COLD-SIDE CONVERSION OF COUNCIL BLUFFS ENERGY CENTER UNIT 3 PRECIPITATOR

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1. Abstract

Midwest Power is currently in the design and material procurement phases of converting the Council Bluffs Energy Center Unit 3 precipitator from hot-side to cold-side operation. Burns & McDonnell has been hired to provide engineering, design, material procurement, construction, testing, start-up and training services. Engineering work began in June 1992. The unit outage for the cold-side conversion is scheduled from August 28 through December 19, 1993. The benefits of the cold-side conversion will be to 1) extend the life of the existing precipitator and to 2) eliminate the need to take the unit out of service every three to four months to clean the precipitator. This paper summarizes the reasons for converting the precipitator to cold-side operation and presents the engineering, design and other tasks required to complete the project.

2. Background

Midwest Power's Council Bluffs Energy Center Unit 3 is a 745 MW unit burning Powder River Basin coal. The unit began commercial operation in 1978. Unit 3 has four weighted-wire precipitators arranged in a stacked configuration (two upper and two lower). The hot-side design specific collection area (SCA) of the precipitator is 333 ft^2/1000 acfm. There are eight electrical fields and the nominal operating temperature is 800 degrees F. The original design life of the precipitator was 20 years. Figure 1 shows an elevation view of the precipitator at Council Bluffs Unit 3.

Midwest Power decided to convert the Unit 3 precipitator from hot-side to cold-side operation because of precipitator and ductwork structural degradation and because of performance problems with the precipitator. Refer to Figure 2 for a flow schematic showing the hot-side and cold-side configurations of the boiler, precipitators and air heaters.

2.1 Structural Degradation

The precipitator and inlet and outlet ducts were fabricated out of ASTM A242, Type I steel. The remainder of the ductwork was fabricated out of ASTM A588 steel. These are both high-strength, low-allow steels having a minimum yield strength of 50 ksi. Based on the results of metallurgical testing, the precipitator and ductwork plate at Council Bluffs Unit 3 has become embrittled over the past 14 years due to long-term exposure to hot-side operating temperatures. Temper embrittlement of high-strength, low-allow steels is caused by heating, holding, or slow cooling in the temperature range from 600 to 1150 degrees F. Temper embrittlement causes an increase in the ductile-to-brittle fracture transition temperature and drastically reduces the notch toughness of the material. Temper embrittlement in a hot-side precipitator is irreversible.

During unit start-up and shutdown, the thermal gradients across a hot-side precipitator can be as high as 350 degrees F. Because not all of the steel heats up or cools down at the same rate. The thermal stresses developed during nonuniform heating and cooling cause the embrittled steel to crack and internal bracing members to buckle. The cracking and bowing becomes an ongoing maintenance problem. If left to accumulate, the local damage can turn into major damage that could cause the precipitators to be taken out of service for replacement.

In order to determine how much the existing precipitator and ductwork plate has deteriorated over time, Midwest Power had two groups of steel samples tested in 1988 and in 1990. The material samples were subjected to chemical analysis, tension testing, charpy impact testing and metallographic examination.

In 1988, 50 percent of the steel samples tested were found to be embrittled. However, in 1990, 100 percent of the steel samples tested at that time were found to be embrittled. The charpy impact testing revealed significant increases in toughness after the de-embrittlement heat treatment (1250 degrees F for one hour). Although the testing program involved only a limited number of steel samples, it appeared that the ductwork material was becoming more embrittled over time.

In 1992, Midwest Power had tests performed to determine the ductile-to-brittle transition temperature and the upper shelf temperature of the precipitator and ductwork steel. The ductile-to-brittle transition temperature is the temperature at which the material changes its fracture mode from a ductile to a brittle fracture mode. The upper shelf defines a plateau in energy where further increases in temperature will not affect a material's ability to absorb energy. If a component is known to be operating in the upper shelf temperature range, no additional benefit in fracture toughness would be gained by increasing the operating temperature.

Based on the testing performed, the A242 steel is significantly more embrittled than the A588 steel. According to the test results, the ductile-to-brittle transition temperature for the A588 material is 75 degrees F and the upper-shelf temperature is 150 degrees F. The ductile-to-brittle transition temperature for the A242 material is 160 degrees F and the upper-shelf temperature is 200 degrees F. Because subsize specimens were used in the test program, the testing lab estimated that the actual transition temperature for the A242 steel may be as high as 200 degrees F and the upper-shelf temperature as high as 300 degrees F.

The expected cold-side operating temperature of 300 degrees F is in the upper-shelf temperature range. Thus, the toughness of the material will provide adequate safety margin against brittle fracture in the presence of cracks. However, the testing lab recommended repairing any large cracks detected by non-destructive examination by using appropriate weld repair procedures.

The testing lab stated that peak embrittlement normally occurs at about 800 degrees F, which is the current operating temperature upstream of the air heaters. Also, based on the phosphorus contents and the in-service time, these plates probably have reached maximum embrittlement and any prolonged service exposure at 800 degrees F is not expected to further increase the ductile-to-brittle transition temperature.

To date, the cracking problem has been manageable. However, Midwest Power was concerned about the structural integrity of the precipitator over the next 20 to 30 years. Converting the precipitator from hot-side to cold-side operation will reduce the differential thermal stresses, prevent further structural degradation, and allow continued use of the existing precipitator and ductwork for an additional 20 to 30 years.

2.2 Precipitator Performance

When the precipitator plates and wires are clean, opacity of Unit 3 has been as low as 7 percent. After several days of continuous operation at full load, the plates and wires build up a layer of fly ash and opacity gradually increases. Usually, within three to four months of precipitator cleaning, the opacity approaches the permitted limit of 20 percent and Midwest Power must take Unit 3 off line to clean the precipitator. Each outage typically lasts about four days.

The build-up of fly ash on the plates and wires has been attributed to a phenomenon called sodium ion depletion which has been found to occur at hot-side temperatures of 800 degrees F. It is expected that, operating at a cold-side temperature of 300 degrees

F and with SO_3 flue gas conditioning, the precipitator will be capable of continuous operation within the permitted opacity limits.

