Baghouse with Activated Carbon and Dry Sorbent Injection Systems

Final Deliverable Report

for:

New Technology Implementation Grant (NTIG) Program

582-15-53907-1471

Submitted by:

Southwest Research Institute

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Abstract/Executive Summary

Southwest Research Institute (SwRI), a leading research and development institution headquartered in San Antonio, Texas, is one of the oldest and largest independent, nonprofit, applied research and development (R&D) organization in the United States. As a leading R&D institution, it is also a major stationary source of air emissions. For this, SwRI proposed the installation and operation of an emission control system aimed to remove a limited number of both, criteria pollutants and hazardous/toxic air pollutants, from research related activities performed in one area of our campus.

SwRI obtained a grant from the New Technology Implementation Grant (NTIG) program to control and reduce emissions of hazardous air pollutants (HAPs) from the Fire Technology Department, of the Chemistry and Chemical Engineering research division. For this, SwRI installed a baghouse equipped with a combined Activated Carbon Injection (ACI) and Dry Sorbent Injection (DSI) system, providing service to three contiguous buildings in the Fire Technology area.

The implementation of this project allows emission reductions by capturing and controlling emissions of particulate matter, hazardous, and toxic air pollutants to the atmosphere. Although, most of the tests are events of relatively short duration and utilize limited quantities of flammable materials, this system allows a better control of emissions from research tests that are often difficult to characterize, as well as allowing concurrent testing in some facilities.

The start-up of this system occurred on March 24, 2016. This final implementation report presents a summary of the actions taken to complete all the Tasks of the Scope of Work, which have been delineated in the Grant Agreement Contract.

Introduction/Background

Southwest Research Institute (SwRI), headquartered in San Antonio, Texas, is one of the oldest and largest independent, nonprofit, applied research and development (R&D) organizations in the United States. Founded in 1947, SwRI provides contract R&D services to industrial and government clients. SwRI consists of 11 technical divisions that offer multidisciplinary, problem-solving services in a variety of areas in engineering and the physical sciences.

The Fire Technology department, a branch of the Chemistry & Chemical Engineering Division, is one of the world's leading organizations dedicated to fire research testing, with more than 40,000 square feet of floor space. The department offers multidisciplinary fire and explosion research, development and testing services. Most research projects involve burning a variety of materials in a manner designed to evaluate physical and chemical properties of the materials and their by-products during combustion and/or dynamic characteristics of the combustion process. Most of the tests are events of relatively short duration and utilize limited quantities of flammable materials; however, the exact composition of these materials is often unknown for (client) proprietary reasons.

Due to the frequent changing nature of research projects, forecasting the types and quantities of emissions from all potential tests programs is not possible. In order to allow flexibility required to perform fire technology research and control potential hazardous air pollutant (HAP) emissions, the addition of a dedicated pollution abatement system (PAS) for these facilities was desired. Although, this system was neither required by regulation, nor necessary to maintain compliance with permit limits.

The goal of the proposed emission reduction project was to capture and control emissions of particulate matter, as well as hazardous and toxic air pollutants from three buildings in the Fire Technology area. This was achieved by ducting emission from these buildings to a common centralized PAS that treats the emissions before releasing them to the atmosphere. This configuration allows better control of emissions from research tests that are often difficult to characterize, as well as allowing concurrent testing in some facilities. Figure 1 depicts a schematic of the area where the system was installed.

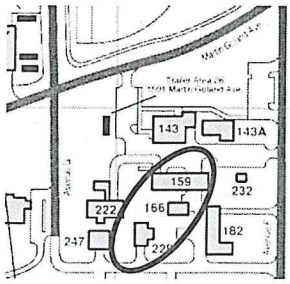


Figure 1: Fire Technology area showing the location of the three buildings and proposed space for the PAS (red oval).

SwRI has significant previous experience using a wet electrostatic precipitation unit (cloud chamber scrubber) system to treat the emissions from testing in a Steiner Flame tunnel. SwRI experienced significant difficulty in operations. In addition to safety hazards, the system generated significant quantities of wastewater, all of which required chemical analysis and some of which required offsite transport for proper disposal. The system operations were complex, with numerous feedback and control loops that required constant maintenance and hampered operational flexibility.

The combined use of baghouse filtration and dry scrubbing technology with both acid neutralization and carbon sorption of organics and metals is considered an innovative approach to control highly variable emissions generated from fire/combustion related research. In addition to low energy consumption, the system is relatively easy to maintain with only a few system feedback controls and well suited to non-continuous use, as experienced in fire test events. The system produces less waste material which is dry and therefore, easier to handle and less expensive for disposal.

Project Objectives/Technical Approach

The main objective for this work was the installation of the PAS for three buildings in the Fire Technology department, mitigating air emissions above and beyond air permit requirements from fire and explosion research and testing, including but not limited to the following combustion emissions:

- Carbon monoxide (CO);
- Volatile organic compounds (VOCs);
- Particulate matter (PM) in the form of large particulates greater than 10 microns (μm) in diameter;
- PM equal to or smaller than 10 μm in diameter (PM_{10});
- PM equal to or smaller than 2.5 μm in diameter ($PM_{2.5}$);
- Sulfur dioxide (SO_2)
- Metals such as lead (Pb) or mercury (Hg); and
- Acid gases, such as hydrogen chloride (HCl), hydrogen bromide (HBr), hydrogen fluoride (HF), and hydrogen cyanide (HCN).

