Modifications to the Precipitator Girder Blower System for Solving Design Inadequacies

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By

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Acceptance Page

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Table of Contents

List of Figures

Abstract

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This research paper was completed as a requirement for the Master of Science Degree in Industrial Management at the University of Southern Indiana. It explains how competition in the electrical power industry forced electric utilities to enact aggressive cost controls to lower their operating costs. One method of lowering costs at the Rockport Power Plant involved forming a committee to investigate and complete projects aimed at improving the overall plant efficiency.

This paper details the evaluation and final proposal for such a project on the electrostatic precipitator girder blower system. The committee believed major improvements could be made to this system to reduce maintenance costs and to improve the operating efficiency. The girder blower system produced too much air flow, entrained damaging moisture, and provided damaging cold air during winter operation.

These three major problems were identified, the effects associated with the problems explained, and possible solutions were developed to solve each problem. Eventually, a final modification was recommended by combining the individual solutions to best solve all three problems.

Rockport Plant Background

The Rockport Plant, located in Rockport, Indiana, produces electricity with two 1300 megawatt (mw) coal-fired generating units (Figure 1.) The plant is owned and operated by American Electric Power (AEP) of Columbus, Ohio. AEP is one of the largest electric utility systems in the United States, providing electricity to over seven million people in seven East-Central states. The total generating capacity is 24,084,000 kilowatts (kw) from 123 separate units at 39 power plants. Coal-fired plants produce 88% of the total capacity and nuclear sources provide 9%. The remaining 3% is produced from 16 hydro facilities, one pumped-storage project, and one gas-fired turbine.

Figure 1. Rockport Power Plant.

AEP has been a leader in the electric industry since 1917 with a long record of milestones. It has pioneered, innovated, and implemented some of the most advanced technologies in power generation. For example, AEP built and owns seven of the eight largest generating units in the world. These units, rated at 1300 mw, have excellent efficiency and reliability. The AEP Mountaineer Plant in West Haven, West Virginia, holds the world record for continuous operation of a power plant at 607 days. By maintaining performance of its plants, AEP has traditionally ranked among the most efficient utilities in the United States, thus saving its customers millions of dollars every year in energy costs. Efficient operation also helps minimize adverse environmental effects of powerplant emissions.

The electric industry started to change during 1994. Competition was beginning to be introduced for the first time. Previously, utilities supplied power only to the customers in their service areas; much like the telephone industry did several years ago. However, many large customers, such as aluminum smelters, were unhappy purchasing their electricity from only one supplier; especially if other electric utilities were selling electricity for less. Eventually, political bodies started introducing legislation making utilities compete head-on to dismantle the so-called monopolies. Their ultimate goal was to enable a customer to purchase its electricity from any supplier just like customers purchase long distance telephone service today. As a result, electric utilities started aggressive cost controls to lower their production costs and become more competitive.

Rockport Plant did not escape any cost cutting measures. Starting in 1995, the workforce was reduced by 27%, non-capital spare parts inventory was reduced by $700,000 or 8.7%, preventative maintenance was greatly reduced, and so was equipment performance testing. In the end, the entire plant structure was recast in an effort to better utilize employee skills and increase efficiency. Another method of reducing operating cost was implemented earlier in the fall of 1994. A small committee of engineers and department superintendents was created and met weekly to investigate ways of improving the performance of the plant. It reviewed operating procedures and completed projects aimed at improving efficiencies of equipment. The committee was referred to as the "Heatrate Team" and was chaired by Diane Keafer, Supervising Engineer of the Performance Department. The plant efficiency is measured by the heatrate; the amount of heat energy from burned coal needed to produce one kilowatt of electricity. Better plant performance lowers the heatrate which reduces the amount of coal burned. Because the cost of fuel is nearly 50% of the plant operating cost, reducing the amount of coal burned has a direct and dramatic effect on the production cost of electricity.

Power Plant Theory

A power plant has many systems essential to producing electricity. Each system is important and serves a specific purpose. One such system is the Electrostatic Precipitator (ESP) which cleans the boiler gas by removing the particulates before they reach the atmosphere. Particulates are the residual material produced by burning coal.

Coal is crushed and mixed with air inside the boiler to create a ball of fire. The heat from this fire turns the water flowing in the walls of the boiler into steam which is eventually used to turn the generators which produce the electricity. Burning the coal produces gases and ash which is kept airborne inside the boiler due to the rapid and continuous air flow needed to keep the fire burning. This ash is more commonly called "flyash" since it "flies" through the boiler. As new coal and air are sent to the boiler, the gases and flyash must be removed to sustain the fireball. They exit the boiler through ductwork leading to the ESP where the flyash is removed. The gases then exit the ESP and are exhausted to the atmosphere through the smokestack.

Each generating unit at Rockport Plant produces an average of 25 tons of flyash each hour. This amount would create a small dust storm as it left the smokestack if it was not controlled. Allowing the flyash to readily escape would be very messy and pose a serious health threat to local residents due to the fine particles and the chemical makeup of the flyash. The fine particles would damage lungs, and minute traces of heavy metals could be poisonous if enough were inhaled. Therefore, environmental laws exist mandating almost 100% of the flyash be captured for proper disposal. The ESP is the device responsible for capturing the flyash, and it is designed to remove 99.7% of the particulates. Luckily, many safe uses have been found for the Rockport Plant flyash. Uses include: as an additive for cement or paint, and as the primary material in a patented process for filling potholes in roads (called Flashfill). Flashfill pours like a liquid into a pothole, but hardens like concrete in less than one hour, allowing traffic to return to the street.

ESP Theory

The basic design of an ESP requires a very large metal box, called the casing, through which the boiler gas flows. The casing is gas-tight to prevent leaks to the atmosphere, and it provides the framework for mounting all other components. The size of the ESP is much larger than the ductwork providing the boiler gas. This allows the speed of the boiler gas to slow down greatly, to about three to five feet per second, which helps in flyash removal. At that speed, most of the large particles simply fall out of the gas due to their weight. However, the fine particles must be captured, and the slower speed provides more time inside the ESP for this to happen.

The casing is filled with rows of electrostatic fields which are simply groups of alternating metal plates and wires hanging down from the roof (Figure 2.) The wires in a field, called electrodes, are connected to a high voltage transformer rectifier (TR) that creates an electrical charge up to 50,000 volts direct current. The plates do not have a charge because they are electrically grounded to the earth. As the boiler gas passes between the electrodes and plates, the high voltage imparts an electrical charge to the individual flyash particles causing them to stick to the plates, thus preventing them from escaping the casing. The remaining gases continue on to be vented from the smokestack. The flyash continues to collect on the plates until a thick layer exists and no more can be attracted. This layer is routinely knocked off by large metal hammers turned by a motor-driven gearbox which is controlled by a timer. The flyash falls straight down into hoppers located below the fields. These hoppers resemble upside-down pyramids which collect the flyash for disposal. A vacuum system consisting of pumps, piping, and valves then pulls the ash from the hoppers into big storage silos.

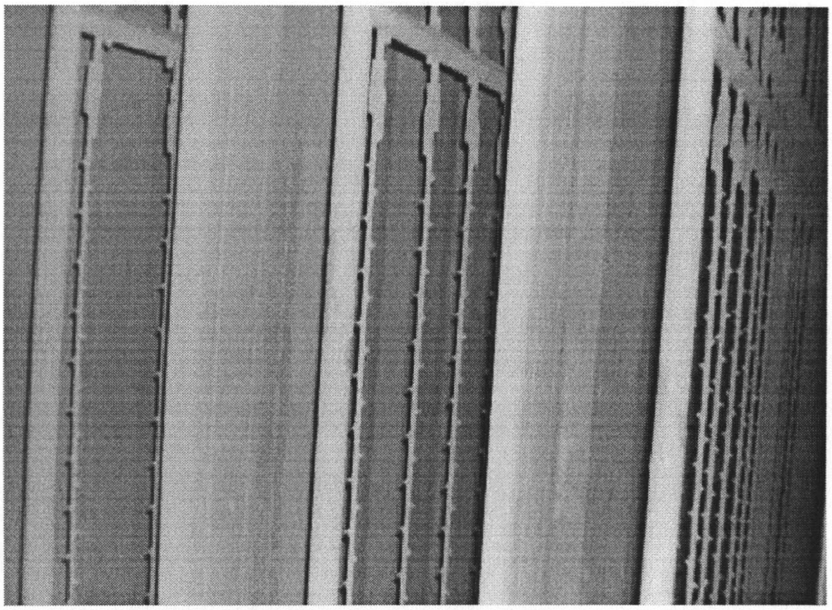


Figure 2. Electrostatic Field Construction.

The ESP for each generating unit at Rockport Plant is built with a modular design actually consisting of four separate ESPs, called boxes, working in parallel (Figure 3.) The design requirements for such a large plant made it unfeasible to build one large ESP. The boxes were manufactured by Wheelabrator-Frye, Inc., of Pittsburgh, Pennsylvania. They are approximately 123' wide by 141' long and 60' tall. Therefore, due to the modular design, evaluations can be done on a single box and still be representative of the entire ESP.

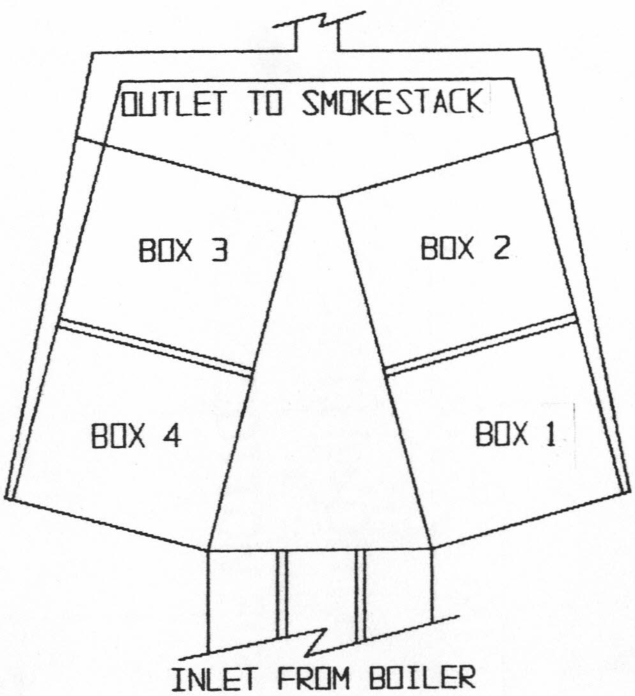


Figure 3. Precipitator Layout.

Just like the power plant, the ESP has its own systems essential for correct operation. There are four major and three auxiliary systems as identified by the manufacturer. The major systems include the discharge system, collecting system, gas distribution system, and the casing. The auxiliary systems include the high voltage control system, key interlock system, and the roof girder blower system.

The discharge system contains the high voltage electrodes hanging inside the ESP causing ionization of the flyash particles. It provides the electric charge which causes the flyash to stick to the plates. The collecting system, many times referred to simply as "the plates," catches and holds the flyash particles. The plates are assembled from eight 18-gauge sheetmetal pieces to form larger plates 12'-6" wide by 46'-6" tall. There are 16 plates and 16 electrode frames in each field. The flyash is knocked off the plates by metal hammers swinging on a motor-driven shaft. The gas distribution system is a series of perforated baffles located at the inlet and outlet of the boxes for evenly distributing the flow of gas through the casing. The final major component is the casing. It is a gas-tight box providing the foundation for the three other major systems.

The first auxiliary system is the automatic voltage controllers with TR's for providing the high voltage to the electrodes inside the ESP. The interlock system is the second auxiliary system. It is a safety feature which prevents a person from entering the ESP when high voltage is present. It ensures specific steps are taken to de-energize and ground all electrical equipment before any doors can be opened. Keys are released when each piece of equipment is properly shut down. The door keys cannot be retrieved from a cabinet until all keys from the electrical equipment have been collected. The final auxiliary system is the roof girder blower system. It maintains air pressure inside the girder boxes, where distribution of the high voltage to the fields occurs, to prevent fouling from flyash inside the ESP.

The girder blower system, the topic of this paper, is shown in a plan view in Figure 4. The casing of each box is separated into two chambers, "A" and "B", by a partition in the middle parallel to the gas flow. Each chamber has a set of two centrifugal blowers connected in parallel sitting on the roof and supplying air to ductwork located on the outside edges of the chambers. One blower in a set of two is a spare. Each blower is a size 222-85 by Sheldons Manufacturing Company driven by a 50 horsepower (hp) electric motor at 3600 revolutions per minute (rpm). The ductwork connects to the nine girder boxes on top of the roof running perpendicular to the gas flow. The girder boxes are constructed of steel plate to form a rectangle 6' 8" high by 2' 10" by 62' long. The girder boxes also serve as structural beams to support the ESP roof. Inside the girder boxes is the equipment necessary to support and supply power to the fields. The girder blowers pressurize the girder boxes to prevent flyash from contaminating the electrical components inside.

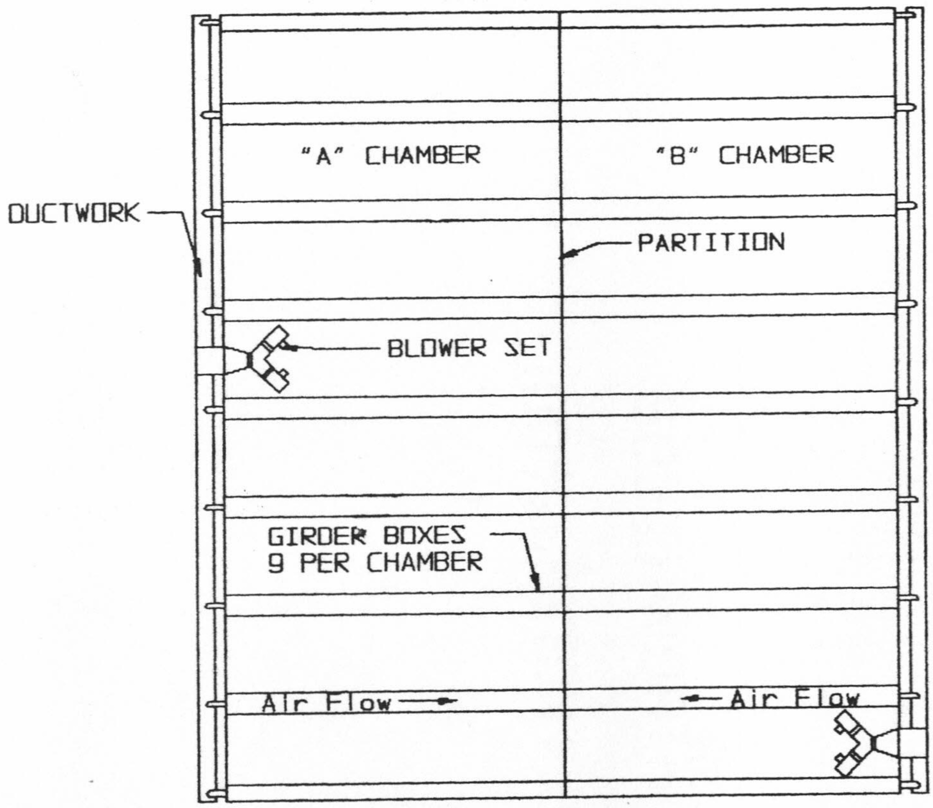


Figure 4. Girder Blower Layout.