2.3 Previous Repair/Improvement History

Prior to considering a cold-side conversion, Midwest Power tried several precipitator improvements and repairs to help keep the precipitator plates and wires clean. Some of the repairs and improvements made are included below:

- Replaced all original rappers with either gravity impact or pneumatic rappers.
- Added new rapper controls in the first four fields.
- Replaced precipitator voltage controls in the first two fields.
- Straightened all plates, except for leading and trailing edges, in the first two fields.
- Replaced all wires in the precipitator.
- Added a puffer pipe system in all four of the precipitator inlet ducts.

Some improvement in the precipitator performance was gained with these repairs and modifications. However, the precipitator still had problems meeting opacity compliance.

2.4 Cost

Estimated cost of the project in 1992/93 dollars is $16 million. This amount includes:

1. Midwest Power engineering.
2. Consulting engineering.
3. Flow model study.
4. Structural steel demolition and erection.
5. Ductwork demolition and erection.
6. Ductwork insulation and lagging.
7. Expansion joints.
8. Precipitator hopper heaters.
9. Precipitator penthouse pressurizing air heaters.
10. SO_3 flue gas conditioning system.
11. Electrical equipment.
12. Air heater baskets.
13. Contingency.
14. Midwest Power overhead.

2.5 Economic Justification

Midwest Power's primary reasons for converting the Unit 3 precipitator to cold-side operation are the operating and structural problems described earlier. In addition to the technical benefits of the cold-side conversion, there are three primary economic benefits:

1. Saving $2.2 to $3.7 million per year in production cost benefits associated with the elimination of precipitator cleaning outages.
2. The cold-side conversion had the smallest revenue requirements, the greatest present value and an acceptable amount of technical risk when compared to the other options for alleviating the precipitator performance and structural problems. The options considered included:
   a. Make no repairs or modifications to the precipitators and continue with present hot-side operation. Install baghouses at the end of the original 20-year design life for the precipitators.
   b. Perform repairs, materials testing, and structural modifications. Continue with hot-side operation. Assume that precipitators have a 30-year design life.
   c. Convert precipitators to cold-side operation using a multiple-contracts project approach.
   d. Convert precipitators to cold-side operation using a turnkey project approach.
3. The net gain in plant heat rate after the cold-side conversion is estimated to be 124 btu/kwhr. See Table 1 for a list of plant parameters that affect heat rate before and after the cold-side conversion.

3. Study Phase

In 1989, Midwest Power hired Burns & McDonnell to provide technical and economic information needed to evaluate the feasibility of converting the precipitator from hot-side to cold-side operation.

The results of Burns & McDonnell's study were:

- The conversion of the Unit 3 precipitators to cold-side operation is technically feasible.
- Opacity under cold-side operation would remain below 20 percent and would eliminate the need for plant outages to clean the precipitator.
- The structural problems caused by differential thermal stresses and temper embrittlement would be greatly reduced under cold-side operation.
- Boiler efficiency would improve by 1 percent.
- Plant heat rate would be reduced by 124 Btu/kWh.

- An SO_3 flue gas conditioning system should be installed to ensure opacity compliance with a wide range of fuels.

4. Project Approval

In February 1992, a Midwest Power task force recommended to Midwest Power management that the Unit 3 precipitator be converted from hot-side to cold-side operation. The task force was made up of engineering personnel who had been involved in maintaining and making previous capital improvements to the precipitator. In June 1992, the project was approved by Midwest Power's management.

5. Engineering

5.1 Turnkey vs. "Multiple Contracts"

During the approval stage of the cold-side conversion project, Midwest Power decided to hire a consulting engineer and to use a "multiple contracts" approach for material procurement and construction. The multiple contracts approach was chosen over the "turnkey" approach which involves hiring one company to perform engineering, fabrication and erection. The recommendation to use the multiple contracts approach was made because 1) Midwest Power would be more involved in the engineering and design phases of the project, 2) Midwest Power would have more control over the selection of equipment suppliers and the installation contractor, 3) Midwest Power would save the cost of the turnkey contractor markups, 4) the overall project schedule would be reduced and 5) a performance guarantee on the precipitator would be provided by the SO_3 system vendor.

Now that several cold-side conversions have been successfully completed, Midwest Power felt using a turnkey approach was not worth the additional cost. It is estimated using the multiple contracts approach will save Midwest Power approximately $1.4 million versus having the work performed on a turnkey basis.

5.2 Midwest Power Project Team

Midwest Power formed a project team consisting of a project manager from the generation engineering department, representatives from the mechanical maintenance department, electrical maintenance department and plant management. The purpose of the project team is to keep plant personnel involved in the decision process. The project team provides design input, makes design decisions and helps select vendors for material procurement contracts.

5.3 *Consulting Engineer*

In June 1992, Burns & McDonnell Engineering was selected to assist Midwest Power with the engineering and design required for the cold-side conversion.

Burns & McDonnell's work scope for the project includes the following:

- Planning, scheduling and progress reporting.
- Engineering and design for ductwork, structural steel, expansion joints, electrical equipment, penthouse pressurizing air heating system and hopper heaters.
- Write specifications needed to obtain third party services including model study, precipitator inspection, general construction and precipitator repairs.
- Perform inspections of the air heater, precipitator and associated ductwork.
- Provide construction management and inspection services.
- Provide start-up, testing and training services.
- Perform project closing services including completing as-built drawings, updating instruction books and microfilming of project drawings.

5.4 *Project Schedule*

Engineering began in June 1992. Pre-outage construction will begin in June 1993. The construction for the cold-side conversion is scheduled to begin August 28, 1993 and to conclude December 4, 1993. See Figure 3 for the complete project schedule.

The critical path activity for the engineering phase of the project is the design of the ductwork and structural steel changes needed to accomplish the cold-side conversion. Ductwork and structural steel design work began in July 1992 and ended in January 1993 with the bidding of the ductwork and structural steel procurement contract.

5.5 *Ductwork General Arrangement*

The changes in the ductwork needed to convert the Unit 3 precipitator from hot-side to cold-side operation are indicated on Figures 4 and 5. To show the differences between the existing hot-side arrangement and proposed cold-side arrangement, Burns & McDonnell constructed the two cardboard models as seen in Figure 6. The ductwork arrangement chosen requires the least amount of existing ductwork to be demolished and the least amount of new ductwork to be installed. This is important in terms of minimizing the unit outage time and construction costs.