This PAS is a high-temperature fabric filter baghouse paired with both dry scrubbing soda ash and activated carbon chemical adsorption systems. The designed maximum flow rate is 25,000 standard cubic feet per minute (scfpm). The system effectively removes particulate from the emissions without additional heating/combustion. The soda ash component neutralizes various acid gases, and removes SO_2, while activated carbon is intended to adsorb HAPs and trace metals, such as lead and mercury. This injected material along with the removed constituents is captured in the filter bags, which are periodically reverse pulsed with injected air to drop the solid waste into a hopper for collection, in order to maintain proper pressure and flow rate of the system. The system uses a variable speed fan to induce flow through duct systems attached to the buildings that draw emissions through the baghouse. The treated gas stream is emitted to

the atmosphere through a stand-alone stack. The PAS is equipped with a computer control system to monitor temperature, flow rate and pressure, and adjust dampers/quench flow rate allowing compensation for proper operation and to prevent damage to the baghouse in the event of extreme conditions.

Summary Tasks

For this Final Implementation report, SwRI is including a summary of all the tasks and the date they were submitted.

- Task 1- Project Definition;
  - Delivered on August 11, 2015
- Task 2- Final Design for PAS, Interface, and Support Systems;
  - Delivered on August 11, 2015
- Task 3- Contractor Selection;
  - Delivered on September 11, 2015
- Task 4: Secure Necessary Permits;
  - Delivered on August 11, 2015
- Task 5- Procurement of PAS, Interface, and Support Systems;
  - Delivered on September 11, 2015
- Task 6- Construct and assemble PAS, interface, and support systems; and
  - Delivered on April 11, 2016
- Task 7- PAS startup and commissioning.
  - Delivered on April 11, 2016

Task 1 – Project Definition

From the Grant Activities (Scope of Work): Task Statement: *Performing party shall define expectations, constraints, and project implementation.*

SwRI defined the expectations, constraints and characterization of the PAS performance requirements.

SwRI developed a budget for this project. This initial concept budget was used for work order approval. In this budget, there was a provision to account for contingency funds of 8% and 10% funds for design and construction contingencies, respectively. A detailed breakdown of this budget was included in Appendix A of the first deliverable report.

A formal execution plan was elaborated, which established the means to execute, monitor, and control the project. This plan listed the project objectives and the group responsible for each of the objectives and tasks. A detailed formal execution plan was included in Appendix B.

Task 2 – Finalize Design for PAS, Interface, and Support Systems

From the Grant Activities (Scope of Work): Task Statement: *Performing party shall prepare and complete design of the PAS, interface, and support systems.*

For the completion of this task, SwRI divided the objective into three subtasks, in order to clearly reflect the accountability of the involved parties.

Task 2A- CR&E System Design

The design of the PAS was completed by CR&E, and approved by SwRI. Documents were issued for construction. The final design plans and equipment selections for the PAS were submitted and marked confidential on August 11, 2105.

Task 2B- Scope Definition of Engineering Services

The definition of scope responsibilities and duties required for the engineering services firms, to document the Implementation phase, were completed. Proposals were received, and contracts were written. SwRI's Design team for the Implementation Phase was the following:

- MEP/Prime Professional: ESA Engineering
- Civil Engineer: Pape-Dawson Engineers, Inc.
- Structural Engineer: RSCR, Inc.
- Architect: SwRI, Facilities Engineering

Task 2C- SwRI Responsibility Design Services

To expedite Implementation, reduce cost and provide more direct control by SwRI Facilities Engineering, it was determined to partition the implementation work into three distinct packages:

- Implementation Package No. 1: Sitework, Concrete, Structural Steel and Control Building
- Implementation Package No. 2: HVAC Systems and Erection of CR&E Equipment
- Implementation Package No. 3: Electrical (to be self-performed)

Project design kick-off meetings with engineering services firms and SwRI stakeholders were completed. Implementation design documents were completed, which were reviewed in coordination meetings at 50% and 95% completion. The finalized Implementation Phase Package documents were included in Appendices D through F, which were submitted confidentially. The Packages included the following plans:

Sheet No.	Title			
G1.1	COVER SHEET	Package No. 1	Package No. 2	Package No. 3
C1.00	SWPPP	Package No. 1	Reference	Reference
C1.10	SWPPP DETAILS	Package No. 1	Reference	Reference
C2.00	DEMOLITION PLAN	Package No. 1	Reference	Reference
C3.00	DIMENSIONAL CONTROL AND GRADING PLAN	Package No. 1	Reference	Reference
C4.00	OVERALL UTILITY PLAN	Package No. 1	Reference	Reference
C4.10	CIVIL DETAILS	Package No. 1	Reference	Reference
FE1.1	PLANS, ELEVATIONS, AND SECTIONS	Package No. 1	Reference	Reference
FE2.1	DETAILS	Package No. 1	Reference	Reference
S1.1	GENERAL NOTES AND TYPICAL DETAIL	Package No. 1	Reference	Reference
S2.1	FOUNDATION AND FRAMING PLAN	Package No. 1	Reference	Reference
S3.1	SECTIONS AND DETAILS	Package No. 1	Reference	Reference
S3.2	SECTIONS AND DETAILS	Package No. 1	Reference	Reference
DMEP1.1	MEP DEMO SITE PLAN	Reference	Package No. 2	Reference
MEP1.1	MEP SITE PLAN	Reference	Package No. 2	Reference
M1.1	MECHANICAL PLAN	Reference	Package No. 2	Reference
M2.1	MECHANICAL DETAILS	Reference	Package No. 2	Reference
MP1.1	MECHANICAL/PLUMBING SPECIFICATIONS	Reference	Package No. 2	Reference
E1.1	ELECTRICAL LEGEND AND NOTES	Reference	Reference	Package No. 3
E2.1	ELECTRICAL PLAN	Reference	Reference	Package No. 3
E3.1	ELECTRICAL SCHEDULES	Reference	Reference	Package No. 3
E4.1	ELECTRICAL RISER DIAGRAM AND DETAILS	Reference	Reference	Package No. 3
E5.1	ELECTRICAL SPECIFICATIONS	Reference	Reference	Package No. 3
P1.1	PLUMBING LEGEND AND NOTES	Reference	Package No. 2	Reference
P2.1	PLUMBING DETAILS	Reference	Package No. 2	Reference
CRE1.1	REFERENCE DRAWINGS	Reference	Reference	Reference
CRE1.2	REFERENCE DRAWINGS	Reference	Reference	Reference
CRE1.3	REFERENCE DRAWINGS	Reference	Reference	Reference
CRE1.4	REFERENCE DRAWINGS	Reference	Reference	Reference
CRE1.5	REFERENCE DRAWINGS	Reference	Reference	Reference
CRE1.6	REFERENCE DRAWINGS	Reference	Reference	Reference
CRE1.7	REFERENCE DRAWINGS	Reference	Reference	Reference
CRE1.8	REFERENCE DRAWINGS	Reference	Reference	Reference
CRE1.9	REFERENCE DRAWINGS	Reference	Reference	Reference
CRE1.10	REFERENCE DRAWINGS	Reference	Reference	Reference
CRE1.11	REFERENCE DRAWINGS	Reference	Reference	Reference
CRE1.12	REFERENCE DRAWINGS	Reference	Reference	Reference
CRE1.13	REFERENCE DRAWINGS	Reference	Reference	Reference
CRE1.14	REFERENCE DRAWINGS	Reference	Reference	Reference
CRE1.15	REFERENCE DRAWINGS	Reference	Reference	Reference
CRE1.16	REFERENCE DRAWINGS	Reference	Reference	Reference
CRE1.17	REFERENCE DRAWINGS	Reference	Reference	Reference
CRE1.18	REFERENCE DRAWINGS	Reference	Reference	Reference
CRE1.19	REFERENCE DRAWINGS	Reference	Reference	Reference
CRE1.20	REFERENCE DRAWINGS	Reference	Reference	Reference
CRE1.21	REFERENCE DRAWINGS	Reference	Reference	Reference

Figure 2: Table showing the interrelation/reference of the Implementation Packages drawings.

Task 3 – Contractor Selection

From the Grant Activities (Scope of Work): Task Statement: *Performing party shall administer competitive selection of contractors for complete installation of PAS equipment and all work required for interface and support.*

The design team for the Implementation Phase of this project was formed by:

- MEP/Prime Professional: ESA Engineering
- Civil Engineer: Pape-Dawson Engineers, Inc.
- Structural Engineer: RSCR, Inc.
- Architect: SwRI, Facilities Engineering

In order to expedite construction work, the construction delivery model for this PAS project was planned to allow competitive bidding of the work by specialty contractors direct to the Owner (SwRI). SwRI Facilities Engineering assumed the role of the general contractor for coordination purposes. This allowed the issuance of Implementation package No. 1 prior to the completion of the Implementation Package No. 2 documents. Contractors were selected based on the following competitive bid packages:

- Implementation Package No. 1: Sitework, Concrete, Structural Steel and Control Building;
- Implementation Package No. 2: HVAC Systems and Erection of CR&E Equipment; and
- Implementation Package No. 3: Electrical (to be self-performed).

A summary of the bid process for the selection of contractors for each Implementation Package was presented.

Implementation Package No. 1

Prequalified selected contractors for bid purposes:

1. Chapman Brothers Construction
2. Diamond Construction

Chronology of Events:

- July 2, 2015 – Plans issued with invitation for Bid.
- July 8, 2015 – Pre-bid conference.
- July 16, 2015 – Bids received.
- July 20, 2015 - Contract issued / Noticed to Proceed

Company awarded: **Diamond Construction**

- Amount: $201,182.00
  - Final cost to complete: $206,986.85
- Completion target: 65 calendar days

Implementation Package No. 2

Prequalified selected contractors for bid purposes:

1. Mission Plumbing, Heating & Air Conditioning Inc.
2. LC Mosel
3. Mueller & Wilson, Inc.

Chronology of Events:

- July 13, 2015 – Plans issued with invitation for Bid.
- July 20, 2015 – Pre-bid conference.
- July 30, 2015 – Bids received.
- August 5, 2015 - Contract issued / Noticed to Proceed

Company awarded: **LC Mosel**

- Amount: $386,519.00
  - Final cost to complete: $420,590.00
- Completion target: 84 calendar days

Implementation Package No. 3

All electrical work was self-performed by Owner (SwRI) Facilities Operations electrical shop, in accordance with the project electrical and instrumentation construction documents.

