine Parts</td>
<td>14</td>
</tr>
<tr>
<td>Figure 15</td>
<td>Chosen Filters</td>
<td>15</td>
</tr>
<tr>
<td>Figure 16</td>
<td>Filter Housing Cutting Dimensions</td>
<td>16</td>
</tr>
<tr>
<td>Figure 17</td>
<td>System with Fan Barrier</td>
<td>16</td>
</tr>
<tr>
<td>Figure 18</td>
<td>Ducting and Window Replacement</td>
<td>17</td>
</tr>
<tr>
<td>Figure 19</td>
<td>Smaller Booth</td>
<td>18</td>
</tr>
<tr>
<td>Figure 20</td>
<td>Larger Booth</td>
<td>18</td>
</tr>
<tr>
<td>Figure 21</td>
<td>Shop Floor Space</td>
<td>29</td>
</tr>
<tr>
<td>Figure 22</td>
<td>Preliminary Drawings</td>
<td>29</td>
</tr>
<tr>
<td>Figure 23</td>
<td>Preliminary Filter Housing Drawing</td>
<td>30</td>
</tr>
<tr>
<td>Figure 24</td>
<td>Filter Housing Base Cuts</td>
<td>30</td>
</tr>
<tr>
<td>Figure 25</td>
<td>Filter Box and Housing Frames</td>
<td>31</td>
</tr>
<tr>
<td>Figure 26</td>
<td>Filter Box and Attached Housing Frames</td>
<td>31</td>
</tr>
</tbody>
</table>
FIGURE 27: FILTER BOX DIMENSIONS .......................................................... 32
FIGURE 28: BARRIER DIMENSIONS ........................................................... 33
FIGURE 29: DUCTING MATERIALS LINEUP ................................................. 33
FIGURE 30: DUCTING VIEWS .................................................................... 34
FIGURE 31: DUCTING ISOMETRIC VIEW .................................................. 34
FIGURE 32: COMPLETE DESIGN ISOMETRIC .......................................... 35
FIGURE 33: COMPLETE DESIGN ISOMETRIC-RIGHT ................................ 36
FIGURE 34: COMPLETED DESIGN ISOMETRIC-REAR .............................. 37
FIGURE 35: HINGES .................................................................................. 39
FIGURE 36: LATCHES, STAPLES, DUCTING ............................................ 39
FIGURE 37: LUMBER AND NAILS ............................................................ 40
FIGURE 38: TRANSITIONS AND DUCTING ............................................. 41
LIST OF TABLES

<table>
<thead>
<tr>
<th>TABLE</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>TABLE 1. BILL OF MATERIALS</td>
<td>13</td>
</tr>
<tr>
<td>TABLE 2: LIST OF MATERIALS</td>
<td>26</td>
</tr>
<tr>
<td>TABLE 3: BILL OF MATERIALS</td>
<td>27</td>
</tr>
</tbody>
</table>
INTRODUCTION

Powder Coating is a process that involves spraying a thermoplastic or polymer powder onto a metallic surface and then curing that item in an oven to produce a strong smooth coating on the surface. Unlike paint, the powder is applied electrostatically. This means that a charged powder is sprayed onto an inversely charged metallic object so that the powder sticks to the metal much like clothing might stick together in a dryer. The powder-covered metal is heated in an oven to allow the powder to liquidize and flow together creating a smooth covering over the surface. The use of powder coating is common among fabrication shops and a very common application of powder coating is on items such as appliances and bicycles.

The San Luis Obispo High School welding and fabrication shop has recently come into ownership of a powder coater and various powder coating accessories. The students have since been learning to powder coat some of their projects. The students must, however, setup and use the powder coating equipment outside a set of rollup doors located at the back of the shop. This outdoor area is also used for grinding and various other operations that may pose a hazard during simultaneous use of the powder coater due to sparks. The outdoor area is also located along a road and parking spaces, and with the addition of wind may result in powder getting onto nearby vehicles. With these conditions, a booth is needed to contain the powder coating operations as well as designate a safe and adequate space for the students to use the equipment.