The stacked arrangement of the precipitators make the demolition of the existing ductwork and erection of the new ductwork and difficult because access for large cranes is limited, because the economizer to air heater ductwork is located inside of the boiler enclosures, and because of the configuration of the new ductwork (sloping transitions between sections of existing ducts).

5.6 Air Quality Construction Permit

In December 1992, a permit to make modifications to Unit 3's precipitator and to add an SO_3 flue gas conditioning system was applied for with the Iowa Department of Natural Resources. In Iowa, such a permit is required whenever pollution control equipment is installed or modified. The permit is expected to be issued to Midwest Power by June 1, 1993. Table 2 below shows the expected emissions of Unit 3 before and after the cold-side conversion. Only particulates are expected to change as a result of the precipitator cold-side conversion.

6. Equipment and Material Procurement

The items to be purchased by Midwest Power for the cold-side conversion include the following:

- Flue gas conditioning system.
- Precipitator automatic voltage controls (AVCs).
- Electrical power distribution equipment.
- Precipitator penthouse pressurizing air heating system.
- Ductwork and structural steel.
- Ductwork expansion joints.
- Air heater heating elements (baskets).

6.1 Flue Gas Conditioning System

In September of 1992, Midwest Power placed an order with Wahlco, Inc. for an SO_3 flue gas conditioning system. The SO_3 system is designed for an injection rate of 20 ppm and is scheduled to ship in June 1993. Wahlco has provided a guarantee stating the precipitator will maintain opacity and particulate emissions within permitted limits.

The specific collection area (SCA) of the Unit 3 precipitator as a cold-side unit will be 500 ft^2/1000 acfm. Based on precipitator performance models with the Powder River Basin coals Midwest Power plans to burn, Midwest Power should be able to operate the SO_3 system intermittently. According to Wahlco, Midwest Power may have to operate the SO_3 system continuously at an injection rate of 5 to 8 ppm to maintain the precipitator in a clean condition.

In order to guarantee that the Unit 3 opacity will remain within permitted limits during cold-side operation, Midwest Power decided to install flue gas conditioning.

6.2 Automatic Voltage Controls

In December 1992, Midwest Power placed an order for new precipitator automatic voltage controls (AVCs) and an energy management system from Forry, Inc. The new controls will be used to replace 72 original AVCs and 24 microprocessor-based AVCs installed in 1987. The new AVCs will help reduce wire breakage and will provide better spark control at the higher voltages required for cold-side operation. The new controls will be installed in 1993 prior to the cold-side conversion outage.

6.3 Electrical Equipment

In order to supply power to the new precipitator hopper heaters and the new purge air heating system, Midwest Power will be purchasing a new 6900- to 480-volt secondary unit substation transformer and two new 480-volt motor control centers.

6.4 Penthouse Pressurizing Air Heating System

As part of the cold-side conversion, Burns & McDonnell recommended that Midwest Power install electric heaters for the existing precipitator penthouse pressurizing air fans. Controls for the heaters and new controls for the fans will also be installed.

The pressurizing air heaters will be used primarily during unit start-up and during low load conditions when heated air is needed to keep the high-voltage wire insulators dry and to help prevent sulfuric acid from condensing on the precipitator hot roof (see Figure 7).

6.5 Hopper Heaters

With the precipitator operating at a hot-side temperature of 800 degrees F, moisture in the hoppers during start-up is driven out due to the relatively high temperature flue gas. During normal operating conditions, the fly ash collected is hot enough to flow freely from the precipitator hoppers.

After the precipitator conversion, it will operate at a temperature of 300 degrees F. During start-up there is not enough heat in the precipitator hoppers to keep moisture from condensing on the hopper walls. When fly ash combines with moisture at low temperatures, the fly ash could solidify and plug the hopper throat. To prevent the problem of moisture condensing on the hopper walls during start-up and to help prevent the fly ash from plugging the precipitator hoppers, Midwest Power will install hopper heaters on all 48 of its precipitator hoppers.

The hopper heater control system includes a single thermocouple located near the bottom of each hopper. The temperature controller has a single temperature setpoint near 300 degrees F. Whenever the hopper temperature is below 300 degrees F, all heaters on the hopper will be energized. The power for each hopper's heaters will be controlled by a silicon controlled rectifier (SCR) to help prolong the life of the heaters and to help save energy by modulating the power to the heaters when there is sufficient heat in the hoppers to keep the fly ash near 300 degrees F.

6.6 Ductwork and Structural Steel

Approximately 739 tons of new ductwork will be fabricated and supplied by the ductwork and structural steel vendor. Upstream of the air heaters, the new ductwork will be made from ASTM A572, Grade 50 steel. Downstream of the air heaters, the new ductwork will be fabricated from ASTM A36 steel. Approximately 311 tons of new structural steel and miscellaneous steel will be fabricated and supplied by the ductwork and structural steel vendor.

6.7 Expansion Joints

Twenty four new ductwork expansion joints will be installed during the course of the ductwork erection. Because Unit 3's new operating temperature is being decreased from 800 degrees to 300, the cold-side expansion joints will be fabricated from 1/4-inch-thick Viton material. Midwest Power expects to reduce pressure loss in the ductwork by 2.0 to 3.5 inches W.C. by eliminating the flow liners at the ID fan inlet expansion joints.

6.8 Air Heater Baskets

One of the disadvantages of converting Unit 3's precipitator from hot-side to cold-side operation will be the increased ash loading on the air heater. The increased loading occurs because 100 percent of the fly ash will pass through the air heater. Unit 3 has two trisector air heaters with dense pack heating elements (baskets). The baskets have never been replaced and the air heaters have not required cleaning since their soot blowers were relocated from the gas side to air side of the air heaters in 1984.

The original manufacturer inspected the air heater and recommended the dense pack baskets be replaced with loose pack baskets. The recommendation was based on past operating history of other hot-side units converted to cold-side operation. All of the previously converted units either installed loose pack baskets before their cold-side conversion or did so shortly after because of pluggage problems experienced with dense pack baskets.

Midwest Power decided to replace the existing dense pack baskets with loose pack baskets in order to minimize the number of future outages needed to clean air heater and because the baskets had never been replaced. Midwest Power will also be moving the air heater soot blowers back to their original location on the gas side of the air heaters.