- Final Cost to complete: $75,076.00

Task 4 – Secure Necessary Permits

From the Grant Activities (Scope of Work): Tasks statement: *Performing party shall prepare information to obtain an air quality standard permit for pollution control projects and secure permits required for operation of the PAS.*

For the completion of this task, SwRI submitted a Standard Permit for Pollution Control Projects application to the TCEQ on March 11, 2015. TCEQ issued the Standard Permit on April 13, 2015. A copy of this permit was included in Appendix G of the first deliverable report.

Task 5 – Procurement of PAS, Interface, and Support Systems Equipment

From the Grant Activities (Scope of Work): Task Statement: *Performing party shall procure all equipment, controls and instrumentation for the PAS, interface, and support systems.*

SwRI received all the equipment needed for this project. The following table provides a list of the equipment, as well as a link to the corresponding picture for each component.

Equipment Inventory - Photos and Received Receipt	
Equipment	**Photo**
Quench Tower & Instrumentation	Quench
25,000 CFM baghouse	Housing
	Cages
	Frames
Inlet Outlet and Bypass Dampers	Valves
AC & DS Injection System	Hopper
	Loader
ID Fan	Fan
Stand-alone Stack	Stack
Ductwork, x-joints, supports	Elbows
	Ducts
	Flanges
	Supports
Control System and Panels	Panels
VFD for ID Fan	VFD

Figure 3: Table listing the Equipment Inventory with links to photographs and delivery receipts.

Task 6 – Construct and Assembly of PAS

From the Grant Activities (Scope of Work): Task Statement: *Performing party shall oversee general construction to: complete sitework, foundations, utilities, modifications to existing buildings/structures, electrical mechanical, fire protection and controls to interface with PAS equipment; and complete installation of PAS equipment.*

SwRI Facilities Engineering assumed the role of the general contractor for coordination purposes. As a result, the three implementation packages were completed. The steps that were completed in this phase are:

A. Access driveways
B. Sitework and drainage
C. Foundations
D. Ancillary buildings/enclosures
E. Primary electric service
F. Secondary electric service
G. Controls & and Instrumentation
H. Quench soft water
I. Compressed air
J. Supplementary ductwork with dampers & valves
K. Supplementary electric power
L. Place and erect CRE furnished equipment
M. Deliver and install supplementary equipment
N. Final connection of utilities (Power, water, CA, etc.)
O. Final connection of controls

The construction of the PAS was completed on March 14, 2016. The photographs depicted in Figures 4 through 13 show the system's components. Each photograph contains a description of the relevant parts and a letter that corresponds to the steps mentioned above.

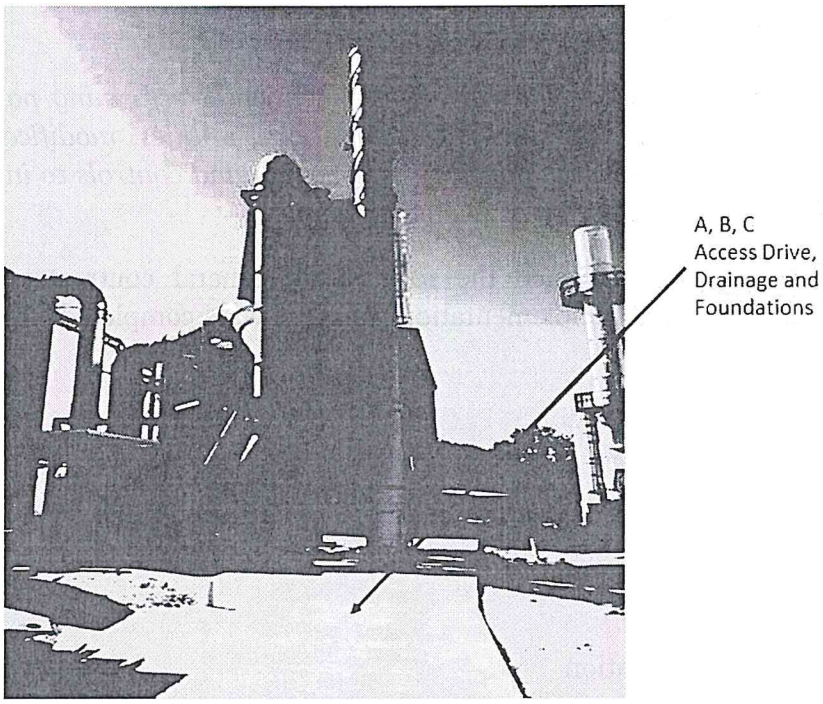


Figure 4: Photograph of access drive, drainage, and foundations.