A mostly unused area of the shop floor has been agreed upon as the location of where the powder-coating booth is to be installed. This area is limited in space, however; and this lack of space will need to be taken into account when designing the layout of the ventilation system for the booth as this area will need to be used efficiently. The ventilation duct will also need to be mounted and run through a window that is approximately seven feet above the ground in the area designated for the proposed booth; this will also need to be kept in mind when designing the ventilation system.

The main concern for the project, however, is the cost of the system. The high school welding team has a limited budget, so the main goal is to design a ventilation system that is inexpensive as compared to a premanufactured system. A cost analysis will be conducted to compare the cost of building a powder coating ventilation/filtration system rather than purchasing one from a manufacturer.
LITERATURE REVIEW

What is Powder Coating?

Powder Coating is an effective technique for applying a protective coat when it comes to the strength of the bond between the surface and the protective coat. Powder Coating is a process of easily applying a uniform covering of powder onto a surface. The applied powder is very small, usually between 10 and 125 microns (Dow, 2007), which allows it to fill pores and thoroughly coat the work piece. This powder-covered work piece is then heated in an oven. The heating causes the powder to liquidize and flow, allowing it to bond together and flow uniformly about the surface of the object.

Process of charging and applying. Paint applications utilize mechanical attraction or adhesion to hold the liquid to the surface. However, in the application of powder coating there is not mechanical attraction, but rather electrostatic attraction (Liberto, 2010). Through electrostatically charging the particles of powder, the powder clings to the surface of the object to which it is applied just as clothes may stick together in the dryer. There are two main processes of charging the powder: Corona and Tribo charging.

The Corona and Tribo charging processes are pretty similar; the significant difference being the way in which the particles are charged. Corona charging is achieved by producing an electric field between the applicator nozzle and the work piece. For this type of charging there is an electrode at the end of the spray nozzle that creates an electric field in the air between the electrode and the work piece. When the powder enters the charged air it picks up the charge and finds its way to the work piece to discharge and adhere to the piece (Mayr, 2006). Figure 1 provides a visual for better understanding of the corona charging process.

Figure 1: A Tribo Charging Gun
Instead of using an electrode, Tribo charging is achieved by applying a charge through friction just as a person may apply a charge to himself or herself by rubbing socks on the carpet. The powder is sprayed through a Teflon or nylon barrel where it rubs against the sides, picking up a charge as seen in Figure 2. It then, for the most part, follows the same path as Corona charged particles toward the work piece (Mayr, 2006).

![Figure 2: Inside a Tribo Charging Gun Barrel](image)

**Why Powder Coat?**

Many materials and object surfaces are at risk of corrosion or damage, so often times a protective coating is applied to protect surfaces and elongate the effective life and use of an item. The application of a protective coating can range from multiple methods such as rolling, brushing, or dipping paint; or spray-painting the surface. However, these methods do not provide as effective of a coat as provided by the application of powder coating.

Paints do not create a strong bond between the paint and the item’s surface like powder coating does. Paint can easily dry and crack or even chip off, exposing underlying materials to corrosion or rust. This is where powder coating prevails; the charged powder statically clings to a surface and provides a uniform and thorough covering of the surface to which it is applied. Upon heating of the powder covered surface in an oven, the powder liquidizes and flows about the surface to create an even more uniform and thorough covering of every bit of the surface as to eliminate the air bubbles or chipping that may occur with paint.

**Ventilation System**

**Reasons for Requiring a Ventilation System.** A ventilation system is needed for two specific reasons; to maintain safe working condition, and to provide powder recovery. The safety concern is to prevent the powder-air mixture from reaching combustible levels.
(Liberto, 2010). Particles in the air can be combustible; an example would be flour: when flour is tossed into the air, certain particle-air concentrations can be ignited and explode. Therefore, the air must be ventilated in order to remove particles from the air and remove the possibility of an explosion from the spraying area. In the design, safety will be the main priority while powder recovery will be of secondary concern.

For powder recovery it is important to maintain a negative pressure in the booth to prevent powder from leaving through the entrance (Hughes, 1984). This is easily done through the implementation of a fan that pulls air into the booth and out through the back of the spraying area. The air should pass through a filtration system in order to remove the particles from the air. In Figure 3 there is a ventilation system at the rear of the booth where the air will be pulled into the booth creating a negative pressure.