7. Construction

The construction phase of the hot-side to cold-side conversion will be carried out by a general contractor hired by Midwest Power. Burns & McDonnell will provide construction management services to help ensure the general construction work is carried out in accordance with the specifications, within the agreed upon price and within the schedule specified by Midwest Power.

Pre-outage construction is scheduled to begin June 1, 1993. Construction for the cold-side conversion outage work is to begin August 28, 1993 and end December 4, 1993. The general contractor will be given 14 weeks to complete the essential part of the work. The cold-side conversion work is the critical path activity for the Unit 3 outage. The Unit 3 control system will also be replaced during the same outage.

8. Conclusion

Midwest Power's decision to convert the Council Bluffs Energy Center Unit 3's precipitator from hot-side to cold-side operation is based on the need to extend the life of the precipitator for an additional 20 to 30 years. The economics of avoiding up to four 4-day precipitator cleaning outages also helped justify converting the precipitator to cold-side operation.

By using the multiple contracts approach rather than hiring a single turnkey contractor to do design, procurement and construction, Midwest Power will have more control over the project and can complete it at a lower total cost.

The past success of other precipitator conversions allows Midwest Power to make its conversion with confidence that the Unit 3 precipitator will perform reliably and economically for many years to come.

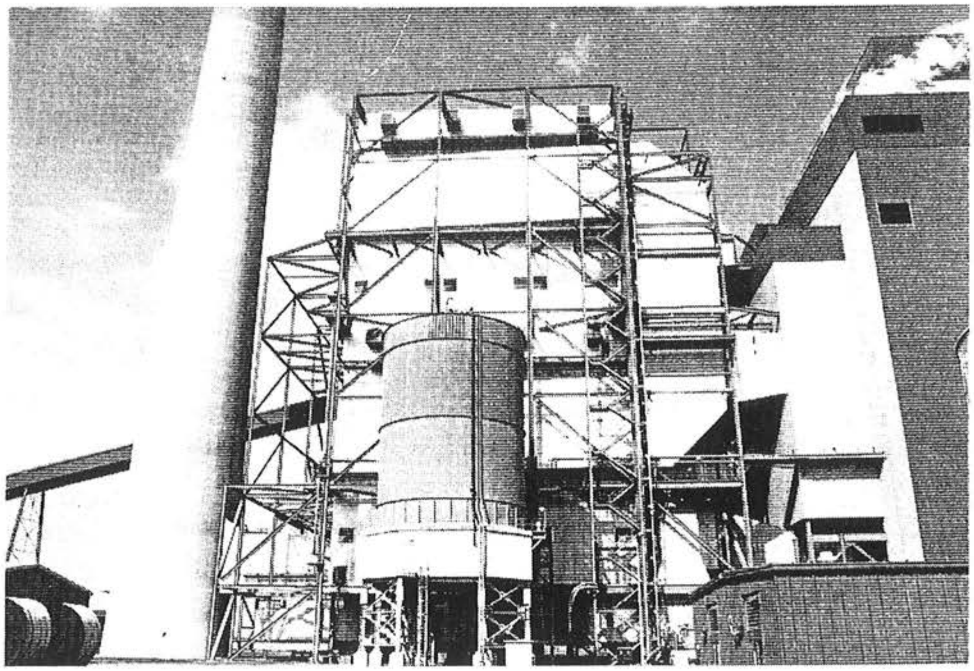
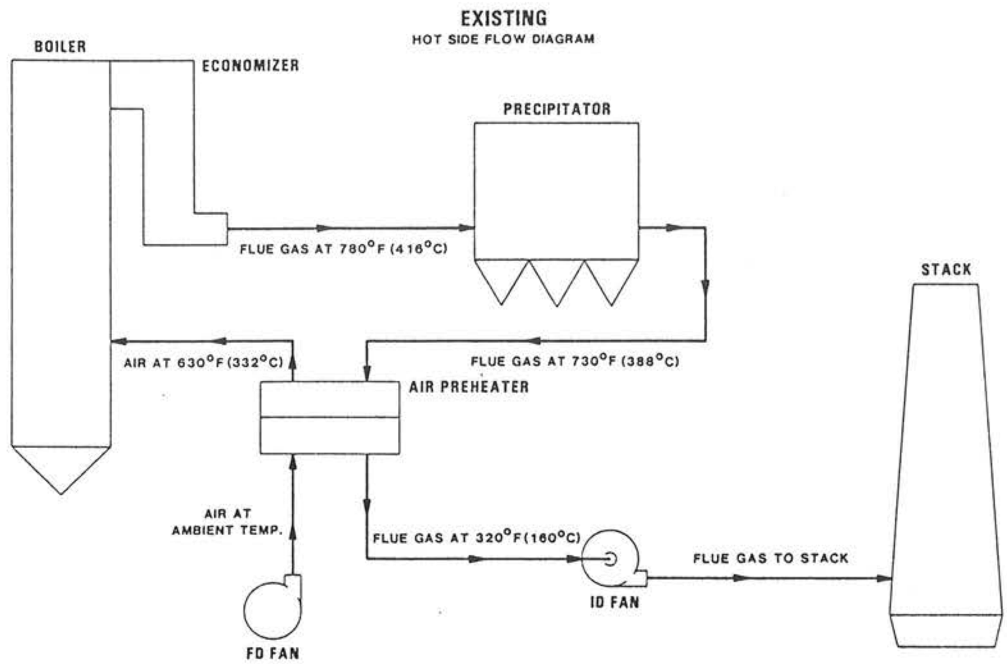