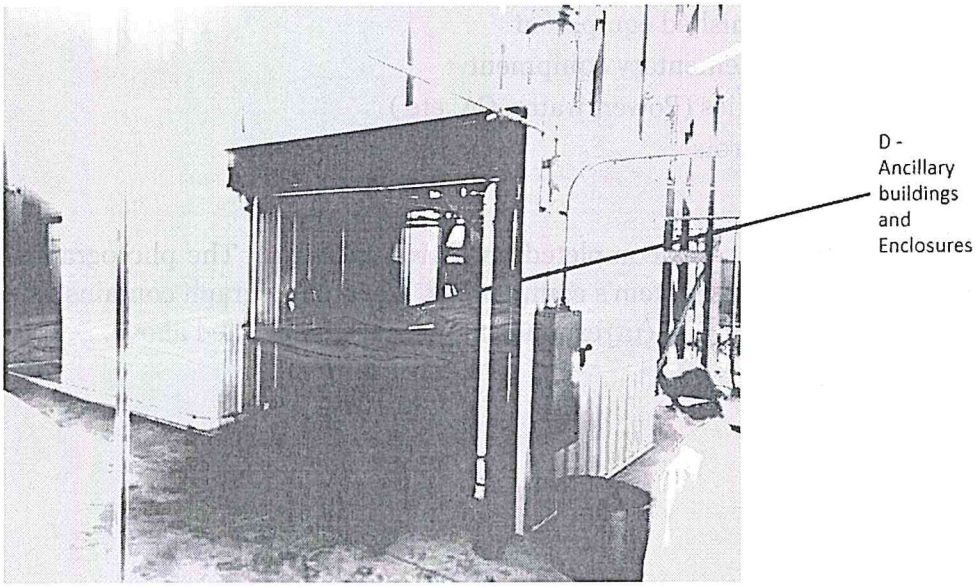


Figure 5: Photographs of ancillary buildings and enclosures.

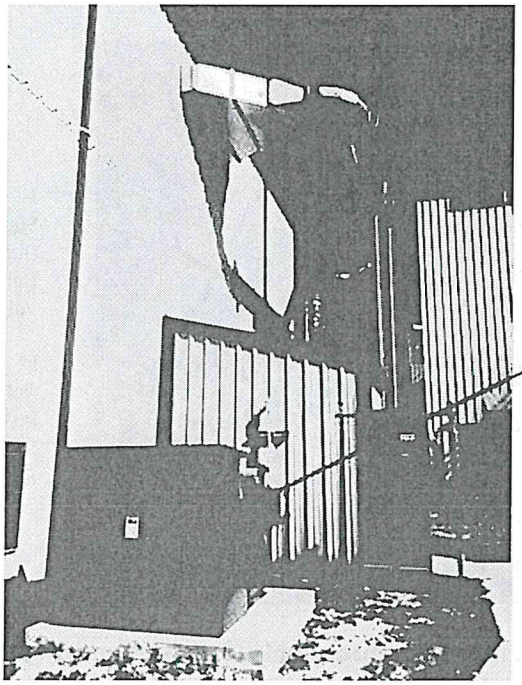


Figure 6: Photograph of the primary electrical service.

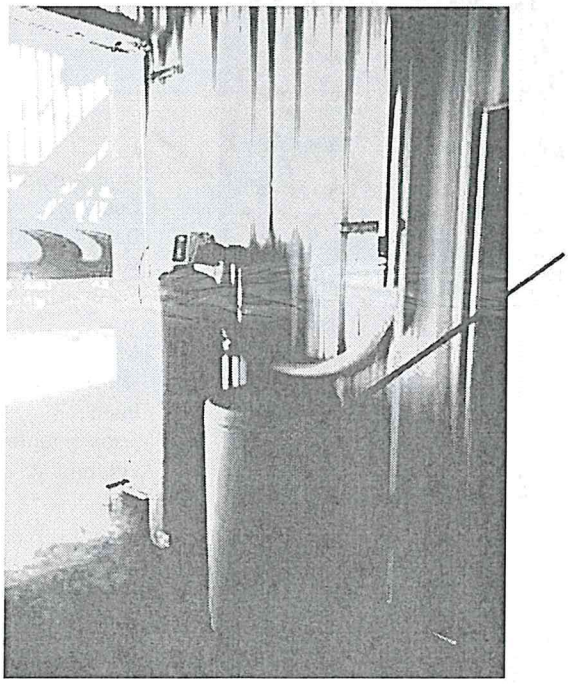


Figure 7: Photograph of the quench soft water.

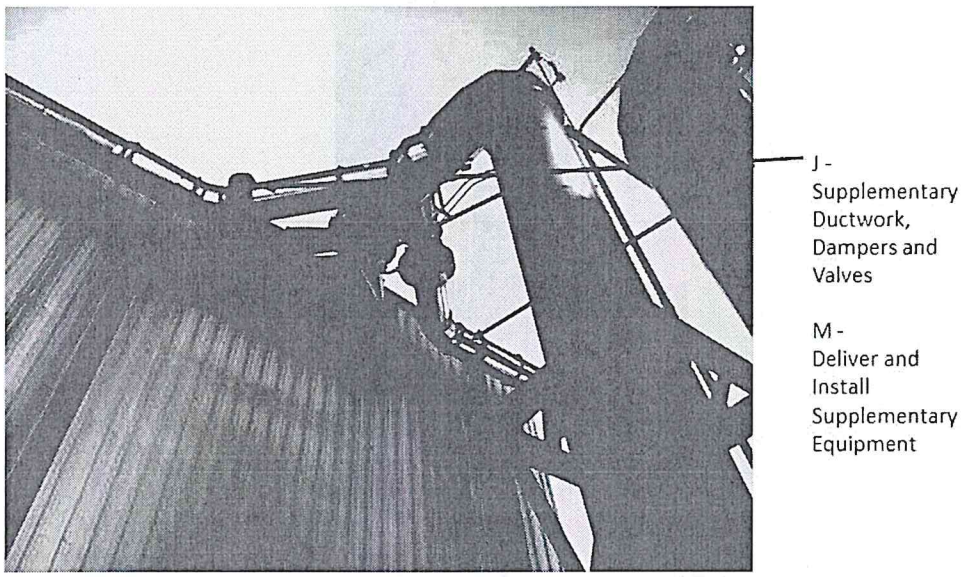


Figure 8: Photograph of the supplementary ductwork, dampers, and valves.