The girder blowers allow for passing the electrical charge from the TR's, located on the roof, to the electrodes in the fields. The electrodes must be electrically isolated from all other parts of the ESP. If not, the charge on the electrodes cannot be produced because they would be electrically grounded. The ESP would not work. The difficulty arises from the need to penetrate the roof to send the high voltage to the fields without grounding the circuit or causing a leak of boiler gas.

The electrodes in each field are supported by a rectangular frame constructed of 8" steel channels (Figure 5.) Each of the four corners is then supported by a 1.875" diameter support pipe. The support pipe penetrates the ESP roof and passes through a porcelain insulator where it is secured with a nut. The electrodes hang inside of this frame. A high voltage lead is then connected between the TR and one of the support pipes to supply the voltage to all electrodes.

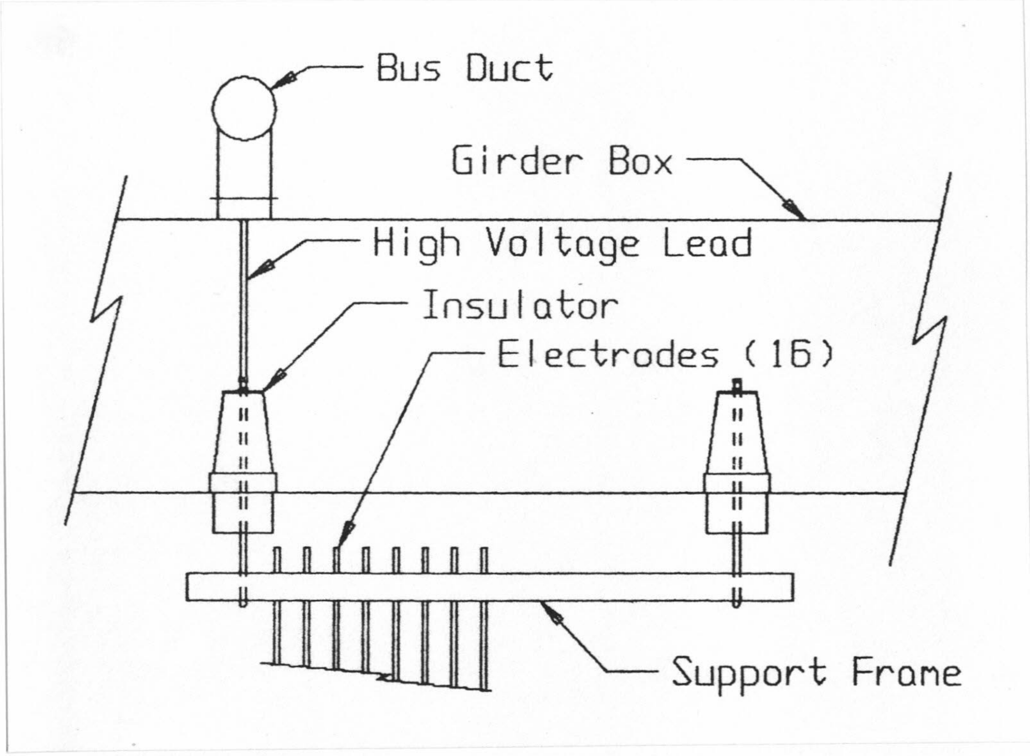


Figure 5. Electrode Support Frame.

This construction technique is prone to grounding out the electrode voltage. It is possible for the flyash to accumulate between a support pipe and the ESP roof penetration allowing the electricity from the field to flow through the buildup of flyash to the ESP casing. Therefore, a small amount of purge air is continuously blown through holes in a metal cap on top of the insulators to keep flyash from accumulating around the support pipes. This purge air is supplied by the girder blower system.

Problem Definition

The girder blower system has developed or contributed to several major problems in the ESP boxes. These problems are more obvious on the Unit 1 ESP which has been in service since 1984. The Unit 2 ESP has been in service since 1989. Three major problems exist with the girder blower system. It provides too much air flow, large amounts of moisture are pulled into the system, and the air temperature is too low during cold weather. The goal of this project is to explore all three major problems, evaluate possible solutions, and then recommend modifications to incorporate into the system. These modifications will eliminate these three problems and improve the overall performance of the girder blower system.

Air Flow Problems

The girder blowers are currently operating without any flow control, thus causing maximum air flow. Both blowers in the system require 49.5 hp while operating at 12,800 cubic feet per minute (cfm) with 15" of water pressure. This performance is based on the duct pressure and on the fan performance curve. This amount of air flow delivers 100 cfm to each insulator. However, the Precipitator and Flue Gas Section of AEP Service Corporation (AEPSC), where major engineering duties are performed for the Rockport Plant, recommends only a flow of 50 cfm per insulator. Precip Tech, a precipitator speciality company in Kansas City, Missouri, also recommends 50 cfm per insulator. Based on the fan performance curve and the ESP design, the blowers are producing twice the needed amount of air, thus wasting power (Appendix page 1.)

This point is also confirmed by the original equipment design. The blowers installed by Wheelabrator-Frye were rated for 12,800 cfm at 15" of water which would equal 100 cfm per insulator. However, the blowers were installed with inlet vanes for reducing the air flow. The manufacturer apparently intended for the blowers to operate at much less than 12,800 cfm. There would be no reason to install the inlet vanes if the actual flow requirement was close to full blower capacity. The blowers would have simply been allowed to operate at maximum capacity.

A check of the internal operating pressure of an ESP box at different generating unit loadings found it to be 0" of water at 1300 mw and 1.7" of water at 750 mw. Measurements were taken by using a water manometer attached to a pressure tap welded to the wall of a box. These low pressure values also indicate too much air is being produced. The girder box pressure is currently 15" of water which is much greater than needed to keep the insulators clean. Precip Tech recommends four to five inches of water pressure greater than the ESP box pressure. Also, the control system does not alarm until the pressure reaches five inches of water. Plus, modifications have been made to the girder blowers at the Mountaineer Plant, which has the same system, allowing them to operate at pressures equivalent to five to six inches of water and no failures have occurred. They have even operated some girder boxes without any purge air for a full year due to equipment constraints, and still have not suffered any problems in the girder boxes. It is conclusive that the girder blower air flow can be dramatically reduced.

The loss of air flow control is caused by the inlet vanes failing at the blower inlets. The air flow is regulated by these inlet vanes (Figure 6.) They are made of small triangular pieces of metal welded to shafts. The shafts are arranged in a circular fashion forming a 24" diameter circle when the triangles are flat. By rotating the shafts, openings are created, allowing air to pass through. Maximum flow is reached when the shafts are rotated 90 degrees, placing them parallel to the air flow. The shafts are all connected by a series of linkages so they can all be rotated by moving one handle. However, the linkages fail often, which causes the triangles to be out of alignment, thus disrupting the air flow and causing vibrations in the fan. To solve this problem, the maintenance department has welded every vane 100% open on most of all 32 blowers. Many other inlet vanes have simply been removed. This repair destroyed the method of controlling the amount of air flow. It is permanently set at maximum, causing the blowers to operate at their full capacity, which requires additional electricity.

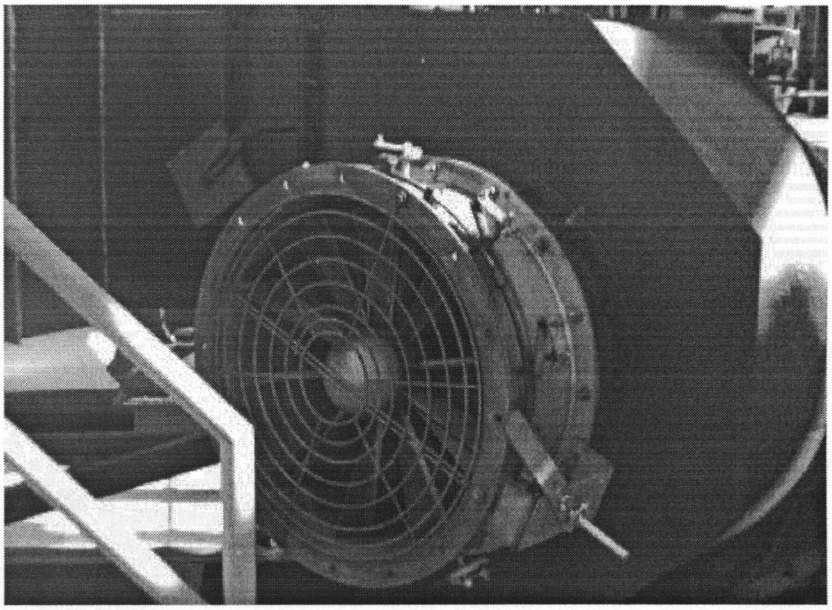


Figure 6. Blower Inlet Vanes.

The increased air flow causes yet another problem. The insulators helping to prevent flyash from collecting around the electrode support pipes must be heated (Figure 7.) If unheated, the purge air passing through will cool the support pipes inside. The boiler gas in the ESP is around 300 degrees F. and contains sulfur dioxide. If the support pipes are cooled to below 280 degrees F., the sulfur dioxide will condense with water vapor and create sulfuric acid which erodes the support pipes. Eventually, they will break. The heaters keep the purge air hot enough to prevent cooling the support pipes below this acid dewpoint. They also keep moisture from condensing on the insulators, which are used for electrical isolation, to keep them from electrically shorting out.

Each insulator has a 760 watt blanket heater for warming the purge air to at least 290 degrees F. It is wrapped around the base of the insulator and covered by insulation. When the insulator reaches the correct temperature, the heater turns off. The failed inlet vanes allow greater amounts of air to pass through the insulators. The heaters must warm twice the necessary air flow which causes them to stay on longer thus using more power. The design power usage is a maximum 778 kw for an entire ESP which represents 1.2% of the plant's auxiliary power; power needed by the plant itself to produce electricity. It is important to keep the heater operating times at a minimum to save power and reduce the operating cost of the plant.

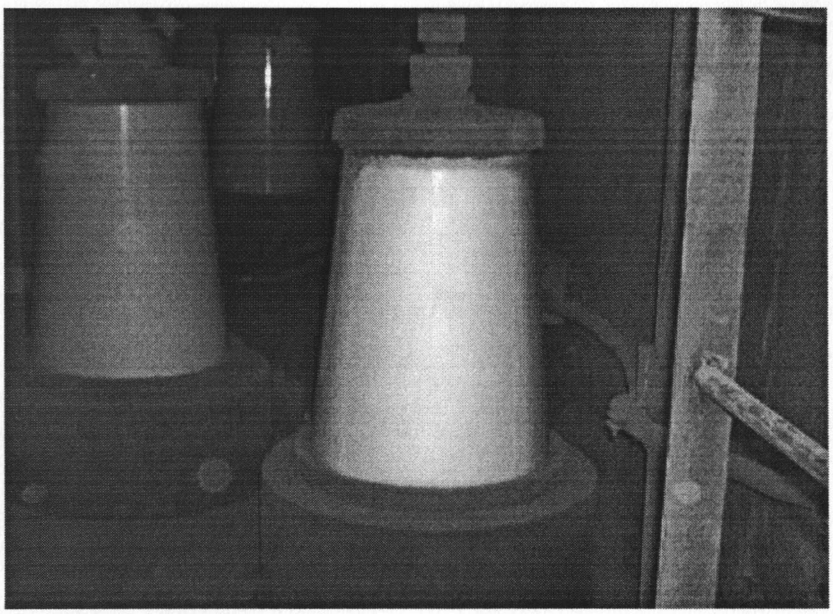


Figure 7. Insulator Assembly.

Moisture Problems

Moisture being pulled into the system creates additional problems. The girder blowers are located outdoors on the ESP roof where they are continuously exposed to the weather. They are completely unprotected. This arrangement allows rain and moisture to be pulled into the blowers and spread throughout the system. During heavy rainstorms, gallons of water can become trapped inside the ductwork. The blowers also atomize the rain as it hits the blades creating a humidifier. The high humidity eventually condenses throughout the system. Condensation also occurs due to changes in the weather. The result is water accumulating inside the girder boxes. Maintenance personnel have reported seeing "water marks" several inches off the floor in some areas while other marks and drips are routinely seen on electrical equipment during inspections.

This moisture causes two serious problems. First of all, the girder boxes are made of steel and have started rusting. Unless there is some corrective action, this corrosion will continue and eventually weaken the material. The result can be a loss of purge air or escaping boiler gas due to holes. More importantly, these boxes also serve as structural beams holding up the roof of the ESP and the equipment on top. If the rusting is not controlled, the structural strength of the roof will be reduced, increasing the chance of collapse. Unfortunately, the worst area of condensation happens to be directly above the insulators. The girder boxes are insulated except where the 16" diameter round ducts, called the bus ducts, travel to the TRs (Figure 8.) A half inch diameter copper pipe carries the voltage though the bus ducts from the TRs to the fields. Water collects in the uninsulated bus ducts and drips directly onto the insulators below, saturating the insulation. The heaters underneath the insulation become wet and eventually fail from corrosion.

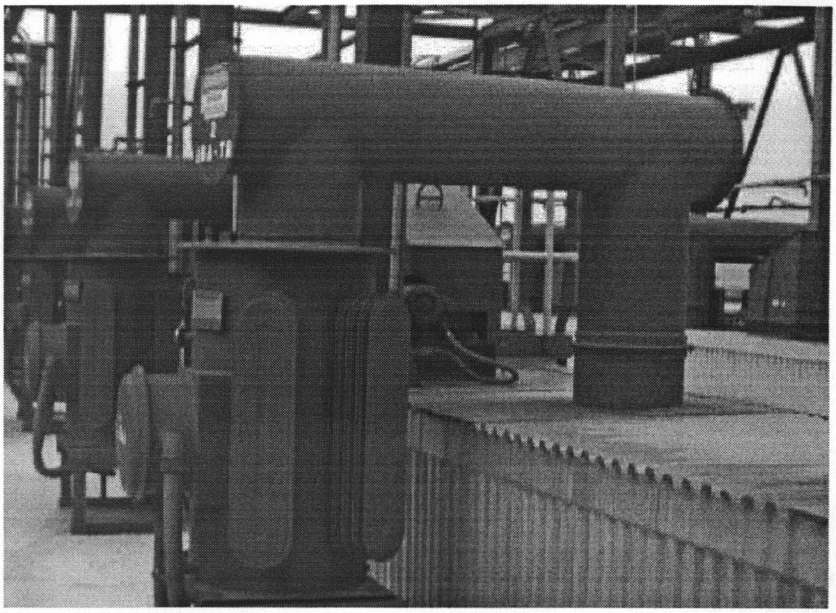


Figure 8. TR Bus Ducts.