FIGURE 1
COUNCIL BLUFFS ENERGY CENTER
UNIT 3 PRECIPITATOR

Wahlco Flue Gas Conditioning



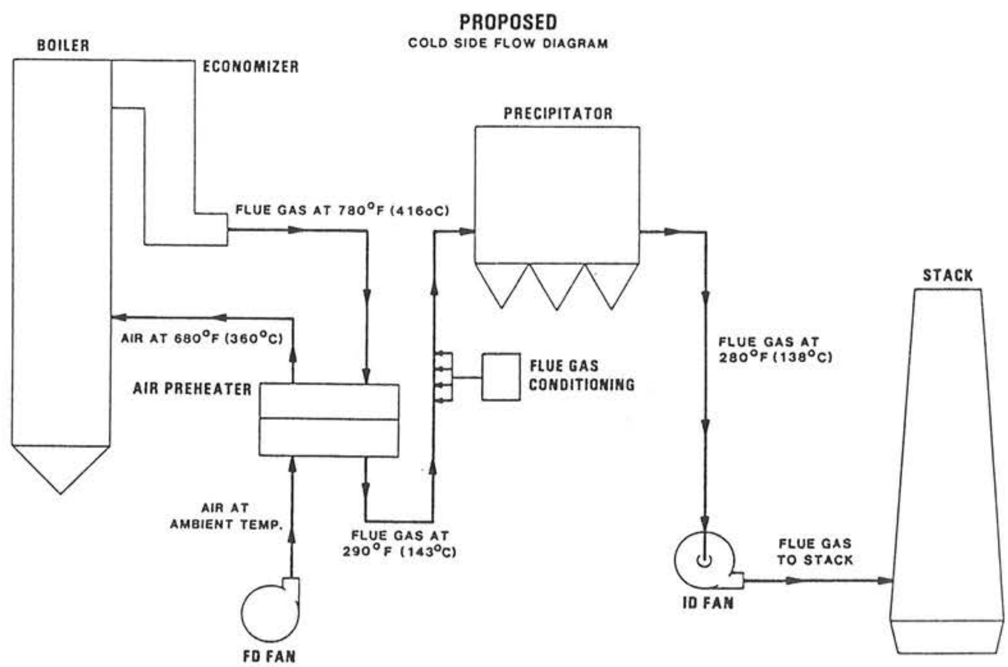


FIGURE 2

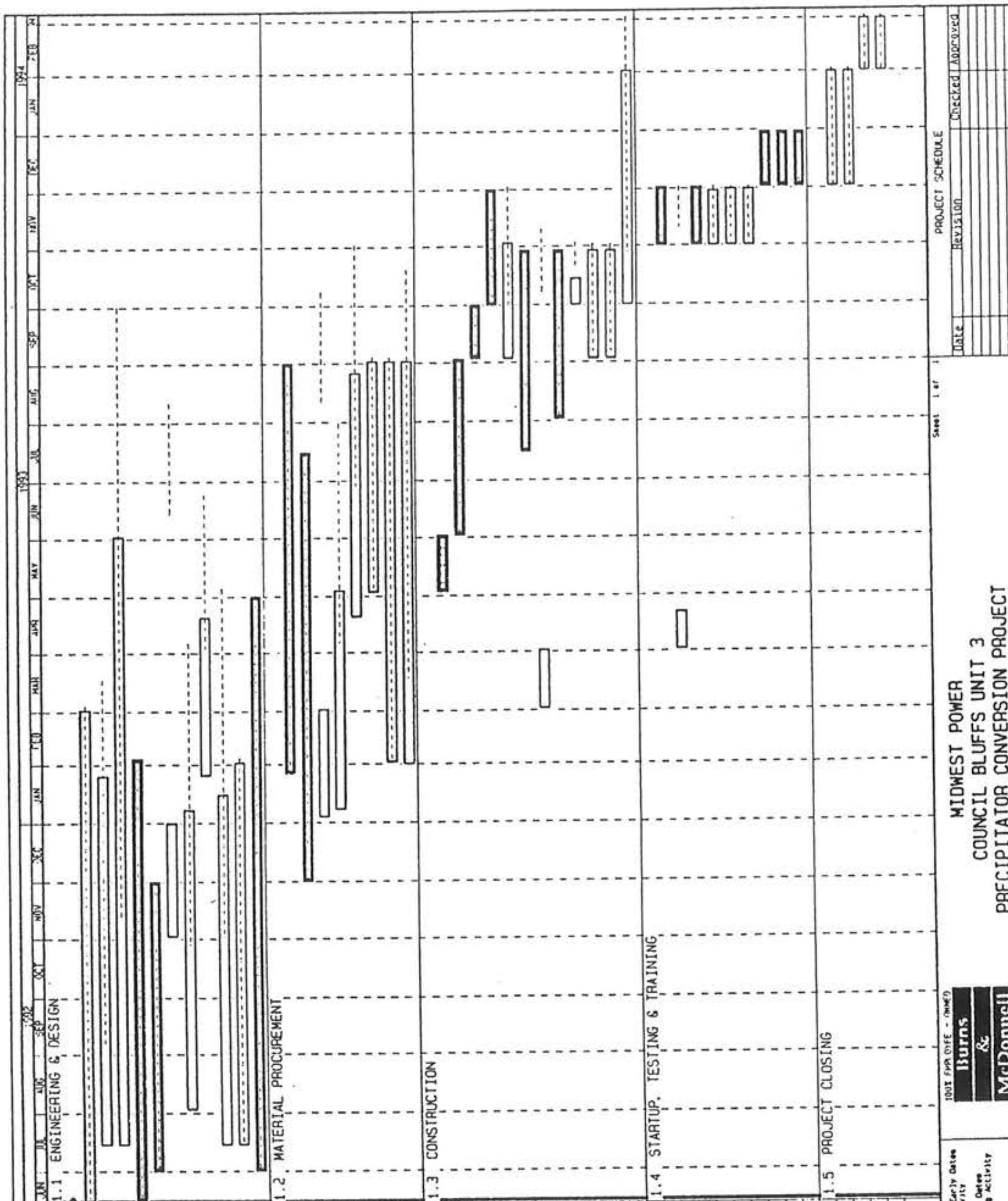

ACTIVITY ID
ACTIVITY DESCRIPTION
1992
1993
1994
JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR
1.1 ENGINEERING & DESIGN
1 AWARD A/E
1.1.1 MODEL STUDY
1.1.2 AIR HEATER MODIFICATIONS
1.1.3 PRECIPITATOR ENGINEERING
1.1.4 DUCTWORK & STRUCTURAL STEEL
1.1.5 SO3 SYSTEM
1.1.6 AUTOMATIC VOLTAGE CONTROLS
1.1.7 ELECTRICAL EQUIPMENT
1.1.8 EXPANSION JOINTS
1.1.9 PURGE AIR SYSTEM
1.1.A HOPPER HEATERS
1.1.B GENERAL CONSTRUCTION
1.2 MATERIAL PROCUREMENT
1.2.1 DUCTWORK & STRUCTURAL STEEL
1.2.2 SO3 SYSTEM
1.2.3 AUTOMATIC VOLTAGE CONTROLS
1.2.4 ELECTRICAL EQUIPMENT
1.2.5 EXPANSION JOINTS
1.2.6 PURGE AIR SYSTEM
1.2.7 HOPPER HEATERS
1.2.8 AIR HEATER BASKETS
1.3 CONSTRUCTION
1.3.1 MOBILIZE
1.3.2 GROUND FABRICATION
1.3.3 DEMOLITION
1.3.4 DUCTWORK & STEEL ERECTION
1.3.5 PRECIPITATOR REPAIRS
1.3.6 SO3 SYSTEM
1.3.7 AUTOMATIC VOLTAGE CONTROLS
1.3.8 ELECTRICAL
1.3.9 AIR HEATER BASKETS
1.3.A HOPPER HEATERS
1.3.B PURGE AIR SYSTEM
1.3.C INSULATION & LAGGING
1.4 STARTUP, TESTING & TRAINING
1.4.1 SO3 SYSTEM
1.4.2 AUTOMATIC VOLTAGE CONTROLS
1.4.3 ELECTRICAL EQUIPMENT
1.4.4 MISCELLANEOUS PIPING
1.4.5 PURGE AIR SYSTEM
1.4.6 HOPPER HEATERS
1.4.7 PRECIPITATOR TESTING
1.4.8 AIR HEATER TESTING
1.4.9 ID FAN TESTING
1.5 PROJECT CLOSING
1.5.1 AS-BUILT DRAWINGS
1.5.2 INSTRUCTION MANUALS
1.5.3 MICROFILMING
1.5.4 FILING
Plot Date 2MAR93
Data Date 15JUN92
Project Start 15JUN92
Project Finish 1MAR94
(c) Primavera Systems, Inc
Activity Bar/Early Dates
Critical Activity
Progress Bar
Activity Late Dates
Milestone/Flag Activity
Burns & McDonnell
MIDWEST POWER
COUNCIL BLUFFS UNIT 3
PRECIPITATOR CONVERSION PROJECT
Sheet 1 of 1
PROJECT SCHEDULE
Date
Revision
Checked
Approved