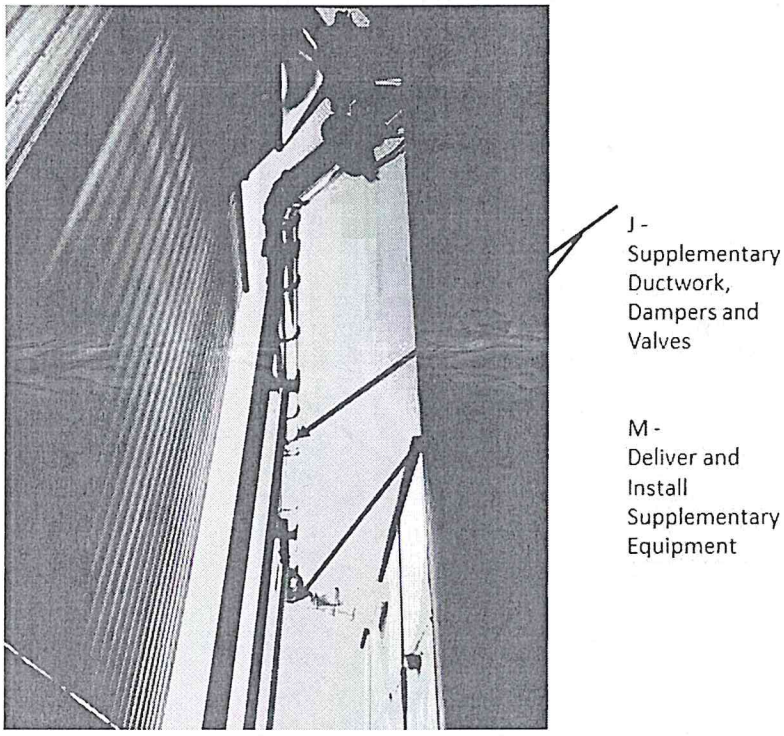


Figure 9: Photograph of the supplementary ductwork, dampers, and valves.

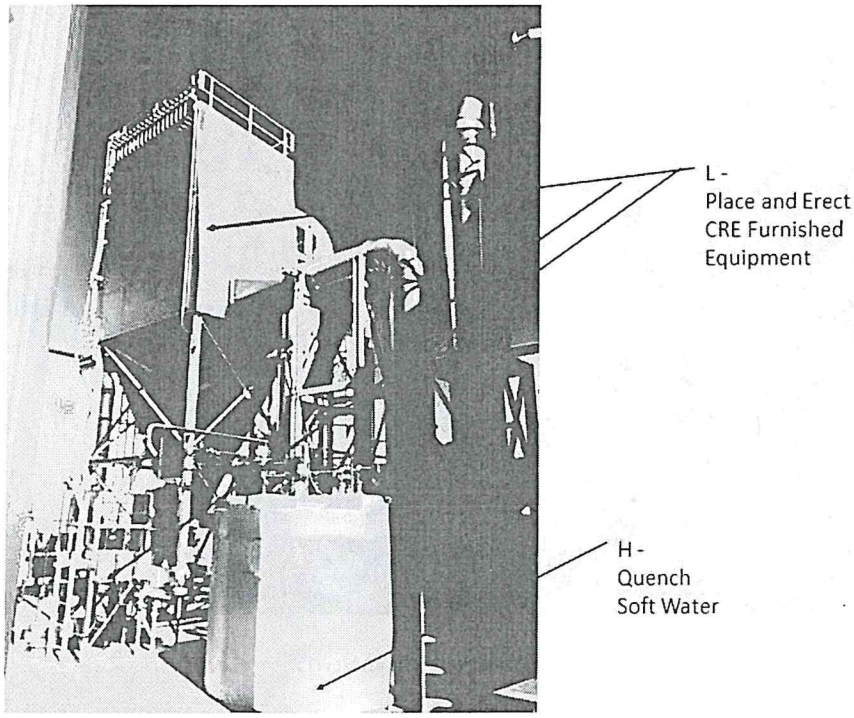


Figure 10: Photograph of the supplementary ductwork, dampers, and valves.