The plant has suffered a very high heater failure rate. Inventory records show 120 heaters being used over the past two years. This represents almost 6% of all the heaters for both ESPs. However, repairs have not been made to all the failed heaters due to the large number and limited time. Each heater costs $125 and takes three hours to replace for a total cost of about $200 each. The best way to make repairs is to individually check each heater for proper operation during a unit outage (when the plant is shut down for six weeks for major repairs). The work is completed during an outage using several electricians working continuously. They electrically isolate each heater at a junction box outside of the girder box to check the resistance to see if it has failed. A failed heater will be grounded out or have infinite resistance.

The failed heaters allow cool air to pass through the insulators into the ESP boxes causing corrosion on the support pipes. If severe enough, the pipes will fail, leading to a catastrophic failure. An entire field could fall, damaging the surrounding fields and shorting out large areas of the ESP. Most likely, the generating unit would have to shut down to prevent releasing too much flyash and exceeding the limits set by environmental regulations. A worst case scenario would have repairs lasting for weeks and costing several hundred thousand dollars, not including the cost of lost generation from the unit. Support pipes have already been found with corrosion severe enough to cause the metal to flake off in large rusty pieces. An analysis of one of the worst cases showed a 30% reduction in material.

Heater failures cause yet another problem. The control system for the insulator heaters is not sophisticated enough to compensate for failed heaters. The girder boxes are controlled in groups of three. One bimetallic thermostat is located in each girder box inside the insulation surrounding the heater on just one insulator. It turns the heaters on at 290 degrees F. and off at 325 degrees F. Each girder box has 16 insulators for a total of 48 per heater control circuit. If the temperature of any one of the three insulators with a thermostat is below 290 degrees F., then all the heaters in the three boxes will be turned on until all three thermostats are above 325 degrees F. If any one of three heaters with a thermostat fails, which is common, the controls will keep all 48 heaters on continuously. The heater circuit will never shut off because no heat can be applied to the coolest insulator. Power is then wasted because the air is being heated more than necessary. This problem is very wide spread. On the Unit 2 ESP, only three of 24 heaters groups have been seen cycling off during the hottest days of summer. Obviously, most of the heaters are staying on when they should be off.

Temperature Problems

The third major problem is also caused by having the girder blowers mounted outside. During the winter months, the blowers pull in ambient air which can be below 0 degrees F. for several days at a time. It is not unusual to have temperatures below freezing for several weeks at time. This cold air is sent to the girder boxes by way of the ductwork. It enters at the girder box outer ends and flows towards the partition (Figure 4.) The air is coolest as it enters the girder box. By design, the floor of the girder box is also the internal roof of the ESP. Therefore, this cold air cools the roof. The cooling is greatest at the ends and lessens as the air picks up heat traveling towards the center. As with the support pipes, the cool metal temperatures cause condensation of the sulfur dioxide, producing sulfuric acid which creates corrosion. Inspections have shown corrosion at the outer ends of the precipitator roof to be occurring. Blowers running at full capacity only compound this problem by lowering the girder box temperatures even more due to the additional air flow. Also, unheated insulators, due to failed heaters, compound this problem.

Having the blowers outside on the roof also creates a maintenance problem. They require a lot of maintenance to keep running properly, and being outdoors only contributes to the problems. Every couple of months one blower of the 32 requires some type of repair. The fans are located on top of the ESP which is 60' above the ground. They are also located at the roof edges making access difficult. It is more time-consuming to make repairs because all material must be carried to the location by way of stairs and an elevator. Also, if large components are replaced, overhead cranes must be used to transport the materials. This increases the element of danger while making repairs. Finally, poor weather conditions such as rain, snow, wind, or extreme cold can make the work more difficult.

The goal of this project was to address each problem, evaluate possible solutions, and then select a final solution best satisfying all three major problems. The ideal solution would keep air flow at the design rate, prevent condensation in the girder boxes, keep air temperatures warm enough to prevent acid formation, and hopefully make maintenance work easier and safer. Resolving these issues will prevent the problems of corrosion, heater failure, and eliminate a large amount of electricity from being wasted.

In return, a reduction in the overall operating cost of the plant will be realized by reducing labor cost, material cost, and auxiliary power usage.

Air Flow Solutions

The first issue to resolve is the high air flow, which is currently twice the necessary amount. The most obvious solution is to simply repair the inlet vanes and adjust them to the proper air flow. This repair would be best accomplished by purchasing new inlet vanes. The old vanes would be unbolted and the new ones installed in their place. Replacing all four fans on one ESP box would cost $4950. Although an acceptable solution, the vanes have already proven to have a short life, even for heavy duty construction, and would probably have to be replaced every two to four years. An experiment at the Mountaineer Plant, which has the same ESP as Rockport Plant, found closing the inlet vanes to drop girder box pressure from 30" to 6" of water reduced the fan motor power from 49.5 to 43 hp. Therefore, similar savings could be expected at Rockport Plant for a reduction of about 14 hp on each box. These reductions would produce savings in electrical usage totalling about $1650 per year (Appendix pages 2 - 4.)

Another idea, requiring only $400 in labor and practically no material, is to simply loosen and re-weld the existing inlet vanes into a position reducing air flow to the desired amount. The inlet vanes on the first blower would have to be repaired so they could be adjusted and measurements could be taken. These measurements would then be used to set the remaining fans. This solution would also save $1650 per year, just like replacing the inlet vanes, but the vanes would not wear out, thus saving the future cost of repairs (Appendix page 5.)

A third possible solution is to remove the inlet vanes completely and install slower motors. The existing motors turn at 3500 rpm. A slower motor turning at only 1755 rpm could be installed. The blowers would turn slower thus changing their performance. According to fan affinity laws which calculate performance based on changes in rpm, the air flow would be approximately 6400 cfm with a pressure of four inches of water and an operating power of six hp (Appendix pages 6 - 8.) This performance is very close to the anticipated needs and provides 50 cfm per insulator. The pressure is still several inches greater than the internal ESP box pressure. This modification was tried at the Mountaineer Plant with very good results and should work equally well at the Rockport Plant.

The larger 50 hp, 3500 rpm motor would be electrically disconnected, unbolted, and removed from the blower base. A new 10 hp, 1755 rpm motor, which is physically much smaller, would be installed on a thick metal plate to raise the height of the shaft to match the blower shaft. Also, the new motor shaft would be smaller in diameter and would require a new coupling to connect to the fan. Since the fan shaft diameter is not changing, it would be possible to re-use that side of the coupling. The new motor would then be electrically connected to the existing control system and be ready to operate. It may be necessary to install an additional junction box next to the new motor. The wires supplying the electricity to the old motor would be re-used. However, they would be much larger than necessary since they were designed for a much larger motor and may not fit into the new motor's junction box.

The total cost of this modification would be $6500, including the purchase of four 10 hp motors complete with coupling and junction boxes. This cost also includes changing the motors by installing the base plate, coupling, and wiring. The power usage should then drop from 49.5 to seven hp for each of the two blowers. Using the same criteria for the inlet vanes, the annual savings would then be $10,200 (Appendix pages 9 - 10.)

One last possible solution is to split the air supplied from one blower. Instead of supplying one chamber, a single blower could supply the entire box. A comparison between the blower performance and the design requirement for insulator purge flow found twice the amount of air actually needed was being produced. The blowers are producing 12,800 cfm and only 6,400 cfm is needed. One blower operating at full capacity could supply all the air needed by a box instead of the two currently used. The inlet vanes could then be removed since the air flow would not need to be controlled. This arrangement would also reduce the number of blowers in service by 50% which should also reduce the associated maintenance by half. In addition, no changes to the control system would be necessary.

There are three possible ways of splitting the air flow between the girder box chambers. First of all, a large hole could be cut between the girder boxes and a pipe installed by welding (Figure 9.) The pipe is needed because a 2" gap between the girder box ends at the partition would allow the air to escape before reaching the other girder box. The air would simply flow from one box to the other through the pipe. Either blower set could be used. The out-of-service blowers would prevent air loss with a check valve currently installed in the ductwork. The existing ductwork size is suitable for the higher air flow because it has been operating at 12,800 cfm without any problems for many years.

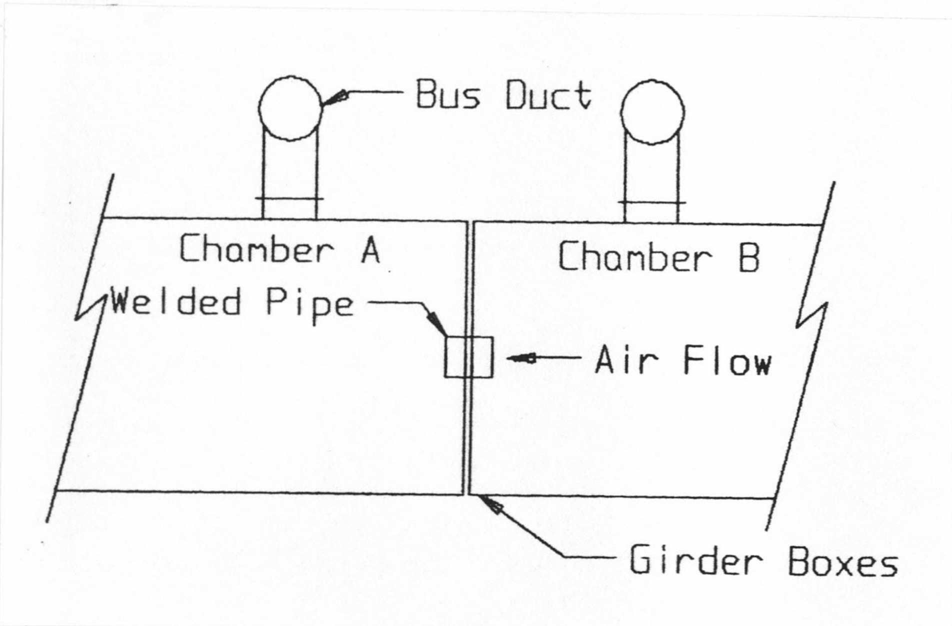


Figure 9. Connecting Girder Boxes with Pipe.

Further review of this modification found it to be a difficult job which should be avoided. The girder boxes are a confined space meaning they have limited access and poor ventilation. It would be easy for a person to become trapped or injured due to an accumulation of poisonous gases or lack of breathing air. Extra safety measures as required by the Occupational Safety and Health Administration (OSHA) would be necessary to do this work. The air would have to be routinely monitored for oxygen and poisonous gases. Permits would also have to be issued and the work supervised very closely by Rockport Plant supervision. The paint used inside the boxes is most likely lead-based which would call for testing and then special techniques for welding and cutting operations if lead was found. This modification would also be labor intensive because of having to work from the inside of each girder box to complete the installation of the pipe.

The second method is to connect the inner-most bus ducts together to form a duct between the girder boxes. The Rockport ESP is tremendously oversized. In order to reduce power consumption, half of the TRs were disconnected from the fields. The fields were then connected to adjacent fields by running a lead inside the girder boxes. This allows one TR to control two fields. Most often, the TRs closest to the partition and outside edge of the ESP were disconnected.

The existing 16" diameter bus ducts would be unbolted then disassembled. New pieces of round ductwork similar to an upside down "U" would then be bolted back into place (Figure 10.) The air would then flow from one box to the other through the ductwork connected to the bus duct openings in the girder box roof. This method is much easier than the previous one because there is no confined space issue or concerns of lead-based paint. All of the work is done outside with plenty of room. However, by removing the bus ducts, the two TRs utilizing those ducts could not be easily placed back into service if the neighboring TR failed. The pathway for connecting to the field would no longer exist. The bus duct would have to be re-established and a new duct for passing the purge air installed. There is also a problem with uniformity between the spare TRs. The two inner-most TRs are not always spares and available for this modification. This increases the cost of the modification because longer runs of duct using bends and additional supports would be needed to move around existing bus ducts. The short runs are under 7' while the longest would be 32'. Material cost and labor cost would also increase. Another concern is that the longer ductworks, which are uninsulated, would allow cooling of the air during cold weather as it passes to the other girder boxes.

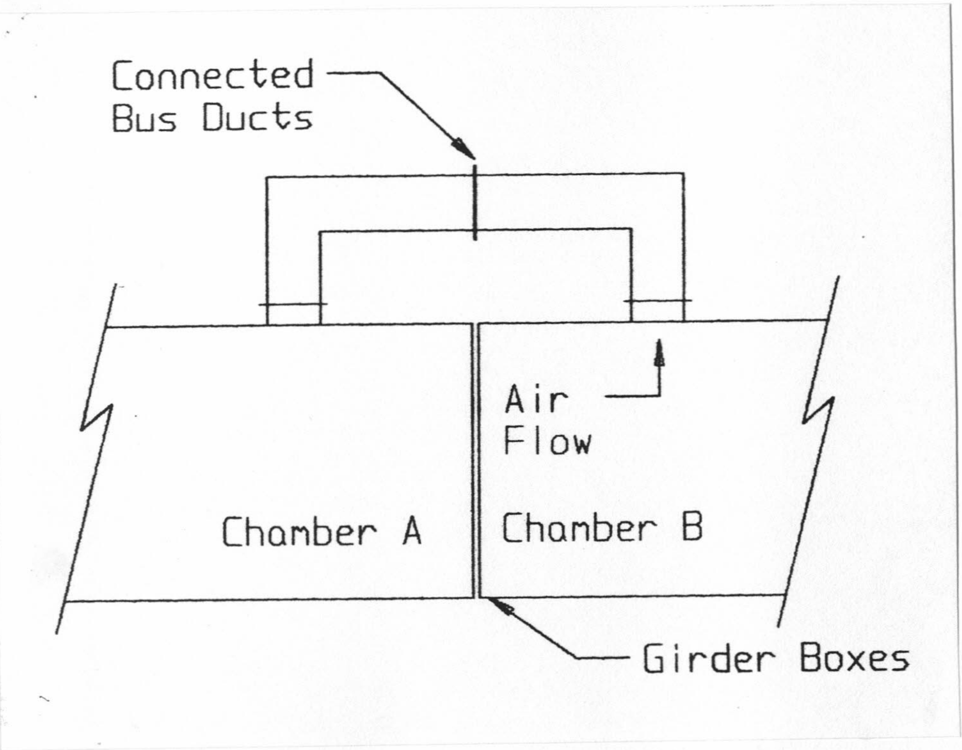


Figure 10. Connecting Girder Boxes with Bus Ducts.

The third option is a variation of the second. Connect the bus ducts between the inner-most transformers by welding a slightly smaller piece of circular ductwork forming a "Tee" at each bus duct (Figure 11.) This allows for leaving all of the TRs in service with no concerns for future changes. The amount of ductwork installed would be kept to a minimum. Also, there are no confined spaces. This method of splitting air flow would be the easiest and most cost effective compared to the previous two methods. No equipment would have to be disconnected and all duct runs would be identical and at the minimum length. The estimated cost is a total of $2700. With this modification, the use of one blower operating at 50 hp would be eliminated for a savings of $5900 per box each year (Appendix page 11.)