FIGURE 3

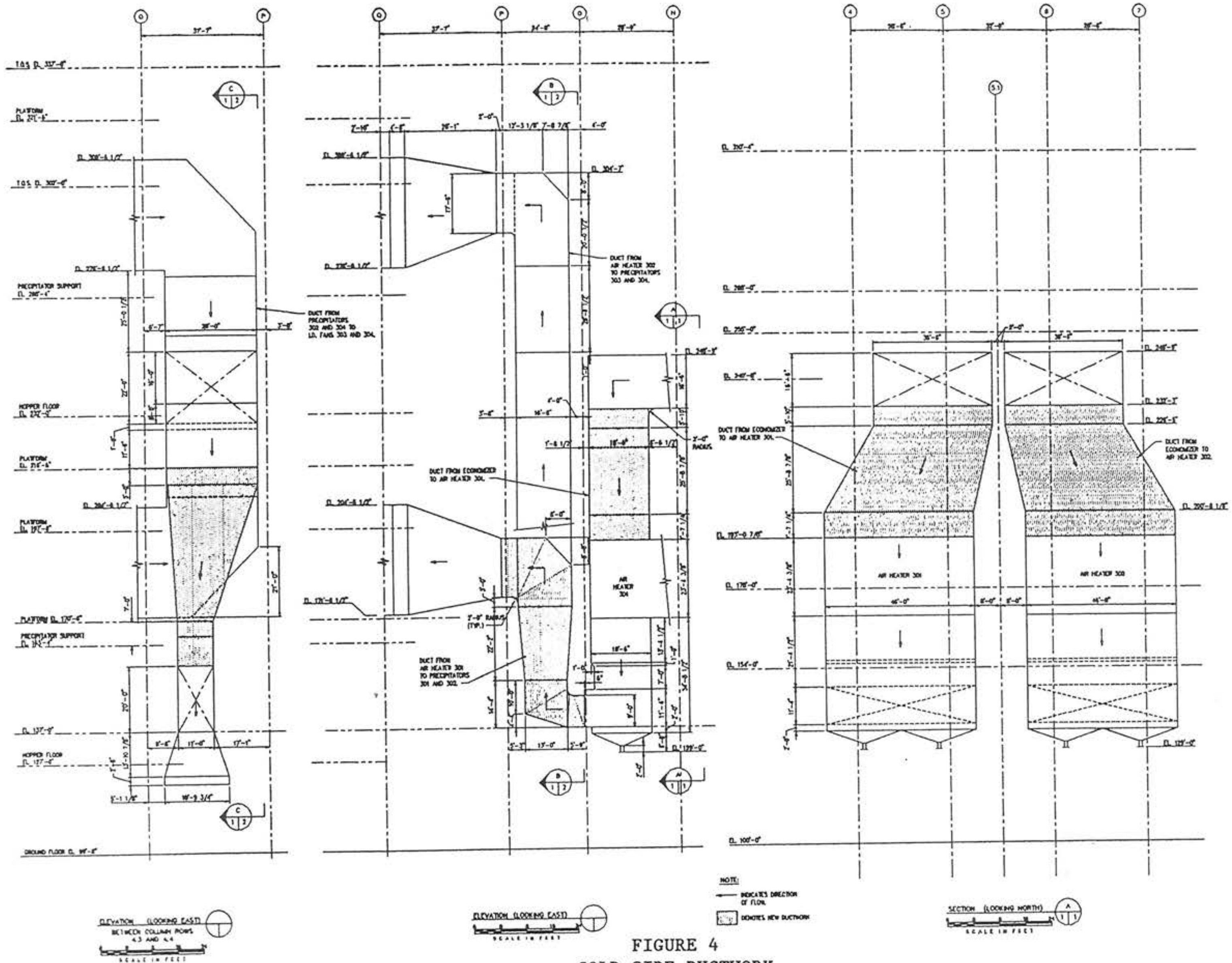


FIGURE 4
COLD-SIDE DUCTWORK
GENERAL ARRANGEMENT

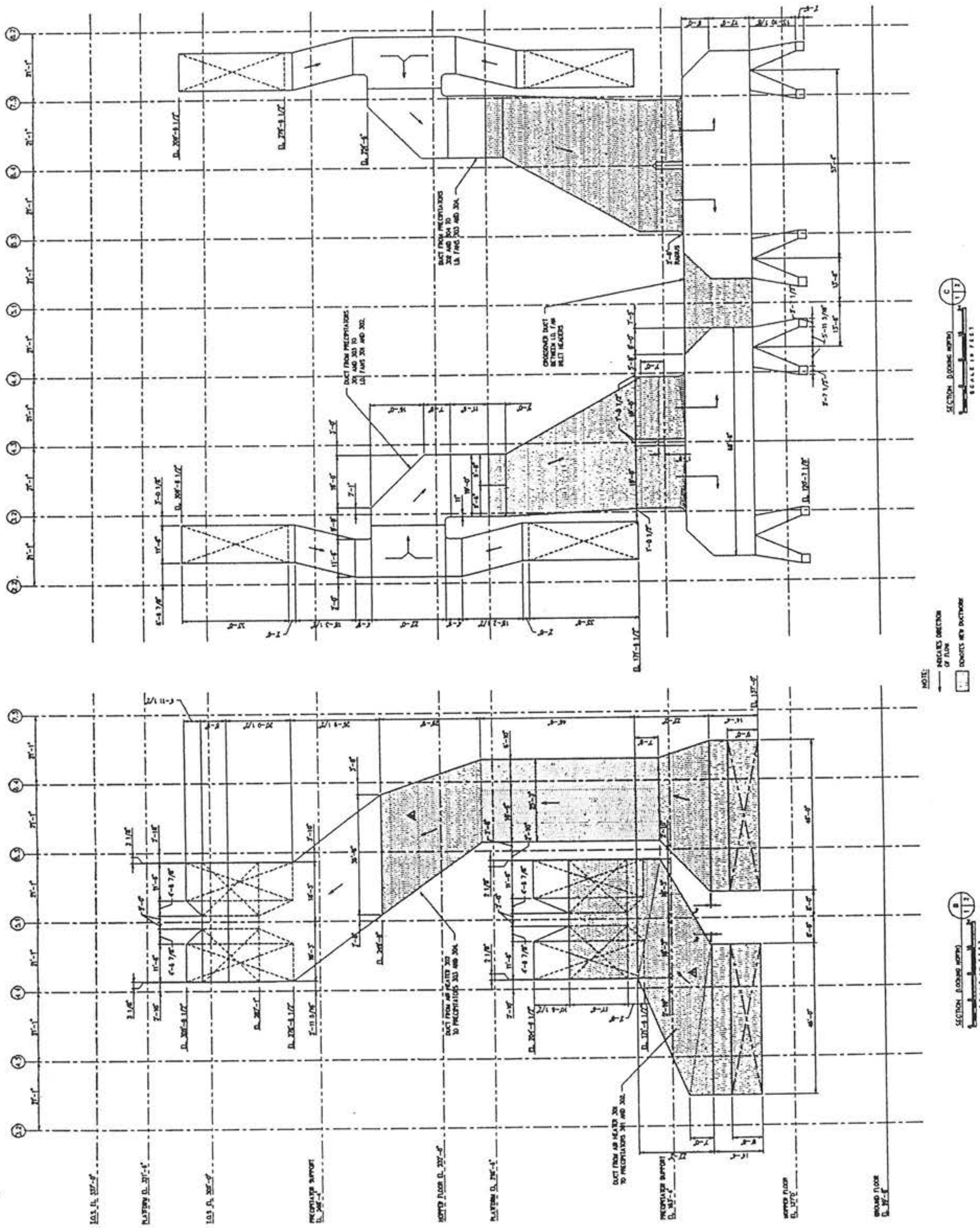


FIGURE 5
COLD-SIDE DUCTWORK
GENERAL ARRANGEMENT

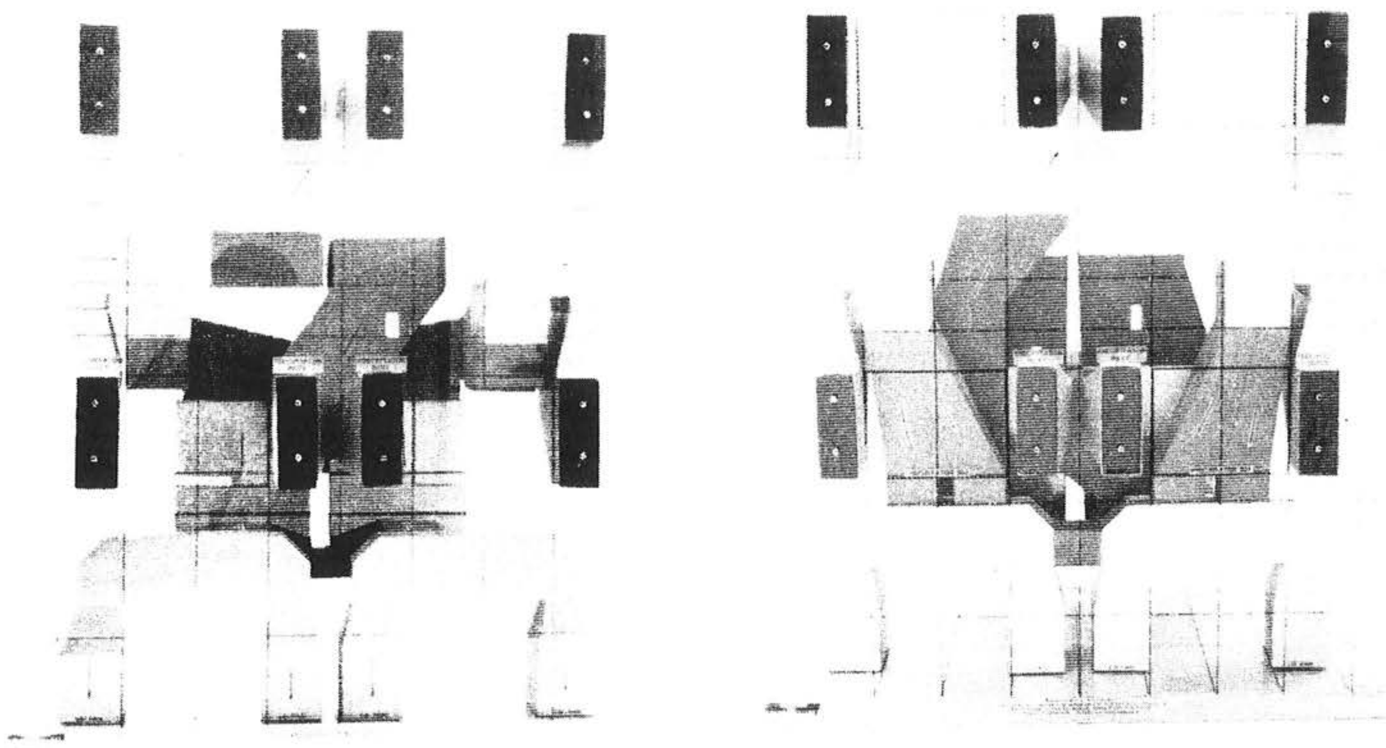


FIGURE 6
DEMONSTRATION MODELS OF DUCTWORK ARRANGEMENTS
LEFT - EXISTING HOT-SIDE ARRANGEMENT
RIGHT - PROPOSED COLD-SIDE ARRANGEMENT