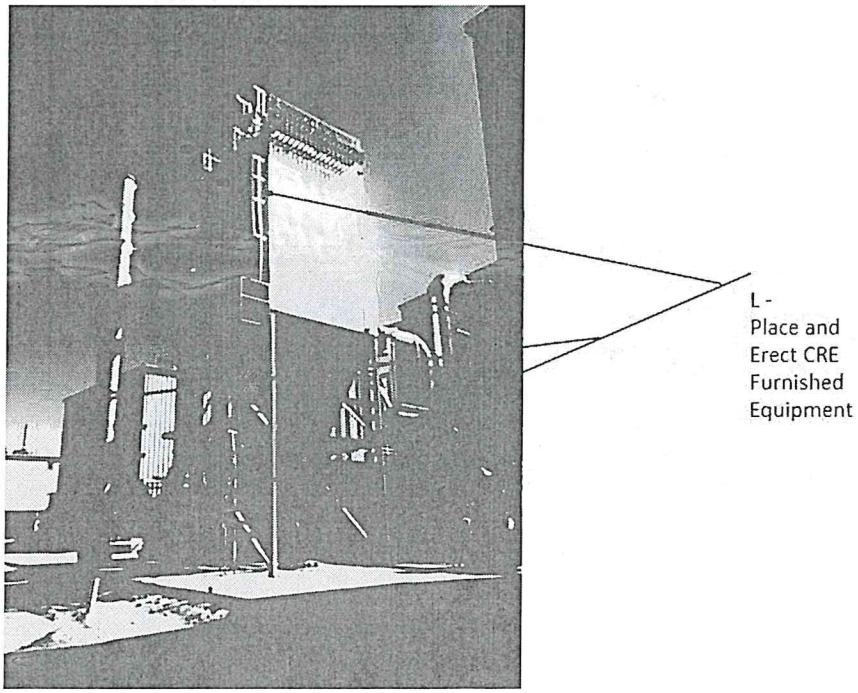


Figure 11: Photograph of CRE's furnished equipment.

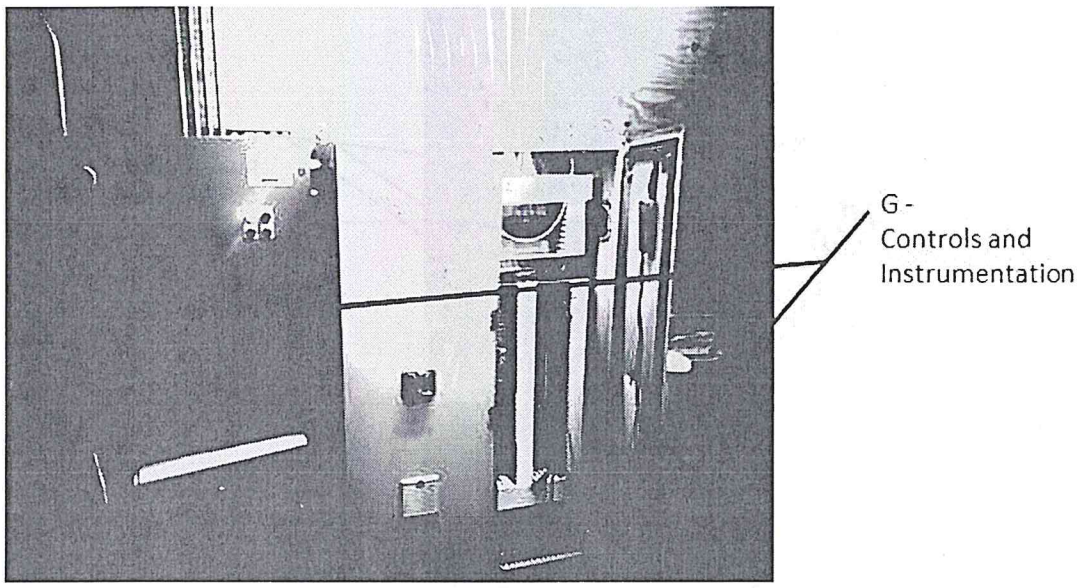


Figure 2: Photograph of controls and instrumentation.

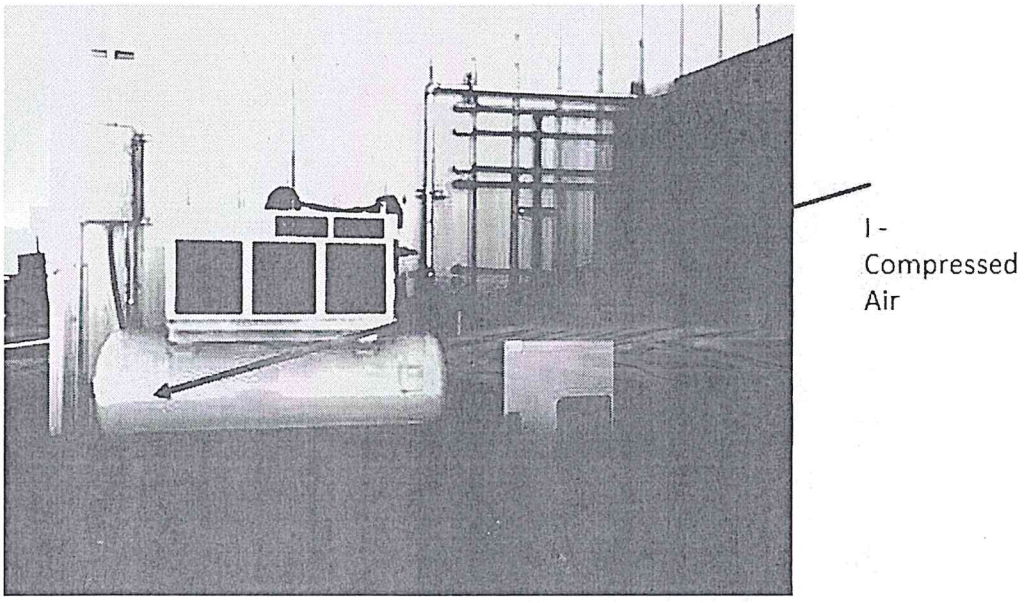


Figure 3: Photograph of compressed air.

Task 7 – PAS Startup and Commissioning

From the Grant Activities (Scope of Work): Task Statement: *Performing party shall start and test all PAS equipment, controls, instrumentation, and safeties for proper operation.*

The system started the Commissioning process on March 15, 2016. The checklist for all the tasks completed under this activity is shown in the Appendix.