![Figure 3: A Booth with a Rear Ventilation System](image)

**Filters.** Many companies offer many different forms of filters for spray booths. The size of the filter will depend on the size of the fan. If the fan moves a large number of cubic feet per minute (CFM) then a larger filter opening area will be needed. The pocket type filters seem to be the best choice for the system because they have a greater surface area as to catch more overspray and last longer than a flat filter.
Filter Housing. The pocket filters that are currently planned for use are the Koch SprayStop HC Duo-Pak. The filter size that would best work would be 12”x24”x15”. This will allow two columns of filters for the wall. They will be placed 12 inches on the horizontal and 24 inches vertical, side by side to produce a wall that is about 24 inches wide and 24 inches tall.
**Filter Holding Frames.** Filter holding frames for these filters will be constructed from 10 gauge sheet metal. A square will be constructed to hold the perimeter of the filter and a thin strip will run across the square frame to support the joint between the two pockets as seen in Figure 6 below. The Nominal size for the filter is 12 by 24 inches so it will be designed to accommodate this.

![Frame Assembly Example](image)

Figure 6: Frame Assembly Example

**Air Ducting.** Ducts will be used for air flow. Air will be pulled from the filter box to the fan and then pushed from the fan up to and out of the window vent. HVAC air ducting will be used. Ducting will make it easy to guide air flow. Ducting can be purchased at the Home Depot and is relatively inexpensive. Required pieces will be pipes, 90 degree elbows, diameter expanders/reducers, square to round pipe converter, and sealant such as duct tape.
The fan intake is round so the filter box will also need a piece of ducting that will convert square to round. This piece is called a funnel pan and will allow the square opening to fit easily into the square filter box and convert to a round piping to fit onto the fan. A funnel pan may be seen in Figure 8. Additionally, a converter will need to be used on the output of the fan to convert from rectangle to round as the output is rectangular.

Pre-Manufactured Booths

There are currently some manufacturers that produce powder-coating booths for purchase. One such manufacturer is The Eastwood Company. They sell several sizes of booths. The ones that would be most relative to this project would the small and large HCP Benchtop powder coating booths. These booths are made of 18 gauge steel and range from $1999.99 to $2,299.99 depending on whether or not a stand is purchased.
Which, for the needs of the shop, a stand would need to be purchased along with the booth. The two booths can be seen in the figures below.

Figure 9: Small HCP Benchtop Booth

Figure 10: Large HCP Benchtop Booth
PROCEDURES AND METHODS

Shop Floor Area Survey

The very first step in beginning the design of the ventilation system is to survey the area that will be available to the ventilation system. Measurements will be taken and obstacles will be noted. A fixed grinder area and electrical outlets are in the area and will need to be designed around as not to block or interfere with normal use or operation.

Figure 11: Layout of Available Shop Floor Space

Research

The second step after surveying the available floor area is to research current methods of ventilation. Filter designs and filters available will be explored. Specifications and dimensions of the filters will require noting.

Design Structures

Filters. Through the Research phase different types of filters are to be explored and the most desirable filter setup is to be used. Filters will be decided upon by practicality for the size of the booth as well as effectiveness. A filter wall is to be designed and used as the primary filtration.

Filter Housing. Filters are to be designed as the first step of ventilation. The design will include an enclosed rectangular cavity in the back of the shop area. On the outward facing side of the box a wall of pocket filters will face the spraying area. The air will
flow through these filters and into the cavity. The filters will need to be supported and secured in place. This will be done by cutting out a frame housing for the filters from sheet metal. The filters will be placed into a designed holder and then clamped in place.

The pocket filters will remove as much of the particles from the air as possible before it enters the box. At the bottom of the filter box, ducting will lead out of the filter box and into the fan housing. The air will then pass through a section of piping to be exhausted into the outside air through a window fitting. By blowing the air through a fitting in the window and outside, negative pressure will be maintained in the powder coating area, reducing the flow of spray into the shop atmosphere.

**Fan Housing.** The fan to be used was donated by Dr. Gary Weisenberger. This fan will be used to pull the air through the ventilation system. The fan mount needs to be designed so that easy access is available for any servicing or replacement of the fan. The fan also needs to be sealed or at least protected from being sprayed. This housing will also need to cover the ducting for aesthetic reasons.