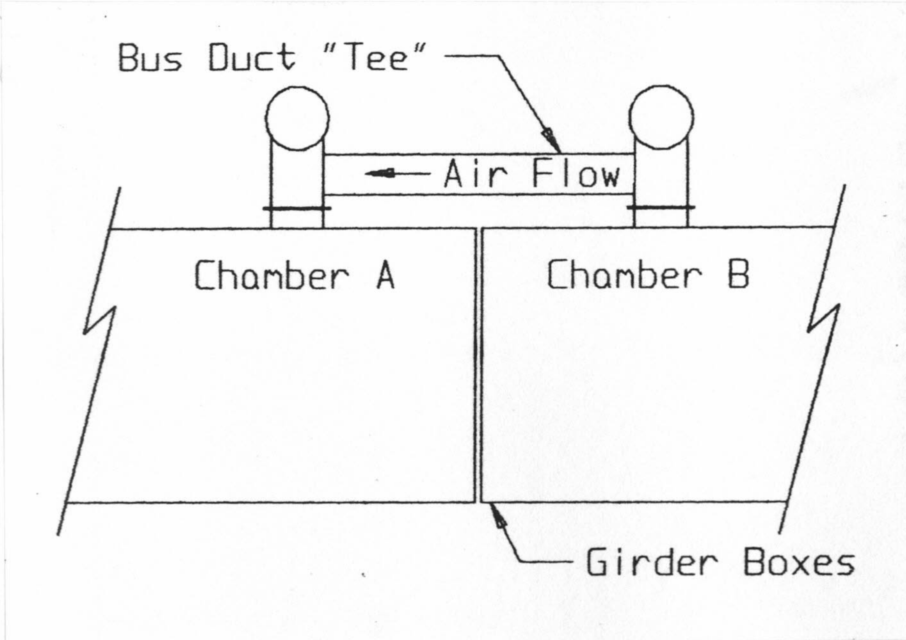


Figure 11. Connecting Girder Boxes with "Tee".

Moisture Solutions

The easiest and most cost effective way to prevent rain from being pulled into the blowers is to build some type of shelter over the blowers to protect them. A large sheet metal cover supported by angle iron welded over the blowers would work very well. This cover would block the rain, keeping it away from the blower inlets. Maintenance should also decrease if the cover kept rain out of the motor and coupling. The total cost of this modification would be $1300 for all blowers on a box (Appendix page 12.) While this would help tremendously, it does not completely solve the moisture problems attributed to condensation.

Inspections have shown the majority of condensation is forming in the bus ducts and dripping down into the boxes. These ducts are not insulated and extend up and away from the girder box. They are cooler because of not being insulated and, therefore, condensation occurs when they come in contact with moisture-laden air. Providing some purge air through the bus ducts would help keep them dry. The air warmed by the floor and insulator heaters would flow up and past the condensation to carry it out through a small hole about 1/8" in diameter in the end of the bus duct. It should be installed above the TR in the bottom of the bus duct. Further research found a recommendation from AEPSC to install a vent hole at the end of the bus ducts above the transformers. Vent holes should have been installed during the initial construction of the ESP. No material cost would be needed and the labor cost would be minimal, about $400 per box, for someone to drill a hole into the ends (Appendix page 13.)

Temperature Solutions

Providing warm air to the girder boxes would not only help to prevent corrosion by keeping metal temperatures above the dewpoint of the boiler gas, but would also reduce insulator heater operating times. It would also help to prevent insulator heater damage due to condensation dripping from the bus ducts. Finding a way to preheat the girder box air would provide many benefits.

The most popular idea is to simply install some type of heater to warm the air. It is not uncommon in industry for heaters to be installed in this type of arrangement of blowers and ductwork. Heaters are actually designed to fit into ductwork using energy sources such as steam, electricity, or natural gas. Since natural gas is not available at the plant, and the nearest steam supply is several hundred feet away, an electric heater was selected as the best candidate. Electricity is also ideal since the plant does not have to purchase it from another supplier. The cost of the electricty would be the cost to produce it. Also, spare electrical breakers are located next to the girder blower motor breakers and they could be used to power a heater.

Duct heaters are designed to fit ductwork and offer a wide variety of physical sizes and standard heating capacities. A large hole is cut into the ductwork after the blower and the heater is bolted into the hole. The heater is then wired to the breaker by running power cables and conduits. The control system would be a simple thermostat with a temperature probe located after the heater. It will simply turn the heater on and off as needed to keep the air temperature at the setpoint.

The goal is not to heat the air greatly, but warm it enough during the winter season to approximate a warm day. This warm temperature, around 70 degrees F., would be high enough to allow the insulator heaters to heat the purge air properly and prevent condensation. A heater was engineered to raise the air temperature from 20 degrees F. to 70 degrees F. at a blower capacity of 6,400 cfm per chamber. Based on these heating calculations, a standard 100 kw heater could be installed for each fan operating at 6,400 cfm. If a single blower is used with the splitting of air flow, then both heaters can be installed in the same ductwork together. The total cost of this modification with control system would be $13,800 (Appendix pages 14 - 21.)

The biggest drawback of heaters is the large amount of electricity needed to operate them. Increasing auxiliary power usage by installing new equipment is completely opposite of the plant's goals since it increases the operating cost. Although the heater would not operate during the warmer months, during the winter months, when about 4500 degree-days of heating would be needed, the estimated operating cost for one box is $8,600 a year for 200 kw of heaters (Appendix pages 22 - 23.) Another problem exists due to the large amount of fugitive dust in the air. Large dump trucks and semi tankers are loaded with flyash nearby, causing very dusty conditions at times. This ash could eventually clog the heating elements causing the heaters to require a lot of repairs.

A 100 kw heater operating at 600 volts would require at least a 175 amp breaker. Upon checking the available spare breakers in the area, none were found large enough to operate a single heater. It is possible the breaker cabinet is not big enough to install a 175 amp breaker. The heater installation price already includes $1700 for installing a 175 amp breaker. However, the heater installation price will be much higher if the upgrade cannot be done by simply changing parts.

Another idea is to install some type of heat recovery system. The ESP is filled with hot gas at 300 degrees F., just minutes from being exhausted to the atmosphere. It would be a perfect heat source with its high temperature and virtually unlimited supply. The purge air would pass through a heat exchanger which would be heated by the gases inside the ESP. The metal of the heat exchanger would be warmed by the exhaust gases which would then pass the heat to the cooler air flowing in the girder blower system.

The most inexpensive and easiest installation is to simply run a 24" diameter stainless steel duct through the outlet ducts of the precipitator and connect it to the blower inlets (Figure 12.) Stainless steel is needed to prevent corrosion which would result from the sulfuric acid formation on the much cooler duct. It would require no maintenance or special operation. This simple design would eliminate any concern of flyash obstruction in a heat exchanger made of tubes. This arrangement is estimated to increase the inlet air temperature to 125 degrees F. under ideal conditions by traveling through the entire length of 40 feet at 300 degrees F. (Appendix pages 24 -25.) However, information gained from the blower manufacturer indicated the maximum design temperature for the fan is 120 degrees F. The bearings would fail at this higher temperature and the fan output pressure would drop. It would be cost prohibitive to replace all the fan bearings. Plus, an additional drop in output pressure is not desirable because the expected air pressure at half of the current air flow is already close to being unacceptable.

Some type of control system utilizing dampers and a bypass would have to be installed to limit the temperature to 120 degrees F. However, this greatly increases the complexity and cost of this option. A concern exists that during the summer months the control system may not operate precisely enough or the dampers may not seal tightly enough to prevent overheating the fans. Should overheating occur, it would probably be undetected until a fan failure occurred. Because of these issues, it was decided not to consider this option any further.

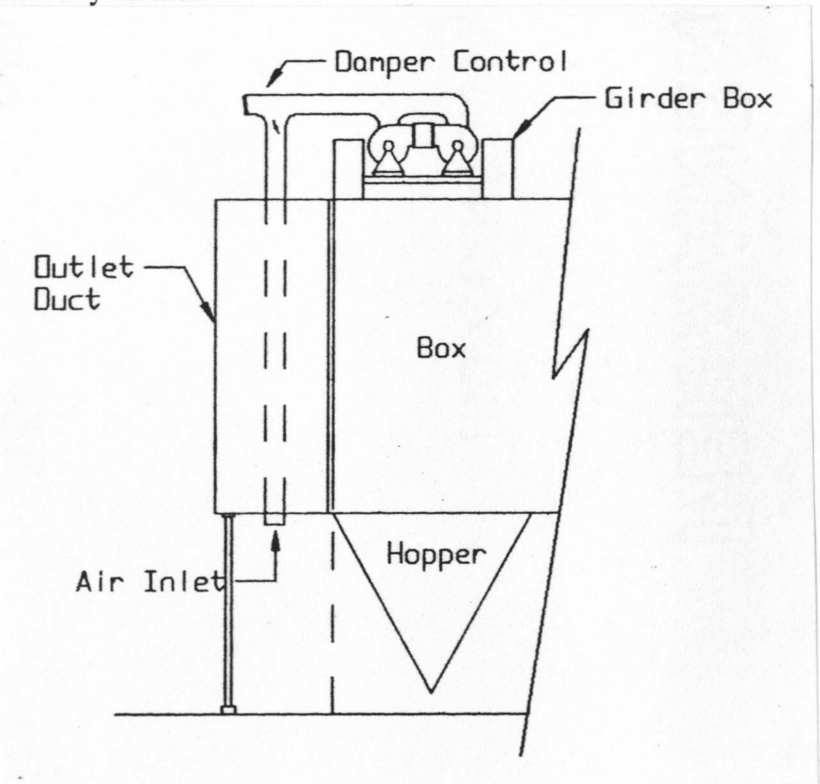


Figure 12. Heated Inlet Duct Design.

Another solution is to pull warm air into the fans from a large supply located nearby. The bottom of a box is completely filled with 48 hoppers collecting the flyash as it falls off the collection plates. These hoppers are covered with large electric heaters to prevent condensation inside, because condensation causes the flyash to bind up and plug the hoppers. The entire hopper area is enclosed with sheet metal walls to prevent heat loss which reduces the operating times of the hopper heaters and saves electricity. The temperature in this area stays close to 70 degrees F. in the winter and rises to 110 degrees F. during the summer. The heat in the hopper area rises to an area between the two adjacent boxes, referred to as the rapper area, where the temperature reaches about 140 degrees F. at the hottest. A measurement this winter with the outside air temperature at 16 degrees F. found the hopper area to be 68 degrees F. and the rapper area 119 degrees F; even with four 1/2 hp exhaust fans rated at 3000 cfm removing the hot air. This exhausted hot air may be ideal for feeding into the girder fans. After all, it is being exhausted directly to the atmosphere for cooling the surrounding area. The exhaust fans could be eliminated if air flow to the girder fans is sufficient to keep the area cool. The blowers would remove the hot air and send it to the girder boxes thus cooling the rapper area.

The high temperature in the rapper area does cause serious problems. Each box has seven motor-driven gearboxes located in the rapper area for rotating the hammers to hit the plates. The high temperatures have resulted in high maintenance costs for these motors and gear boxes. According to Doug McPeek, Supervisor of the Precipitator Maintenance crew for the last five years, the gear box oil loses its lubrication properties due to overheating and turns to a thick substance resembling tar. The gears and bearings in the gear boxes quickly wear out. The motor winding insulation also fails due to the high temperatures. Even though many improvements have been made in the equipment by using high temperature lubricants and heavy-duty motors, the failure rate is still high. The equipment in this area has a life expectancy of only two years. The same equipment located elsewhere and not subjected to the heat lasts around five years.

The high temperature also prevents repairs from being made as failures occur. It is too hot for people to work in this area and it cannot be ventilated enough. Therefore, repairs are usually done during an outage when everything has cooled down. All the gearboxes are removed and rebuilt at a cost of about $900 each. New gearboxes cost $1800 each.

Having a large number of failed rappers hurts ESP performance. The plates fill up with ash and cannot collect any more. This allows more flyash to escape the ESP. If the situation is not corrected and more rappers fail, the amount of flyash released could approach or even exceed the limits set by environmental regulations. To compensate for these dirty plates, more power must be provided to the remaining fields to capture the flyash missed by the dirty fields. This increases the power consumption while removing fewer particulates. Therefore, high temperatures in the rapper area increase maintenance cost for repairing overheated equipment and increase auxiliary power as the ESP tries to overcome the effects of the dirty fields.

There are two ways of getting this hot air to the blowers. The first is to install ductwork from the blower inlets down to the rapper area to pull out the hot air and send it to the girder blower system. This modification was tried last winter at a cost of $10,200 in labor according to the plant accounting system. This cost seems unreasonably high for the work done, and it is estimated that it would cost $2600 if done again (Appendix page 27.) This modification greatly increased the air temperature to the fans. With the outside temperature at 16 degrees F., the air entering the fan was about 60 degrees F. The air lost some heat as it passed through a long distance of uninsulated ductwork to reach the blower. The rapper area temperature did improve by dropping 10 degrees F. However, the rapper area was still hot and the vent fans were still being used for cooling. Although the ambient air in this area is cool enough for the girder blowers, it is possible the rapper equipment will still overheat. Also, installing the ductwork is a difficult task and there is not enough room for the adjacent box to be installed. Another problem is a stairway on the adjacent box would have to be relocated to make room for installing the inlet duct. Moving the stairway is estimated to cost $800 (Appendix page 27.)

A better way to remove this hot air is to actually relocate the blowers to the bottom of the ESP inside the hopper area (Figure 13.) This offers many advantages over the other solutions. To begin with, the fans would be inside and protected from the weather, providing longer fan life and greatly increasing the ease and safety of doing maintenance work. The air provided to the fans would be rain free, would have a lower humidity, and would always be at least 70 degrees F. There would be no concern for overheating the blowers. There is also plenty of room to install the necessary ductwork and it would be rather simple. Insulated ductwork constructed of fiberglass is also available to prevent heat loss. The new fan location would completely reverse the air flow in the hopper area, causing cool outside air to be pulled directly into the rapper area between the boxes. It would then travel across the hoppers to the blowers. This would solve the high temperature problems with the rappers and eliminate the need for the four exhaust fans. Only a slight increase in hopper heating times would be expected because 12,000 cfm of the 25,600 cfm of air required for two boxes would come from eliminating the four exhaust fans. The remaining air would pick up heat as it is moved past the warm surfaces of the ESP.

The blowers and their immediate ductwork can be unbolted into smaller sections and lifted down to a new position inside the hopper area. There is enough room to install the blowers, but new ductwork would have to be run from the outlet to the ductwork about 60 feet above. The equipment would be bolted to the concrete floor. The ductwork would simply connect to the blowers, penetrate the sheetmetal walls of the hopper area, then connect to the header located at the top of the ESP by running up the outside wall. The mounting brackets can be welded directly to the side of the ESP wall under the insulation. The control system would remain the same. However, it would be necessary to run 300' of new power cables from the breaker to the new blower location. The total cost of this modification would be $5800 (Appendix page 28.)