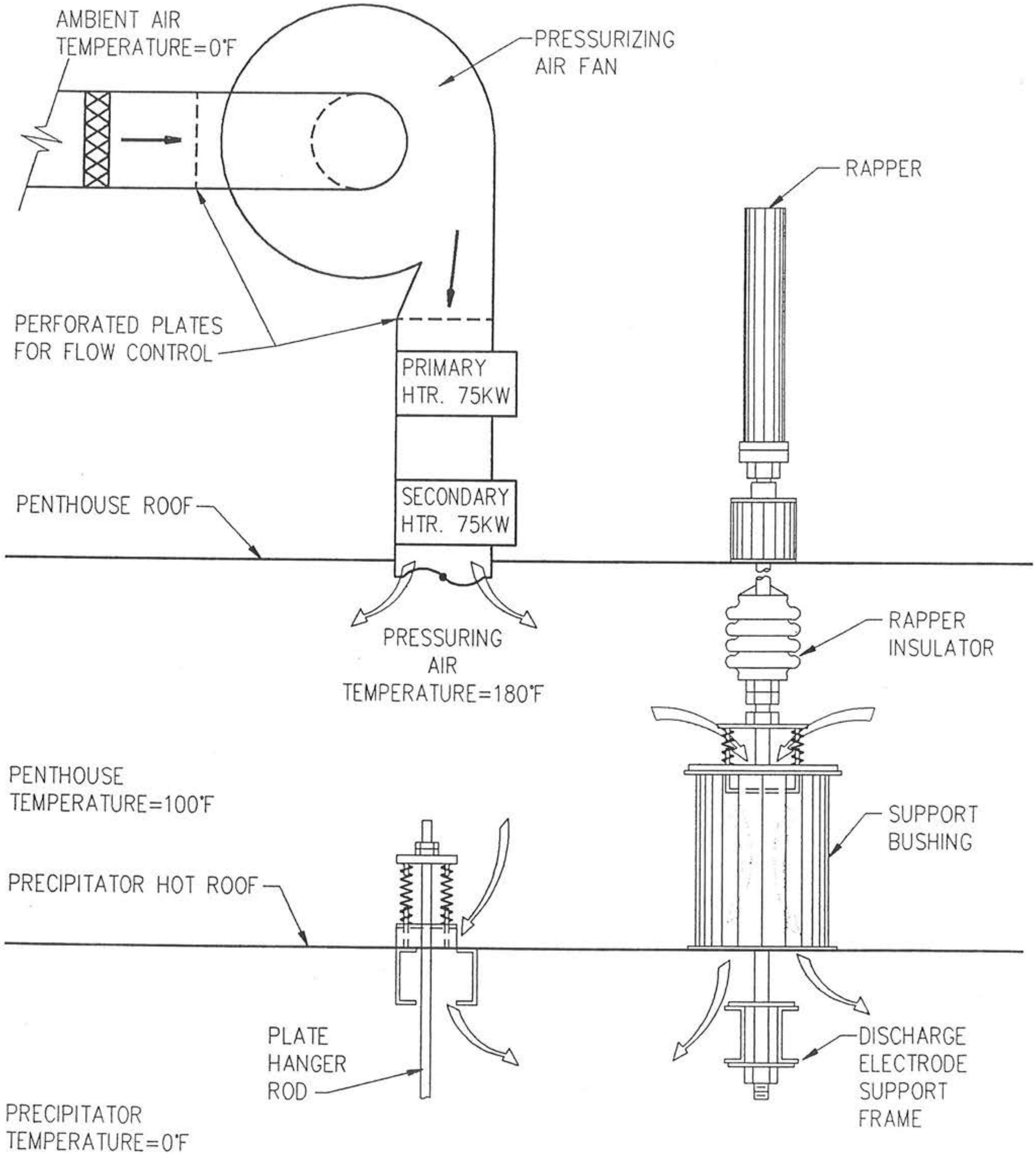


FIGURE 7
PRESSURIZING AIR FAN HEATER PRIOR
TO START-UP ON A 0°F DAY

Table 1
PLANT PARAMETERS BEFORE AND AFTER COLD-SIDE CONVERSION

PARAMETER	HOT-SIDE	COLD-SIDE (Estimated)
1. Boiler Efficiency	83%	84%
2. Auxiliary Power Consumption of ID fans, hopper heaters, purge air heaters, precipitators and SO_3 system	9,230kw	9,730kw
3. Station Auxiliary Power	4.4%	4.5%
4. Total Draft Loss	17 in W.C.	16 in W.C.
5. Ductwork Draft Loss	4.5 in W.C.	3.5 in W.C.

Table 2
EMISSIONS BEFORE AND AFTER COLD-SIDE CONVERSION

EMISSION	HOT-SIDE	COLD-SIDE (Estimated)
1. Opacity (%)	7-20	10
2. Particulate ($^{lb}/_{mm}$ btu)	0.063	0.03
3. SO_2 ($^{lb}/_{mm}$ btu)	0.63	0.63
4. NOx ($^{lb}/_{mm}$ btu)	0.34	0.34