**Window Vent.** After the powder particles are separated from the air, the air will be vented through an available window above the system. A hose/piping from the fan will need to be guided up to the window. The window will need to be removed and replaced with a fitting for the exhaust hose/pipe. This fitting will be modeled after the current vent for the welding stations. A metal sheet will be cut to fit the window and a hole will be cut in the center of the sheet. This hole will have a coupler/fitting for the hose to attach from the fan.

**Analysis**

The system design will be analyzed through the creation of a list of materials and a bill of materials. Materials will include various items including (but not limited to) lumber, sheet metal, air ducting and supplies, and various hardware items. Costs of all materials will be laid out in excel and a final, total estimate for the design will be calculated. The estimated total expense will be compared to the cost of buying a premanufactured system of which will help in deciding the plausibility of constructing the design.
RESULTS

The resulting design fits into the end of the available space in the shop. It also is able to fulfill all of the requirements mentioned in the procedure section.

Main Priorities

The ventilation system is estimated to cost slightly more than the planned budget for the project. The total cost would be approximately $526.80, while the budget was set at $500. The system, however, fits into the required/allocated area for the powder coating operations, as can be seen below in Figure 12.

Filter and Related Sections

Filter Box. The Filter Box was made from Douglass Fir and Pine due to the relatively low cost of lumber. Plywood was then added to the box to add rigidity to the design as well as make for a more pleasing appearance.
**Filtration Components.** The end result for the filtration components was a housing that the Koch SprayStop HC pocket filters would be placed into and then clamped into position with a sheet metal cover and latches on either side to secure the cover in place. This can be seen on the next page in Figure 13.

![Figure 13: Filter Housing Hinges](image)

**Fan, Ducting, and Vent**

**Fan Protection.** A barrier was designed to overlap the front right edge of the filter box and extend out and between the fan area and the spraying area. This barrier can be moved to gain access to the fan.

**Window Vent.** A piece of sheet metal was designed to replace the window above the ventilation system and provide a port for the air ducting to expel the air outside of the spraying area.

**Costs and Bill of Materials**

**Bill of Materials.** The final list of materials to purchase can be seen on the next page in Table 1. At the bottom of the table, the final estimated cost can be seen as well. The materials will be purchased mostly from the local home depot. Some materials, such as the funnel pan and ducting transitions, will need to be custom ordered. The costs for these parts were estimated by comparison of similar parts from a range of manufacturers.
Table 1. Bill of Materials

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<td>Pine S4S</td>
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DISCUSSION

**Main Priorities.** The main priorities for the design were to design a low cost system that would fit into a designated area with limited space. The ventilation system was given an estimated budget of $500 and asked to be designed for the back area of the shop that is currently used for steel storage and sand blasting. After designing the system, a list of materials was created to note every item and quantities of each item. Next, a bill of materials was created to add up all of the costs for the materials. According to the completed Bill of Materials, it can be seen that the total cost for the materials would be roughly $527 (labor would be volunteer; therefore no labor costs were included), resulting in the design being just over budget. However, if scrap metal and/or lumber could be used from the shops, the total expenses on materials could be reduced.

**Filter Box.** In order to minimize costs as much as possible, a simple design made from wood was decided upon. The design incorporates the use of common lumber. The lumber for the frames includes Douglass Fir 2x4’s for the frame and Pine 2x2’s for the inner frame, as seen in Figure 14. Outside of the frames, plywood was used to cover the system and ultimately enclose the filter box to focus the air intake through the pocket filters. Plywood also acts to help brace the frame, adding rigidity and stability to the beams and columns. The design of the Filter Box was made as a simple filter box that would be elevated at a height to match that of the spraying operations, as to be as close as possible to where the powder will be concentrated in the air. This elevation also made a convenient location for the ducting to attach to the filter box. The ducting could be run out of the bottom side of the filter box rather than the sides, rear, or top.

![Figure 14: Douglass Fir and Pine Parts](image-url)
Filters and Filtration Components. The filters that were decided upon are the Koch SprayStop HC Duo Pocket Filters (seen below). These filters are shaped like pockets instead of being a flat surface, which adds much more surface area to the filter surface. These filters come in various sizes, however it was decided that the 24” x 12” filters would be the best size out of the options because this area would closely match the area of the oven to be used. The size of the oven limits the size of the objects to be powder coated. Since an object will not be larger than the area of the oven, this size of filter would be adequate for the objects to be sprayed. The end design for the filtration components was a housing that the Koch SprayStop HC pocket filters would be placed into and then a cover would be clamped into position, sandwiching the filter pads in place. Latches on either side of the housing would be able to slide over the cover and secure it in place.