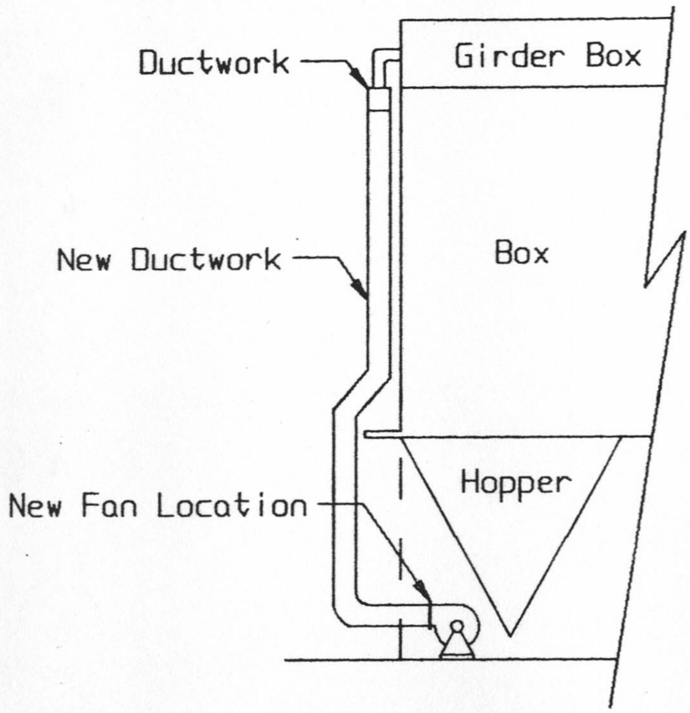


Figure 13. Hopper Area Supply Design.

Optimum Modification Selection

At this point it was necessary to select the modifications best solving the three major problems associated with air flow, moisture, and temperature. This was difficult because some modifications provided benefits difficult to evaluate. They were very subjective. The reduction in fan power was the only item easy to calculate. It was difficult to place a dollar value on such improvements as making fan maintenance easier, reducing corrosion in the ESP, and keeping ESP performance at optimum. It is was also difficult to predict changes in equipment operation, such as the insulator heater cycle times, due to changes in the amount of air flow and temperature. It was necessary to make several educated assumptions, listed in the appendix, in hopes of selecting the best combination.

Each possible modification was listed and its cost of installation was determined. Then the individual modifications were combined together to create feasible combinations best solving all three problems. The total cost of the combinations were then calculated by accumulating the sum of each individual solution (Figure 14.)

All together, six possible combinations were created. Some combinations were not evaluated due to incompatibilities among the modifications. For example, a rain hood would not be necessary if the blower inlet is connected to a hot air source using ductwork. Also, a 1/8" vent hole would be installed in all the bus ducts and was not a part of the combination evaluation.

Air Flow Modifications	Total Cost
New vanes	$4950
Weld Old Vanes	$440
Slower Motors	$6500
Splitting Air Flow	$2700
Moisture Modifications	
1/8" Purge Holes	$400
Rain Hood	$1300
Temperature Modifications	
Install Heater	$13800
Use Rapper Supply	$2600
Use Hopper Supply	$5800

Feasible Combinations	Total Cost
1. New Vanes, Rain Hood, and Heater	$20,050
2. Weld Vanes, Rain Hood, and Heater	$15,540
3. Slower Motor, Rain Hood, and Heater	$21,600
4. Splitting Air, Rain Hood, and Heater	$17,150
5. Splitting Air and Rapper Supply	$5300
6. Splitting Air and Hopper Supply	$8500

Figure 14. Modification Costs Per Box.

All six combinations solved the problems of high air flow, moisture, and low temperature. However, certain combinations provided subjective benefits too large to ignore for the final selection. All combinations reduced the amount of blower power, the expected failure rate and operating time of the insulator heaters, and the corrosion of the precipitator components. Combination six had the benefit of cooling the rapper area, thus decreasing gear box failures and the associated problems. It would also allow for the removal of the four exhaust fans to save additional auxiliary power. Finally, combinations four, five, and six would reduce fan maintenance about 50%, since the number of fans in service would be cut in half. Conservative estimates were made to place a dollar amount on these improvements so they could be added to the blower power savings (Appendix pages 31- 32.)

Possible Combinations	Total Savings
1. New Vanes, Rain Hood, and Heater	$10,500
2. Weld Vanes, Rain Hood, and Heater	$10,500
3. Slower Motor, Rain Hood, and Heater	$19,000
4. Splitting Air, Rain Hood, and Heater	$14,700
5. Splitting Air and Rapper Supply	$23,300
6. Splitting Air and Hopper Supply	$26,300

Figure 15. Annual Savings Per Box.

The information in Figure 15 shows combinations five and six are the top two choices for saving money. They are also fairly close to each in savings and installation cost. Combination five can be installed for $5300 while combination six would cost $8500. Surprisingly, the two cheapest combinations were also the biggest money savers.

Even though number six costs an additional $3200 to install, it will save an extra $3000 a year and is the best selection. The blowers should be moved to the hopper area and the air flow split by installing the bus duct "Tee."

Conclusion

The three major problems related to the ESP girder blower were identified as too much air flow, excessive moisture captured in the system, and damaging cold air during the winter. Upon analyzing each problem, the best modification to the system is to relocate the blowers on the outside edge of the ESP roof to the hopper area. The blowers will connect to the existing girder box ductwork by running an insulated fiberglass duct up the side of the ESP. The air from the blowers will be shared by both chambers by installing a "Tee" between bus ducts closest to the partition. This modification is estimated to cost $34,000 for one complete ESP consisting of four boxes and is expected to save $105,200 each year.

This modification will supply warm, dry air to the girder boxes at the proper flow rate. Condensation responsible for damaging insulator heaters will be eliminated. The warmer air temperatures will reduce insulator heater operating times and prevent acid corrosion of vital ESP parts. The reduced air flow will save auxiliary power by eliminating the operation of a 50 hp motor on each box. Also, the cooling of the rapper drives between the boxes will greatly extend their operating lives and help the ESP to operate most efficiently and stay below emission limits.

Other factors strongly influencing the decision are the substantial benefits received by having the blowers in the rapper area. Maintenance work will be much easier and safer since it can be done at ground level and protected from the weather. Also, reducing the temperature at the gearboxes in the rapper area is very desirable. The reduction in rapper gearbox failures will save large amounts of labor and material costs. With the recent restructuring of the plant, which reduced work force by 27%, reducing labor needs is an attractive benefit. Also, there is great concern about the environmental regulations limiting the amount of particulates released from the plant. If the ESP cannot be properly maintained, the plant will quickly reach the emission limit. At this point, the plant may have to reduce generation or be subjected to fines.

It is recommended this modification be tested on one box to insure the expected benefits can be realized. The Unit 1 ESP will be removed from service during 1997 for a six-week outage. This would be enough time to relocate the blowers, repair all insulator heaters, and install the bus duct "Tee". This modification can be monitored closely while in service to see the heater failure rate, heater cycle times, and air temperature at the rappers. At the next scheduled outage, less than two years later, inspection of the girder boxes and ESP can be conducted to reach a final conclusion. If the benefits are being realized, then the remaining seven boxes for both generating units should be modified during future outages.

Appendix

Form 6357

AEP
INDIANA MICHIGAN POWER

SHEET ______ OF ______

DATE ________ BY ________________

DEPARTMENT ________________

SUBJECT REQUIRED AIR FLOW PER BOX

1. BOX HAS 64 FIELDS

EACH FIELD HAS 4 INSULATORS

$\therefore$ 64 Field $\times \frac{4 \text{ insulators}}{1 \text{ Field}} \times \frac{50 \text{ cfm}}{\text{insulator}}$ = 12,800 cfm/BOX

or 6400 cfm/chamber

Form 6357

AEP
INDIANA
MICHIGAN
POWER

SHEET ______ OF ______

DATE ______ BY ______

DEPARTMENT ______

SUBJECT INSTALLING NEW INLET VANES

Cost

→ EACH BOX HAS 4 FANS

Material cost: 1 damper = $1067
BOLTS & Gasket = $20

$1087

LABOR: Per fan, 2 men * 3 hrs * $25/h
= $150

Total: 1087 + 150 = $1237

4 fan * 1237
= $4950 per box

Savings

Power drops from 50 to 43 = 7HP for 2 fans
2¢ KWH, 90% runtime

7 HP * .746 KW / 1 HP * 24 Hrs / day * 365 days / yr * $.02 / KWH * 2 fans * .9

= $1650 yr / box

COLBY Equipment co. inc.

Fax

To: American Electric Power **Date:** 1-30-96

Attn: Paul Eichenberger

From: C. L. Livengood

Reference: Inlet Vane Damper for Sheldons Size #222-85 Fan

Dear Paul:

Your total cost is $1,067.00 each, full freight allowed, for the following:

1 -- Ruskin 23 7/8" I.D. Inlet Vane Damper with 2" wide flanges, 26 1/8" bolt centers on both flanges with 16 bolt holes per flange, and bullet nose hub.

The delivery leadtime is 4 weeks after receipt of a Purchase Order.

Please review Page #2 of 2 for additional details.

If favored by an order, I will need the following additional information:

(A) "rotation" of fan as viewed from the inlet side of the fan;
(B) diameter of bolt holes;
(C) diameter of fan shaft (if shaft passes thru the hub of the inlet vane damper); and
(D) copy of the flange dimensional data for the existing fan.

Any questions?

Thanks, Paul!

Chuck Livengood

CHUCK LIVENGOOD
COLBY EQUIPMENT CO., INC.
P.O. Box 26327
Indianapolis, IN 46226-0327
1-800-443-2981

3

TO: Mr. Paul Eichenberger

RUSKIN®

3900 Dr. Greaves Rd. • Grandview, MO 64030 • (816) 761-7476 • FAX (816) 765-8955

INLET VANE DAMPER

Class I and II Fans

STANDARD CONSTRUCTION

FRAME
10 (254) gage steel channel frame (see table).

BLADES
16 (407) gage steel.

BEARINGS
Stainless steel.

AXLES
½" (13) diameter plated steel.

THRUST WASHERS
Stainless steel.

HUB
Open.

OPERATING LEVER
Crank Lever (CL) for motor operation or hand quadrant (HQ) for manual operation.

FINISH
Aluminum paint.

MAXIMUM TEMPERATURE
200°F (121°C).

MINIMUM SIZE
12" (305) diameter.

MAXIMUM SIZE
65" (1651) diameter. Consult Ruskin for larger sizes.

VARIATIONS

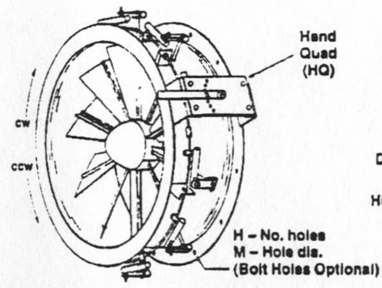
Variations to standard construction are available at additional cost and include:

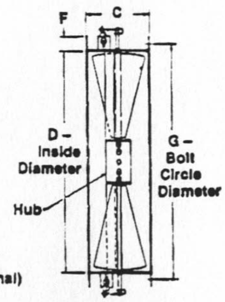
- Heavier construction for higher pressures, air flow (cfm), and temperatures.
- Bullet nose (BN) and flat cap (FC) capped hubs.
- Cantilever (hubless) design.
- Special materials.
- Damper built into a fan inlet cone spinning furnished by the customer.
- Bolt holes in flanges.
- Electric and pneumatic actuators.

NOTES: 1. Heavier duty dampers are available for applications not covered by IVD standard construction. Consult Ruskin for details and pricing.

2. If CFM or static pressure is significantly less than shown, and opposite factor (CFM or SP) is higher than shown, standard construction may still be applicable. Consult Ruskin.

Dimensions in parenthesis ( ) indicate millimeters.





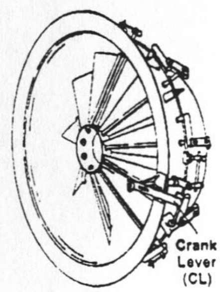
VIEW FROM AIR INLET SIDE
Inlet air rotation (CW or CCW) determined from air inlet side of fan. Rotation must be supplied with order.

FRAME DIMENSIONS
Standard Construction

D - INSIDE DIAMETER		FRAME	
ABOVE	THROUGH	F-Flange	C-Webb
12" (305)	24" (610)	1½" x 10 ga.	9"
24" (610)	41" (1042)	2" x ¼"	9"
41" (1042)	57½" (1461)	2" x ¼"	10"
57½" (1461)	65" (1651)	2" x ¼"	11"

MAXIMUM AIR FLOW
Standard Construction

D-DIAMETER		MAXIMUM CFM	MAXIMUM SP
ABOVE	THROUGH		
12" (305)	16" (407)	11,000	8"
16" (407)	19" (483)	14,000	8"
19" (483)	21" (534)	16,500	8"
21" (534)	24" (610)	18,000	8"
24" (610)	27" (686)	20,500	8"
27" (686)	30" (762)	22,500	8"
30" (762)	33" (838)	25,000	8"
33" (838)	37" (940)	27,000	8"
37" (940)	41" (1042)	29,700	8"
41" (1042)	45" (1143)	32,500	8"
45" (1143)	52" (1321)	35,000	8"
52" (1321)	57" (1448)	40,000	6"
57" (1448)	62" (1575)	43,000	6"
62" (1575)	65" (1651)	44,500	5"



Inlet vane dampers available custom fabricated in customer furnished fan inlet cone spinning.

QTY.	DIMENSIONS					HUB			AIR ROTATION**		LEVER TYPE		VARIATIONS
	D	G	H	M	FANSHAFT DIAMETER*	OPEN	BN	FC	CW	CCW	HQ	CL	
1	23 7/8	26 1/8	16				X				X		

*This information required when fan shaft passes through hub. **This information required for order processing.

JOB American Electric Power **LOCATION** Rockport Plant

CONTRACTOR

 ALL STATED SPECIFICATIONS ARE SUBJEC… …HANGE WITHOUT NOTICE OR OBLIGATION.

Form 6357

AEP
INDIANA MICHIGAN POWER

SHEET ______ OF ______
DATE ______ BY ______
DEPARTMENT ______

SUBJECT WELDING VANES

Cost

→ 4 fans per box

Material - (rod) $10/fan

labor - 4 hrs/fan × $25 = $100/fan

total = 4 fan × (100 + 10) = $440/box

Savings

→ Same as new vanes!

$1650/yr/box

AEP INDIANA MICHIGAN POWER

SHEET ______ OF ______

DATE ______ BY ______

DEPARTMENT ______

SUBJECT INSTALLING SLOWER MOTORS

→ FAN affinity laws (from Sheldons fan curve)

@ 3500 rpm pressure is 15" H_2O and 12,800 cfm and 49.5HP

$$cfm_2 = cfm_1 \left(\frac{rpm_2}{rpm_1}\right)$$

$$= 12800 \times \left(\frac{1755}{3500}\right)$$

$$= \underline{6420\ cfm}$$

$$HP_2 = HP_1 \times \left(\frac{RPM_2}{RPM_1}\right)^3$$

$$= 49.5 \times \left(\frac{1755}{3500}\right)^3$$

$$= \underline{6.2\ HP}$$ → use 10 HP motor

$$SP_2 = SP_1 \times \left(\frac{RPM_2}{RPM_1}\right)^2$$

$$= 15'' \times \left(\frac{1755}{3500}\right)^2$$

$$= \underline{3.8''}$$

MANUFACTURING CORPORATION
1400 Sheldon Drive
Elgin, Illinois 60120
Telephone (312) 742-5700
Telex 72-2470

DRAWING TRANSMITTAL

REFER TO THESE NUMBERS					RQSTD. SHIP
#1	1	2	6/24/87	U- 871981	
CUST P.O.	28224-831-7X				
CUST DT.	6/23/87				10/1/87

REPRESENTATIVE(S)	TERMS	F.O.B. FACTORY AT	CARRIER	TRANSPORTATION CHG. BILL DIRECT	PPD & ADD	COLLECT	ALLWD
LYW	NET 30	ELGIN, ILLINOIS				X	

	SHIP. SCHED. WEEK	STATE SALES TAX	REFERENCE DRAWINGS
☒ RELEASED FOR FABRICATION 9-17-87 GB ☒ HELD FOR APPROVAL BW 7/7/87	9/25/87		

SOLD TO:
INDIANA & MICHIGAN ELECTRIC CO.
ROCKPORT PLANT CONSTRUCTION
P.O. BOX 246
ROCKPORT, IN 47635-0246

SHIP TO:
SAME
EAST OF ROCKPORT
1 MILE NORTH OF JCT 66 ON 231
ROCKPORT, IN 47635

QUANTITY	SIZE	TYPE WHEEL	ARR.	MOTOR POS.	MOTOR MTG.	CLASS	DISCG.	ROTAT.	WIDTH SWSI	WIDTH DWDI	FAN TYPE	PROD. CODE	APP. CODE
8	222-85	BC	7		YES	4	TH	CW	X		N CENTRIFUGAL	21	GIP

INTEGRAL FAN ACCESSORIES & SPECIAL FEATURES:

- INLET AND OUTLET FLANGES
- VARIABLE INLET VANES
- INLET SCREEN
- INTEGRAL FAN AND MOTOR PEDESTAL
- DRAIN W/PLUG
- SHAFT SEAL
- MOUNT MOTOR AND DRIVE

PERFORMANCE

DESIGN:	ACFM	STATIC PRESSURE	TEMP.	ELEV.	DENSITY	RPM	BHP REQ.
NORMAL:	12,800	15"	70°F	SL	.075	3500	49.5

AUXILIARY EQUIPMENT

8 - SIZE 60T10 FALK STEELFLEX COUPLING WITH COUPLING GUARD
8 SETS OF R.I.S. VIBRATION ISOLATION MOUNTS

BY OTHERS

50 HP, 3600 RPM, 3/60/575V, 326T FRAME MOTORS

MARK SHIPPING PAPERS.	CHANGE #1 (8/7/87) RELEASE FOR FAB, ADD SHIP DATE.
MARK NAMEPLATE:	CHANGE #2

Drawing no. UA-871581 & 871582

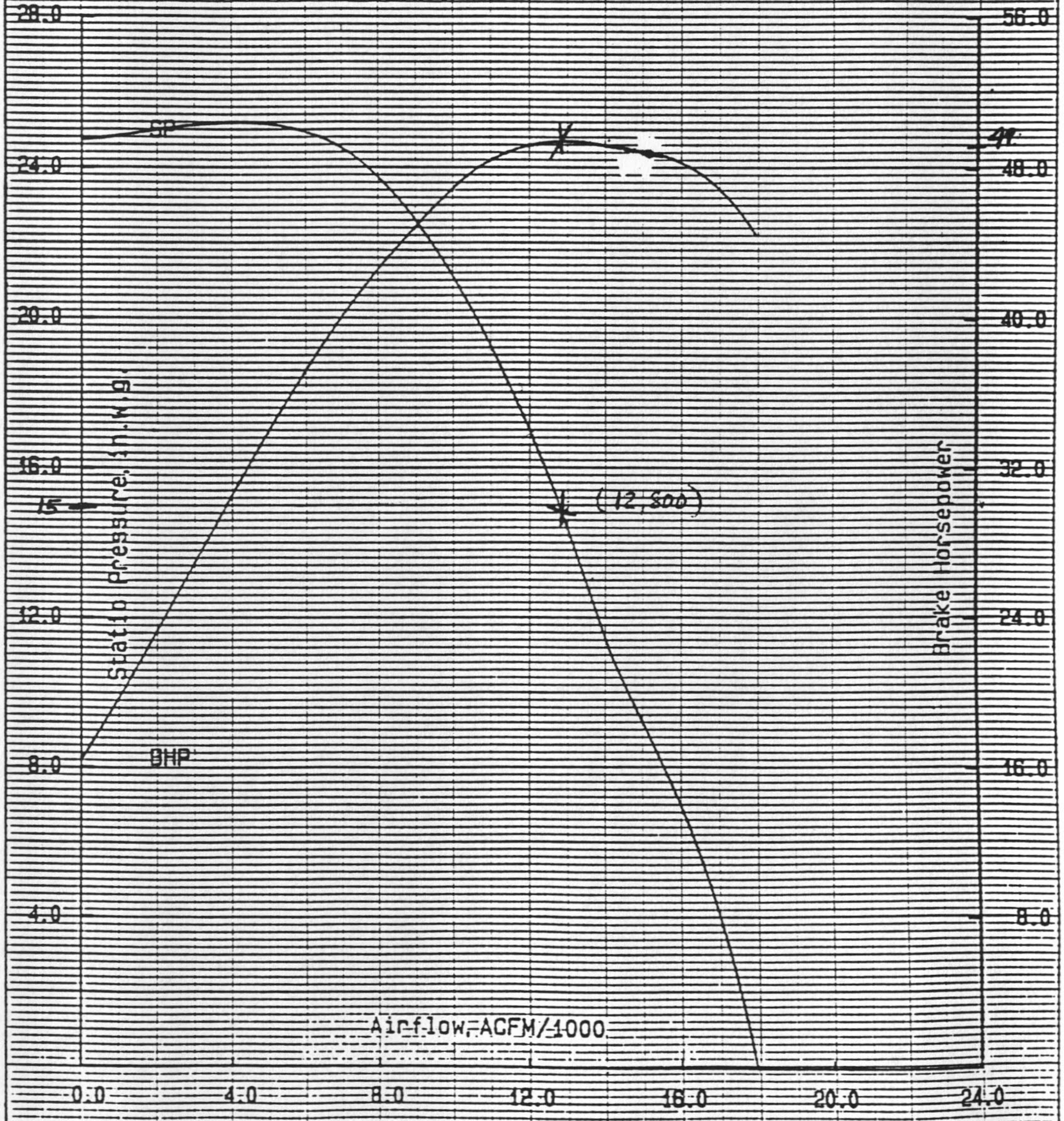
SMC

Manufacturers of Quality Air Handling Products

FAN PERFORMANCE CURVE

Fan Laws (for speed changes):
CFM2=CFM1(RPM2/RPM1)   SP2=SP1(RPM2/RPM1)^2 HP2=HP1(RPM2/RPM1)^3

Type: 222 85 BC SWSI   Arr: 7   Class: 4
Speed: 3500 rpm Inlet dens: .075 #/ft3 Inlet temp: 70 F
For: A.E.P.SERVICE CORP.



AEP INDIANA MICHIGAN POWER

SHEET ____ OF ____

DATE ____ BY ____

DEPARTMENT ____

SUBJECT ____

Material

10 HP motor $735
coupling $200
base Plate $50
Junction box $40

$1025 per fan

LABOR

2 men in 12 hours to replace fan including removing old fan.

2 men * 12 hours * $25 = $600

total = (1025 + 600) * 4 fans/box = $6500/box

Cost savings

49.5 HP to 6.2 HP per fan for 2 fans per box

(49.5 − 6.2) HP * .746 KW/HP * 24 hr/day * 365 days/yr * $.02/KWH * .9 * 2 fans

= $10,200/yr/box

```
IQII                         MMS INVENTORY ITEM INQUIRY
M&E NO: 20 059215  UM: EA MOTOR 10HP 575/3/60 1755RPM FRAME 215T        02/08/96
CO: 73 SR: 740     MTRL CATG: M&S            SPLIT CAPITAL/M&S:
-----                                                                     -----
SR TYPE: PLANT   SR SUPPLY: PURCHASE   HOW-TO-USE CODE: 01
STANDARD PHRASES:
BIN LOCATIONS:      57-27
CLASS 87 ACCOUNT/RU:                                CLASS 87 PRICING INDICATOR:
QTY ON HAND:           1   QTY UNVOUCH:           0 VOUCHERED VALUE:       734.91
QTY ALLOC:             0   AVG U/P:         734.910 PRICE CODE: N
VENDOR: 14762017
KEY ITEM:              N   REPAIR/RETURN ITEM:      N   RETIREMENT UNIT:        N
EMERGENCY ITEM:        N   SHARED OWNERSHIP:            OBSOLETE:               N
SERIALIZED:            N   LOT/CERT:                N   DELETE ITEM:            N
MINIMUM DAYS:          0   MAXIMUM DAYS:            0   AVG MONTHLY USE:        0
ORIGIN DATE:    12/17/91   NEXT SURVEILLANCE:           FREQUENCY (MTHS):       0
SHELF LIFE:            N   SHELF LIFE (MONTHS):     0   ASSET NO:               0
SHELF LIFE CNTL:       N   Q/A DESIGNATION:             10CFR21 APPLIES:
INACT REVIEW FRQ:      0   LAST INACT RVW DT:
SUPP  MAINT DEPT EXCESS F/COAL SAMPLER
DESC:
```

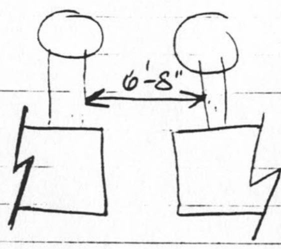
SHEET ____ OF ____

DATE ____ BY ____

DEPARTMENT ____

INDIANA MICHIGAN POWER

SUBJECT: CONNECTING BUS DUCTS USING A "TEE"



9 to connect

Material: 12" ø Duct 6'-8" LONG MADE OF ≈ 3/32" sheet

9 required @ $100

= $900

LABOR: 2 men * 4 hrs. each * $25 = $200

9 * 200 = 1800

total = 1800+900 = $2700/box

Energy Savings: 1 less 50 HP motor per box

50 HP * .746 kw/hp * 24 hrs/day * 365 day/yr * $.02/kwh * .9

= $5900/yr/box

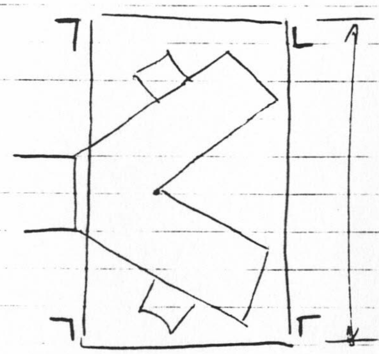
AEP INDIANA MICHIGAN POWER

SHEET ____ OF ____

DATE ____ BY ____

DEPARTMENT ____

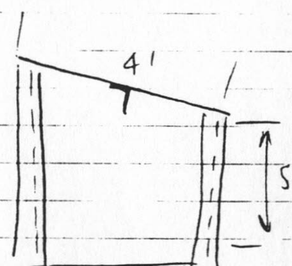
SUBJECT: RAIN HOOD FOR FANS



Angle $3 \times 3 \times 1/4$ + 1 ft

= 20 ft

1/4" plate $4 \times 12 = 48\ ft^2$



Labor 2 men + 8 hr × $25 = $400

total = $150 material + 400 = $650 each

1 box × 2 fan × 2 cover × $650 = $1300

SHEET ______ OF ______

DATE ________ BY ________________

DEPARTMENT ________________

AEP INDIANA MICHIGAN POWER

SUBJECT Installing purge hole in bus duct

(1) 1/8" ∅ holes per bus duct

$$\frac{64 \text{ TR's}}{\text{BOX}} \times \frac{1/4 \text{ hr}}{\text{TR}} \times \frac{\$25}{\text{hr}} \times 1 \text{ man} = \$400$$

SUBJECT: Duct Heater installation

Heater size

@ 6400 cfm for 50 cfm/insulator

warm air from 20° to 70°F

$Q = \dot{m} C_p \Delta T$ — heat transfer book

$$6400 \frac{FT^3}{min} \times \frac{1\,min}{60\,s} \times \frac{(.3048\,m)^3}{FT^3} \times \frac{1.1774\,kg}{m^3} \times \frac{1.0057\,kJ}{kg} \times \left(\frac{70-20}{1.8}\right)$$

= 99 KW per chamber

Material

	100 kW heater	$2346	TEMPCO
	Temp controller	$200	Grainger pg 535
	breaker upgrade	$1700	per LUTZ
	300 ft cable	$300	≈ $1/ft
	300 ft control cable	$300	"
	Misc	$50	
		$4900	

LABOR to mount heater, pull cables, and wire up.

$$2\,men \times 5\,days \times \frac{8\,hr}{day} \times \$25 = \$2000$$

total = 4900+2000 = 6900 / heater

× 2 per box

= $13,800/box

TEMPCO ELECTRIC HEATER CORPORATION

TEMPCO Electric Heater Corporation

607 North Central Ave., Wood Dale, Illinois 60191 U.S.A.

(708) 350-2252 • FAX: (708) 350-0232

COPY

January 26, 1996
Quote # 25863

American Electric Power

Dear Paul Eichenberger:

In reply to your request for quotation, we are pleased to offer the following:

Description	Quantity	Net Price Each
TDH100S5 Duct heater (60) elements, 3 phase Type 'J' thermocouple 100000 watts, 600 volts	2	$ 2,346.40
Setup charge: for duct heaters	1	$ 165.00

Delivery: Four to six weeks - OR PER YOUR REQUIREMENTS. PLEASE SPECIFY.

Terms: Net 30 days, subject to credit approval, F.O.B. our plant Wood Dale, IL U.S.A.

All prices, terms, and conditions of this quotation are in effect for a period of 60 days.

We sincerely appreciate this opportunity to quote on your electric heating element requirements, and we look forward to serving you in the near future.