Figure 15: Chosen Filters

The filter housing is to be cut out sheet metal. As seen in the design picture in Figure 14, several pieces will be burned out and welded together to form the housing and cover. The hinges to be used are weldable and can easily be welded to the housing and cover. Holes can be seen in Figure 16 as well, which are where screws will be used to attach the housing to the filter box.
**Fan Protection.** To protect the fan, a barrier was designed to block spray from being directed toward the fan, while also acting as a guide for or boundary for the spraying area. This Barrier has a section of plywood that will extend from the barrier and overlap the filter box. This helps to stop spray from passing through between the filter box and barrier. The barrier is also not fixed. This will allow easy access to the fan area when needed. An image with the Fan Barrier can be seen below.

Figure 16: Filter Housing Cutting Dimensions

Figure 17: System With Fan Barrier
Window Vent. As was used on the other ventilation systems in the shop, a sheet of metal was used to replace a window with a vent for the ducting to attach to. The air that is pulled through the filters will be expelled outside the shop area, which will maintain a negative pressure in the hallway of the booth. This negative pressure will aid in reducing the flow of spray and powder back into the shop area. As can be seen in the figure below, the rectangular sheet located in the top right corner of the image is the window fitting.

![Figure 18: Ducting and Window Replacement](image)

Costs and Comparison.

Bill of Materials. The final bill of materials indicates that the project would be over budget. This amount does not include labor costs because the welding team, for their new system, would conduct labor voluntarily. The bill of materials also does not include the cost of the air compressors, nail gun, or staple gun because these items are already available for use in the construction of the booth and will not need to be purchased.

Even though the estimated budget it over $500, it could be possible to reduce the total expenses below the budget amount if some of the items could be used from other projects in the shops. The sheet metal is one of the largest expenses. There is a large amount of scrap metals from the projects that the students make for the welding and fabrication classes. Since the sheet metal for the filter housing is dimensioned at only a few inches wide, it would be possible to find scrap that could be used instead of purchasing more sheet metal. Also, if desired, the window vent could be substituted for plywood instead of sheet metal, which would also reduce the costs of materials.
**Cost Comparison.** The cost of this design is currently slightly over the proposed $500, but this is much cheaper than a pre-manufactured system. A comparable pre-manufactured system would cost roughly $2,000 to $2,500 as compared to the designed system for $526.80.

The smaller pre-manufactured booth (seen below) is the cheaper system at $2,000 without the stand and $2,089 with a stand.

![Figure 19: Smaller Booth](image)

The larger booth would cost about $2,099 without a stand or $2,199 with a stand as pictured below.

![Figure 20: Larger Booth](image)

When it the designed system and the pre-manufactured booth are compared relative to cost, the designed system is a quarter of the cost. It would then follow that the designed system would be chosen over the pre-manufactured booths when it comes to cost.
RECOMMENDATIONS

Cost Reduction. In order to attempt to reduce the expenses, it is recommended that scrap bins be surveyed for sheet metal that could be salvaged for the project. The wood shop may also be surveyed to see if there is any salvageable lumber that could be cut or ripped to fit the dimensions of any of the pieces. Any salvageable materials from the wood or welding shops could help to reduce expenses for the system.

One of the largest expenses will be for the sheet metal window fitting. This sheet will cost nearly $100 and if this could be substituted for a cheaper material that is acceptable, the costs could also be reduced. However, the other ventilation systems use sheet metal for the window fitting, so another material may look out of place in comparison to the other systems in the shop.

Construction. During construction, it recommended to follow all safety labels and procedures in handling materials, tools, and equipment. The construction process should be supervised by a qualified foreman or by Mr. Tim Fay to ensure that safety is maintained during construction.