Sincerely,

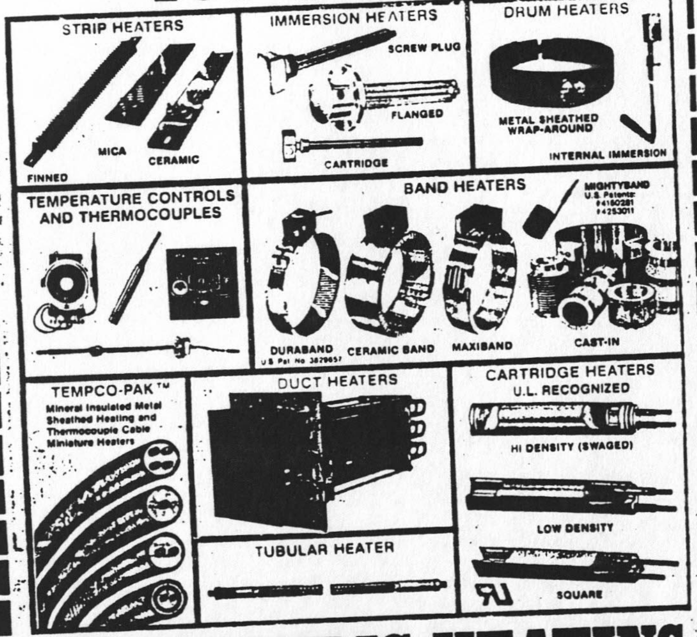
TEMPCO ELECTRIC HEATER CORPORATION

William Kilberry
Territorial Sales Manager

To: Paul A. Eichenberger/American Electric Power
cc:
From: Jerry D. Lutz/INM/American Electric Power
Date: 02-19-96 08:39:07 PM
Subject: Re: 600v MCC Contactors

Yes, it is possible, but I'm not sure a 200 amp breaker will fit in the MCCs. There are a number of issues which need be considered. Will the cables and load be protected by a 200 amp breaker? The breaker will probably cost around $1500 and labor may be $200 if all they are going to do is install it without other modifications.

TEMPCO OFFERS YOU QUALITY



IN ELECTRIC HEATING ELEMENTS

Tempco offers superior Electric Heating Elements of unique design and quality workmanship. Your every need was anticipated in the engineering of our products.

Through our research and development program, we are constantly striving to develop new ideas, innovations, and products.

Our engineering staff is available to assist you in selecting or solving your electric heater applications.

Tempco is out to prove that quality and service go together. May we have the opportunity to serve you.

SEE OUR CATALOG IN THE CATALOG FILE SECTION

All across the USA TEMPCO is only a phone call away™

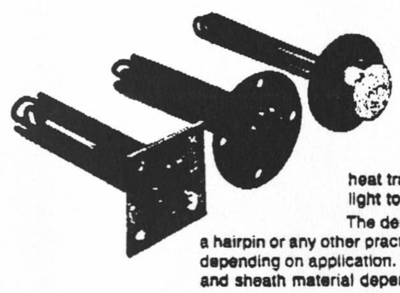
For Complete Product Line Catalog, Call or Write:

TEMPCO Electric Heater Corporation
607 N. Central Ave. • Wood Dale, IL 60191 • 708/350-2252 • Fax: 708/350-0232 • Call Toll Free 1-800-323-6859

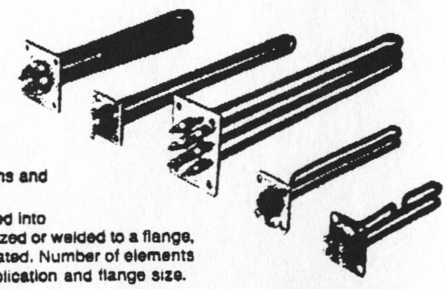
Industrial Process Heaters

TEMPCO ELECTRIC HEATER CORPORATION

NON-ASA SIZE FLANGED IMMERSION HEATERS



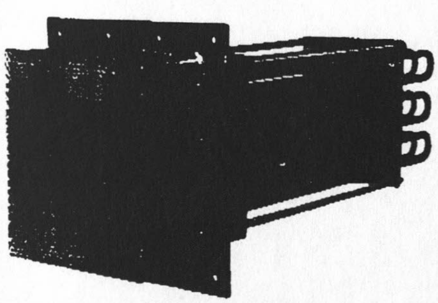
TEMPCO introduces Non-ASA size FLANGE IMMERSION heaters, providing an economical alternative to more expensive SCREW PLUG and pressure rated FLANGE IMMERSION heaters. For heating air, degreasing solutions, heat transfer fluids, water and water solutions and light to heavy oils.



The design consists of tubular heaters formed into a hairpin or any other practical configuration. They are silver brazed or welded to a flange, depending on application. Thermowells can also be accommodated. Number of elements and sheath material depend on the specific heater design, application and flange size.

TEMPCO OFFERS A WIDE SELECTION OF IMMERSION HEATERS IN STANDARD PHYSICAL DIMENSIONS, SHEATH MATERIALS AND ELECTRICAL RATINGS. WITH ROUND, SQUARE AND RECTANGULAR FLANGES—OR MADE TO YOUR SPECIFICATIONS. SEE PAGES 194 THROUGH 197.

PROCESS AIR DUCT HEATERS



DUCT heater designs consist of heavy wall .430 diameter tubular heaters formed into a hairpin and mounted to a heavy gauge steel frame. The elements are held in place by a quick-release removable bracket, providing element field replacement.

The outer mounting flange of the housing is factory pre-drilled for ease of installation.

A NEMA 1 terminal housing provides element wiring protection with steel perforated cover for air circulation.

Terminals and electrical wiring are heat insulated from the process temperature by 4" of mineral insulation located at the retainer box between the heated element section and the terminal housing.

Built-in thermowell for 1/4" diameter thermocouple provides element sheath temperature surveillance to prevent over temperature conditions.

DUCT heaters are rugged, compact and dependable, providing cleaner and safer low pressure heated air through forced air ducts at maximum temperatures of 750°F (399°C). Typical applications are annealing, core drying, heat-treating, sole heat source, booster heaters, forced air dryers, re-heating, dehumidification, curing and drying processes.

TEMPCO OFFERS A WIDE SELECTION OF DUCT HEATERS IN STANDARD PHYSICAL DIMENSIONS AND ELECTRICAL RATINGS—OR MADE TO YOUR SPECIFICATIONS. SEE PAGE 162 AND 163.

HOW TO ORDER

Establish the requirements of your process heating applications. Proceed to select the heater assembly that best meets the criteria of the application. For your assistance, consult the process heater selection guide. See pages 158 through 161. Once the type of heater required has been established, refer to the appropriate pages for a wide selection of standard sizes, physical dimensions and electrical ratings. State quantity, part number, watts, volts, and heater description with all the appropriate specifications. Thermostats and special terminal housings are optional. If required—SPECIFY. For sizes, ratings and style of heaters not listed, TEMPCO will manufacture process heating element assemblies to your specifications—CONSULT TEMPCO WITH YOUR REQUIREMENTS.

INSTALLATION RECOMMENDATIONS

(1) Establish the requirements of your process heating application. Select the heater assembly type, size, watt density, sheath material and electrical rating best suited for your application.

(2) Match the heater watt density (W/IN²) to the medium being processed.

(3) Match the sheath material and operating temperature to the medium being processed in order to avoid sheath corrosion and degredation of the medium.

(4) On large tanks, use several smaller K.W. rated heaters rather than one larger heater for uniform heat and watt density distribution.

(5) Heaters must be fully immersed at all times. Also, air flows must never be interrupted. Such events will cause over-heating and/or premature heater burn-out.

(6) Your installation should include low level liquid cutoffs or high limit temperature controls.

(7) Be sure that the heaters are securely mounted and protected from mechanical damage.

(8) Select the terminal housing that provides the best terminal protection for the environment surrounding the application.

(9) Thermostats are optional—Select the type and temperature rating required for the application. See page 170.

(10) Before you proceed to make any changes on factory prewired heaters—Check the heater wiring schematic or consult TEMPCO. All electrical wiring must be done in accordance with national and local electrical codes.

(11) If practical, heaters should be cleaned periodically in order to extend heater life.

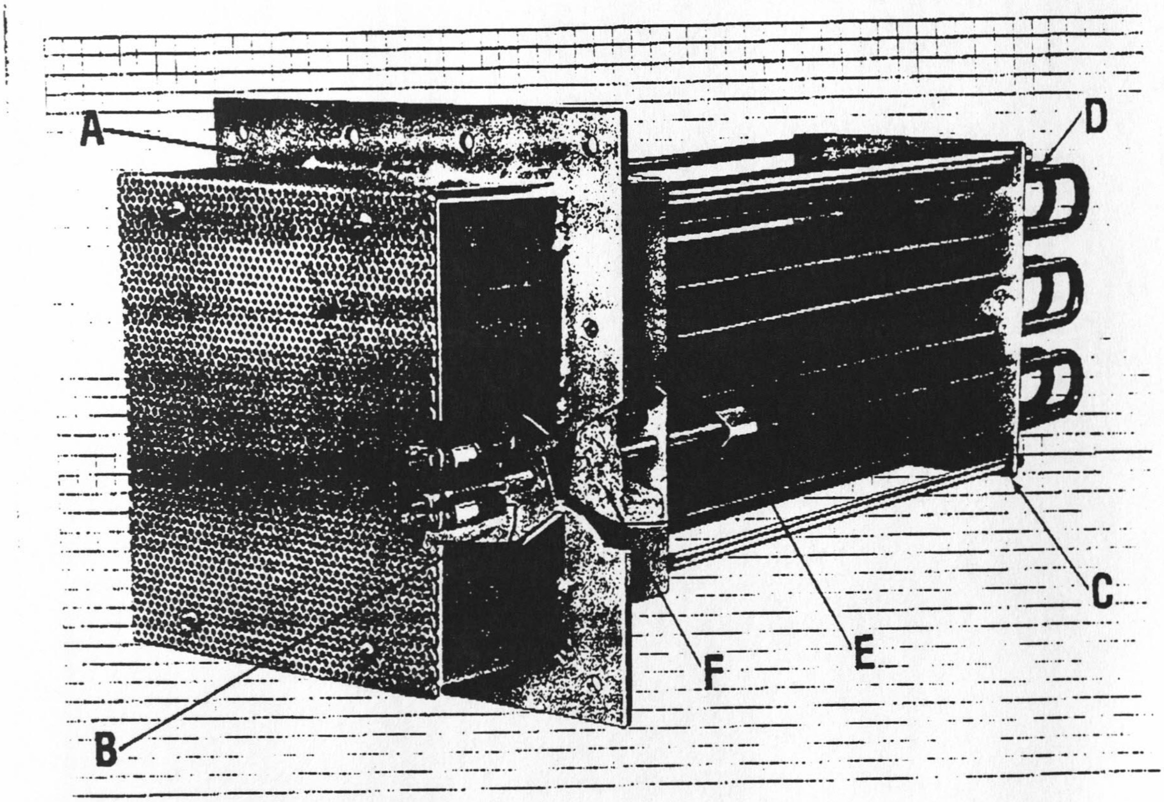
(12) If you should encounter any problems in selecting and/or installing a process heater—For [illegible]ance consult TEMPCO with your specific re[illegible]

TEMPCO ELECTRIC HEATER CORPORATION ®

Duct Heater Design Features

TYPICAL APPLICATIONS

- HEAT TREATING
- FORCED AIR DRYING
- BOOSTER AIR HEATERS
- RE-HEATING OR DEHUMIDIFICATION
- DRYING OPERATIONS
- SOLE HEAT SOURCE
- ANNEALING
- CORE DRYING



A Standard low profile NEMA 1 enclosure terminal box made from 12 gauge steel. The cover is vented with 1/16" perforations to help dissipate heat. Other NEMA rating enclosures available. Specify if required - NEMA 3, raintight—NEMA 4, waterproof—NEMA 7, explosion proof—NEMA 12, dust tight.

B The quick-release clamp consists of a single screw. It enables you to quickly replace individual tubular heaters.

C The heavy duty frame is composed of 1/4" thick steel mounting flange, .060" stainless steel support plate and four 3/8" diameter stainless steel support rods make for a very sturdy frame to rigidly support the tubular heating elements.

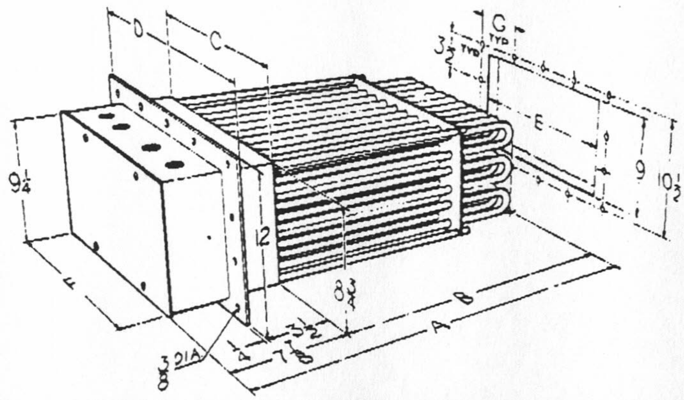
D The tubular heaters used are of special design construction consisting of heavy walled .430" diameter incoloy sheath for better corrosion resistance at high temperatures.

E Thermowell provides convenient access for accurate sheath temperature surveillance with a thermal cut-out device. The well's orifice is located in the terminal box. Thermal cut-out with Type J or K thermocouple provides very responsive input to the adjustable cut-out control. An excellent safeguard for your system.

F Four inches of special mineral insulation minimizes heat losses and keeps the electrical wiring at the terminal end cooler.

Duct Heaters Installation Recommendations

TEMPCO ELECTRIC HEATER CORPORATION ®



INSTALLATION:

1 TEMPCO DUCT heaters may be bolted to the ductwork in any position horizontally or vertically.

2 Whenever possible, it is recommended to be installed vertically up through the bottom of the ductwork. The temperature rise at the heater terminals will be minimized.

3 The inlet side of the unit must be at least 48" downstream from any duct size or direction change or from any air handling equipment outlet.

4 When necessary, DUCT heaters may be gauged in tandem along the same ductwork to combine any total wattage desired. Control devices for air flow, sail or pressure switches should be located on the inlet air side to protect the heaters against insufficient air flow.

5 For better temperature control, the thermocouple should be located near the exiting air stream.

MOUNTING:

1 Before mounting, consideration should be given to the strength of the ductwork required to support the weight of the heater.

2 DUCT heaters are screwed or bolted into place through the flange when installed vertically through the top of the duct. They are self supporting and sheet metal screws are sufficient.

3 When installed horizontally, if it is determined that the ductwork is not heavy enough to support the heater, a frame should be built to accept mounting holes on the flange of the DUCT heater.

WIRING:

1 A fused power supply of appropriate voltage and phase must be brought to the lugs in the terminal box.

2 The conductors must have a minimum ampacity of 125% of the maximum heater load.

3 The power circuit normally is required to include a branch circuit overcurrent protective device, a disconnect and a secondary thermal cut-out with manual reset.

4 The control circuit should include the temperature controller, the primary thermal cut-out and an interlock with the fan motor.

5 The most reliable and economical method to do this is with a pressure air flow switch. It will open the control circuit and de-energize the heater when any circumstance prevents sufficient air flow through the heater.

6 The air handler should run on a 10-15 second time delay after the heater is de-energized. This allows the elements to cool and prevents overheating the adjacent duct and terminal areas.

7 All wiring must be in accordance with the National Electric Code and applicable local codes.

MAINTENANCE:

1 Never perform any type of service on DUCT heaters prior to cutting off all power supply lines.

2 Periodically check that mounting screws or bolts have not become loose due to fan motor vibration.

3 DUCT heaters that sit idle for long periods of time should be step energized.

4 Periodically clean the terminals. Dust and corrosion can cause electrical shorts.

KW [illegible]	Number of [illegible]	Dimensions [illegible]							[illegible]	[illegible]	[illegible]	480 Volts [illegible] Phase	3-Phase
6	6	27 7/8	20	2 3/4	6 1/2	3	3 5/8	2 1/2	22	TDH6S10	TDH6S3	TDH6S11	TDH6S5
12	12	27 7/8	20	4 3/4	8 1/2	5	5 5/8	3 1/2	31	TDH12S10	TDH12S3	TDH12S11	TDH12S5
18	18	27 7/8	20	6 3/4	10 1/2	7	7 5/8	3	41	TDH18S10	TDH18S3	TDH18S11	TDH18S5
24	24	27 7/8	20	8 3/4	12 1/2	9	9 5/8	2 3/4	51	TDH24S10	TDH24S3	TDH24S11	TDH24S5
30	30	27 7/8	20	10 3/4	14 1/2	11	11 5/8	3 1/4	62	–	TDH30S3	TDH30S11	TDH30S5
36	36	27 7/8	20	12 3/4	16 1/2	13	13 5/8	3 3/4	73	–	TDH36S3	TDH36S11	TDH36S5
42	42	27 7/8	20	14 3/4	18 1/2	15	15 5/8	4 1/4	84	–	TDH42S3	TDH42S11	TDH42S5
48	48	27 7/8	20	16 3/4	20 1/2	17	17 5/8	4 3/4	95	–	TDH48S3	TDH48S11	TDH48S5
54	54	27 7/8	20	18 3/4	22 1/2	19	19 5/8	5 1/4	106	–	TDH54S3	TDH54S11	TDH54S5
60	60	27 7/8	20	20 3/4	24 1/2	21	21 5/8	5 3/4	117	–	TDH60S3	TDH60S11	TDH60S5
75	60	32 7/8	25	20 3/4	24 1/2	21	21 5/8	5 3/4	130	–	TDH75S3	TDH75S11	TDH75S5
100	60	40 3/8	32 1/2	20 3/4	24 1/2	21	21 5/8	5 3/4	155	–	–	–	TDH100S5
125	60	49 3/8	41 1/2	20 3/4	24 1/2	21	21 5/8	5 3/4	180	–	–	–	TDH125S5

MAXIMUM OUTLET TEMPERATURE IS 800°F (426.7°C). THIS OPERATING TEMPERATURE REQUIRES A MINIMUM AMOUNT OF AIR VELOCITY OF 200 FEET PER MINUTE. LOWER VELOCITIES WILL RESULT IN PREMATURE TUBULAR HEATER FAILURE AND POSSIBLE DAMAGE TO INSTALLATIONS.

SHEET ______ OF ______

DATE ________ BY ____________

DEPARTMENT ____________

AEP INDIANA MICHIGAN POWER

SUBJECT Heater Power Usage

From Mark's Handbooks ≈ 4500 degree-days / year

4500° days over 6 months = 25°/day

Per box $Q = m c_p \Delta T$

$12{,}800 \frac{FT^3}{min} * \frac{1 min}{60 s} * \frac{(.3048^3) m^3}{FT^3} * \frac{1.1774 Kg}{m^3} * \frac{1.0057 KJ}{Kg K} * \left(\frac{25}{1.8}\right) K$

$= 99.3$ KW / day

$99.3 KW * \frac{24 hrs}{day} * \frac{.02}{KWH} * 180 days = \$8600$/yr/box

??

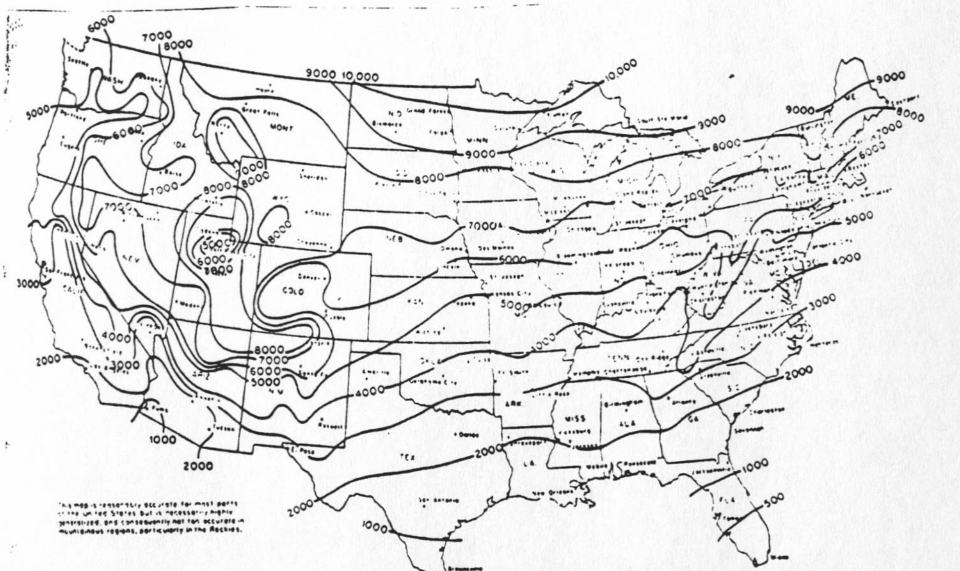


Fig. 3 Number of degree-days in a normal heating season. To convert degree-days (K), multiply by 5/9. [*C. Strock and R. L. Koral (eds.), "Handbook of Air Conditioning, Heating and Ventilating," 2d ed., Industrial Press, New York, 1965.*]

MARKS HANDBOOK MECHANICAL ENGINEERING

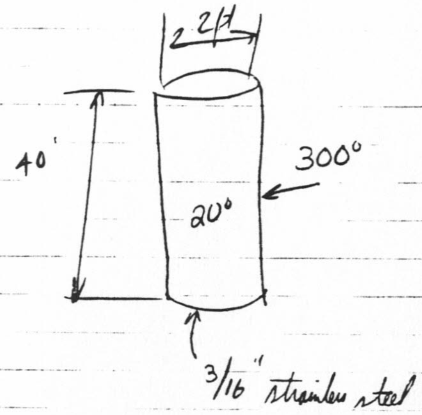
8TH EDITION, Pg 12-71

INDIANA MICHIGAN POWER

DATE ______ BY ______

DEPARTMENT ______

SUBJECT: Optimum heat duct performance

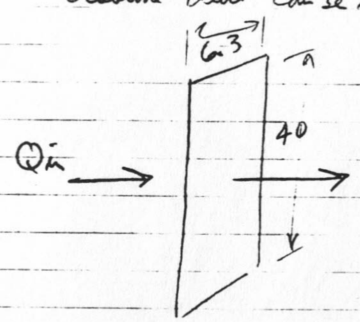


Design for max heat transfer

assume a constant 20° inside and 300° outside

use max convection constant

assume duct can be split into a flat plate



$A = 6.3 \times 40 = 250\ ft^2$

Q_{in} through metal = Q_{out} pick up by air

$$\frac{\Delta T}{\Sigma R} = \dot{m} c_p \Delta T$$

$$\frac{\Delta T}{\Sigma R} = \frac{(300-20)}{\frac{1}{ha} + \frac{L}{KA} + \frac{1}{ha}} =$$ heat transfer with convection + conduction + convection

conduction for SS steel

$$= \frac{280}{\frac{1}{\frac{50\ BTU}{FT^2 F} \times 250 ft} + \frac{3/16 \div 12}{\frac{20\ BTU}{FT^2 F} \times 250 ft^2} + \frac{1}{\frac{50\ BTU}{FT^2 F} \times 250 ft^2}} = 1,716,475\ BTU$$

heat transfer book

AEP INDIANA MICHIGAN POWER

SHEET ____ OF ____

DATE ____ BY ____

DEPARTMENT ____

SUBJECT ____

1,716,475 BTU = $Mc_p \Delta T$

to heat all air for one box

$$1{,}716{,}475 \text{ BTU} = 12800 \frac{FT^3}{min} \times 60 min \times .0735 \frac{lb}{FT^3} \times .24 \frac{BTU}{lb\,F} \times (T_2 - 20)$$

$T_2 = 147°$

∴ Temp increase of ≈ 127°

2nd ADDITION HEAT TRANSFER
KARLEKAR, DESMOND

fluid flow, and fluid properties. The convective heat transfer coefficient will be discussed in greater detail in Chapter 8. Table 1-2 gives estimates for convective heat transfer coefficients under different conditions.

The concept of thermal resistance for convective heat flow can be introduced in a manner similar to that which was presented for heat conduction through a wall. Starting with the general equation for convective heat transfer

$$Q = hA(T_s - T_\infty)$$

and rewriting it in the form

$$Q = \frac{T_s - T_\infty}{(1/hA)}$$

we note that the current flow is Q, the driving force is $(T_s - T_\infty)$, and since

$$Q = \frac{\Delta T_{\text{overall}}}{\Sigma R_{\text{th}}}$$

the thermal resistance for convection must be equal to $(1/hA)$. (See Figure 1-10.)

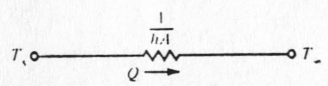


Figure 1-10 Convective resistance for electrical analog.

TABLE 1-2 Representative Values of the Convective Heat Transfer Coefficient

Condition	h Btu/hr ft^2 °F	h W/m^2·°C
Air, free convection	1–3	5–15
Air or superheated steam forced convection	3–50	15–300
Oil, forced convection	10–300	50–1700
Water, forced convection	50–2,000	300–12,000
Water, boiling	500–10,000	3000–55,000
Steam, condensing	1,000–20,000	5500–100,000

AEP INDIANA MICHIGAN POWER

SHEET ______ OF ______

DATE ________ BY ________________

DEPARTMENT ________________

SUBJECT Rapper supply

Trial installation was $10,200. Seem expensive

material = ≈ 60 feet 24"Ø duct ≈ $4/ft

= 60ft × 4 = $240

labor 3 man × 8hr/day × 4 days × $25/hr = 2400

Total = 240 + 2400

= $2600

SHEET ____ OF ____

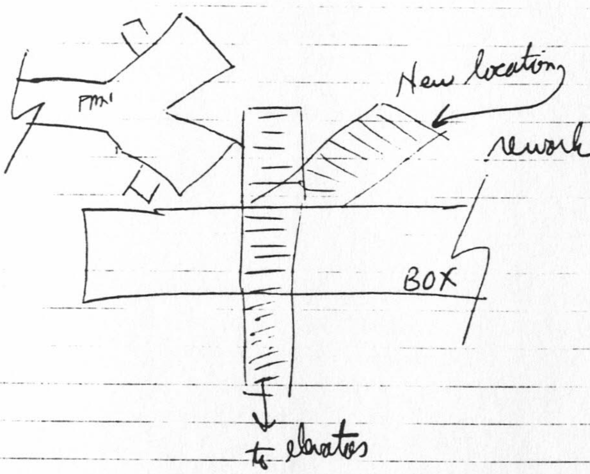
DATE ____ BY ____

DEPARTMENT ____

AEP INDIANA MICHIGAN POWER

SUBJECT Relocating Stairway

2 men × 2 days × 8 hr/day × $25/hr = $400



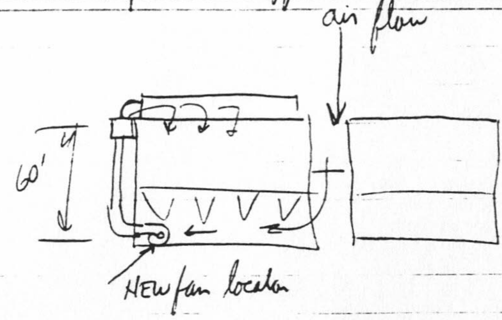
AEP INDIANA MICHIGAN POWER

SHEET ______ OF ______

DATE ______ BY ______

DEPARTMENT ______

SUBJECT Moving fans to hopper area



Material 60 feet 18" x 22" Inside dimension fiberglass duct

≈ $7/ft = $424

total = $820

MISC $100 - nuts, bolt, gasket

300 ft cable @ $1/ft = 300 $

Labor 3 men × 7 days × 8hr/day × $25/hr = 4200

Remove exhaust fans 2 men × 8 hrs × 2 days × $25 = $800

total cost = 820 + 4200 + 800

= $5800

39

SHEET ____ OF ____

DATE ____ BY ____

DEPARTMENT ____

AEP INDIANA MICHIGAN POWER

SUBJECT Subjective Savings

→ heater failure rate

120 used over 2 years for 8 boxes

= 7.5 per year per box, but not all have be repaired to the large number.

∴ use 10 heaters per box per year

10 heaters × [($125 matls) + (3hr labor × $25/hr)]

= $2000/year, box

→ heater power usage

64 field/box × 4 heaters/field × 760 w/heater = 195 KW max power

~~assume~~ ~~be~~ most heaters stay on 100% now

assume 50% cycle time after repairs.

195 KW × 24 hrs/day × 365 days/yr × $.02/KWH × .9 × 50% reduction

= $15,400 yr.

INDIANA MICHIGAN POWER

SHEET ____ OF ____

DATE ____ BY ____

DEPARTMENT ____

SUBJECT ____

→ Component Corrosion - no data available. No savings can be calculated

→ Preventing hopper overheating

7 hoppers being rebuilt every 2 years @ $900

$= \frac{7 * 900}{2} = 3150$ yr

Normal life ≈ 5 years $= \frac{7 * 900}{5} =$ $1260 yr

3150 - 1260 = $1900 yr

→. Saving due to better precip performance.

difficult to measure

assume 2% reduction in power

from Precip DCU

$\frac{220\,KW}{2\,BOX} = \frac{110\,kw}{box} * \frac{24\,hr}{dy} * \frac{365\,dy}{yr} * .02 * 365 * .02 * 9$

= $350/yr

→ Vent fan aux power savings

$$\frac{4 \text{ fans}}{2 \text{ Boxes}} * \frac{1}{2} \text{ HP} * \frac{.746 \text{ KW}}{\text{HP}} * \frac{24 \text{ HR}}{\text{day}} * \frac{365 \text{ day}}{\text{yr}} * .9 * \frac{\$ .02}{\text{KWH}}$$

$$= \$120/\text{yr}$$

→ reduction in fan maint

assume hours saved each month per box

$$2 * 25 * \frac{12 \text{ mont}}{\text{yr}} = \$600/\text{yr}$$

→ Total Savings

	FAN PWR	Heater Pwr / Heater Failure	Htr PWR	RPR FAILE	PRECIP PERFOR	AUX FAN	TAN MAN
1	1650 -860	2000	15400	X	X	X	
2	1650 -860	2000	15400	X	X	X	
3	10,200 -860	2000	15400	X	X	X	
4	5900 -860	2000	15400	X	X	X X	
5	5900	2000	15400	X	X	X	X
6	5900	2000	15400	1900	350	120	600

TOTAL. (1) 10450 (3) 19000 (5) 23300

(2) 10450 (4) 14700 (6) 26270