Other. It is recommended that the booth be used only for powder coating operations, as that is what the pocket filters are designed for. Welding operations and other practices should be conducted in the designated welding areas or suitable areas for the practice.
REFERENCES


APPENDICES
Appendix A:
Senior Project Contract
Background Information

The welding shop at San Luis Obispo High School is in need of a powder-coating booth. The students have currently been operating the powder coating equipment outside. Ideally the equipment should be operated in doors but, with the excess over-spray from the machine, a booth with proper ventilation to collect over-spray needs to be implemented. A booth will provide a designated area for the operation of the powder coating equipment, as well as provide safe and effective ventilation of the area and collection of the over-spray. Buying a premanufactured booth is very costly; so designing and constructing a ventilation/filtration system for a booth should effectively reduce expenses.

Statement of Work

The first phase will include research toward creating a design. The second phase of the project will be to design the ventilation system. The third phase will be to analyze the designed system.

How Project Meets Requirements for the ASM Major

**ASM Project Requirements** - The ASM senior project must include a problem solving experience that incorporates the application of technology and the organizational skills of business and management, and quantitative, analytical problem solving.

<table>
<thead>
<tr>
<th>Application of agricultural technology</th>
<th>The project will involve the application of CAD design and materials analysis.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application of business and/or management skills</td>
<td>The project will involve business/management skills in the areas of equipment/machinery management and cost analyses.</td>
</tr>
<tr>
<td>Quantitative, analytical problem solving</td>
<td>Quantitative problem solving will include a cost analysis</td>
</tr>
</tbody>
</table>

**Capstone Design Experience** - The ASM senior project must incorporate knowledge and skills acquired in earlier coursework (Major, Support and/or GE courses).

| Incorporates knowledge/skills from these key courses | 129 Lab Skills/Safety, 151 AutoCAD, 152 SolidWorks, 203 Systems Analysis, 321 Ag Safety, 342 Ag. Materials, BRAE 418/419 Agricultural Systems Management |

**ASM Approach** - Agricultural Systems Management involves the development of solutions to technological, business or management problems associated with agricultural or related industries. A systems approach, interdisciplinary experience, and agricultural training in specialized areas are common features of this type of problem solving. (insert N/A for any area not applicable to this project)

| Systems approach | The project involves the integration of a ventilation system to remove |
powder-coating over-spray from the shop atmosphere.

Interdisciplinary features

The project touches on systems analysis as well as shop safety.

Specialized agricultural knowledge

The project applies specialized knowledge in the areas of shop equipment and fabrication systems, and shop safety.

Project Parameters - The project should address a significant number of the categories of constraints listed below. (Insert N/A for any area not applicable to this project.)

1. Proper and adequate ventilation must be provided
2. Ventilated air must be released outside
3. The design must fit into an area of limited space
4. Design will be fit to a specified fan
5. The System will require 3-phase power
6. Electrical fixtures (fan motor) must be removed from spraying areas
7. The system must be free standing
8. Expenses must be minimized

List of Tasks and Time Estimate

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<tr>
<td>Consultation with shop manager and advisor</td>
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Financial Responsibility

Preliminary estimate of project costs: $500

Finances approved by (signature of Project Sponsor):

Final Report Due:  Number of Copies: 1

Approval Signatures  Date

Student: ________________________________  _________

Project Supervisor: ___________________________  _________

Department Head: ______________________________  _________
Appendix B:
List of Materials and Bill of Materials
Table 2: List of Materials

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<tr>
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<th>Lengths</th>
<th>Number</th>
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Appendix C:
Design Dimensions and Images
Figure 21: Shop Floor Space

Figure 22: Preliminary Drawings
Figure 23: Preliminary Filter Housing Drawing

Figure 24: Filter Housing Base Cuts
Figure 25: Filter Box and Housing Frames

Figure 26: Filter Box and Attached Housing Frames
Figure 27: Filter Box Dimensions
Figure 28: Barrier Dimensions

Figure 29: Ducting Materials Lineup
Figure 30: Ducting Views

Figure 31: Ducting Isometric View
Figure 32: Complete Design Isometric
Figure 33: Complete Design Isometric-Right
Figure 34: Completed Design Isometric-Rear
Appendix D:
Images of Materials Used in Cost Estimation
Figure 35: Hinges

Figure 36: Latches, Staples, Ducting
Figure 37: Lumber and Nails
Figure 38: Transitions and Ducting