Task 8 – Implementation Reporting

From the Grant Activities (Scope of Work): Task Statement: *Performing party shall prepare and submit quarterly detailed project reports and final report while ensuring compliance with all TCEQ program requirements.*

Quarterly progress reports were submitted in a timely fashion summarizing all aspects of the project based on data from the task completion reports. The

- First Project Status Report – 2nd Calendar Quarter. Submitted on July 9, 2105
- Second Project Status Report – 3rd Calendar Quarter. Submitted on October 7, 2015
- Third Project Status Report – 4th Calendar Quarter. Submitted on January 6, 2016
- Fourth Project Status Report – 1st Calendar Quarter. Submitted on April 8, 2016.

This document will serve as the final implementation report.

Discussion/Observations for Final Implementation

Objectives

- Task 9: Reporting period. Submit annual operation status report for five years (2017, 2018, 2019, 2020, and 2021),
- Submit a final operations report to the TCEQ in the year 2021.

Critical issues

Amendment to deliverable due dates for Tasks 6 and 7

SwRI requested a change to the deliverables due dates on January 15, 2016. The reason for this request was due to delays in the delivery of four (14-inch, 24-inch, 26-inch, and 36-inch) contractor-furnished large isolation dampers located in the exhaust ductwork.

Additional delays were encountered due to constraints in the access to work area for safe erection of one of the vendors (CRE) furnished equipment. Added delays were occasioned by inclement conditions, provoking a postponement in the pouring and finishing of certain concrete slabs.

Spark Arrestor

As documented in the Implementation Package No. 2, Addendum No.1, a Quencher QO24MD Spark Arrestor was installed in the 26-inch duct leaving Building 159. The main purpose of this device was to serve as a precautionary step to assure that sparks would not reach the baghouse fabric. The device, as indicated on the plans, was located in the high ductwork just prior to entry into the Quench Vessel Assembly. During system commissioning and start-up, it was found that the pressure drop through the Spark Arrestor was excessive and unacceptable for fan system performance. Due to this issue, it was decided to remove the Spark Arrestor from the duct system. To support this decision, it was analyzed and concluded that due to the low velocity flow, and relatively long distance between the furnaces (which could generate the sparks) and the baghouse, there is little risk that a spark will carry to the bags inside the baghouse.

Supplementary hood in Building 228

After the system was installed and properly running, it was decided to fabricate and install a 8-ft by 19-ft hood with associated ductwork for transition and direct connection to the existing 24-inch building exhaust connection to the PAS. This hood and duct modification was envisioned to improve the testing process in Building 228. The purpose of this hood is to improve the capture of smoke generated while testing and thus, increased visibility in the workspace, so that staff could safely enter the test area and extinguish fires.

Technical and commercial viability of the proposed approach

Technical barriers

Spark Arrestor: The technical barrier experienced with this system had to do with the inclusion of the Spark Arrestor, Quencher QO24MD. The problems with this safety mechanism are explained in the Critical Issues segment of this section.

Supplementary hood in Building 228: This added hood presents no barriers related to the operation of the PAS. It consisted of a simple design to direct and capture smoke vertically from the test fixture. Placement of the hood is above the bridge crane rails, and is approximately 30 feet high. In addition to this hood, supplementary lighting was included to improve visibility.

Summary/Conclusions

The construction, commissioning and startup phases of the NTIG project have been completed.

Appendix

SwRI overall approved capital expenditure budget with contingency funds for this project was $2,500,000.00. Completed project costs, including all equipment, permitting, testing, design, and implementation total $2,440,240.00

Primary breakdown of the costs is as follows:

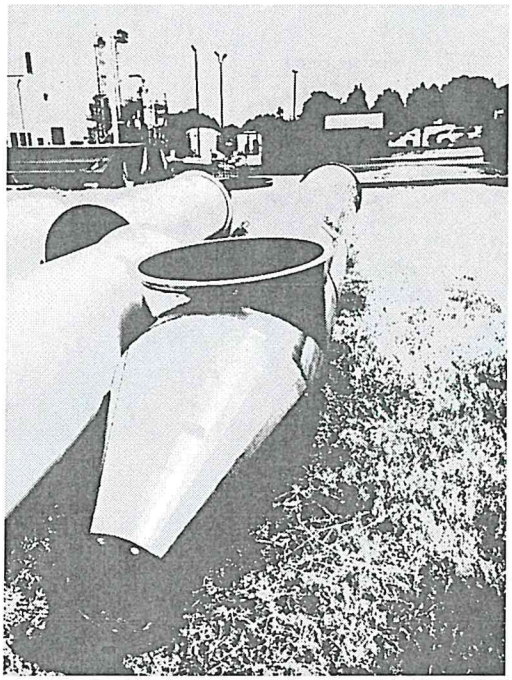
Equipment- CRE:	$1,523,491
Systems Engineering and Start Up-CRE:	$114,330.00
Permitting:	$10,700.00
Testing:	$9,700.00
Implementation:	$24,400.00
Package 1 Diamond Construction	$206,986.00
Package 2 LC Mosel:	$420,590.00
Package 3 Electric—Self Perform:	$75,076.00
Miscellaneous:	$54,967.00
Total:	$2,440,240.00

SwRI plans to submit annual operation status reports for the five subsequent years, followed by a final operation report in the year 2021.

Appendix: Photographs of Equipment Inventory

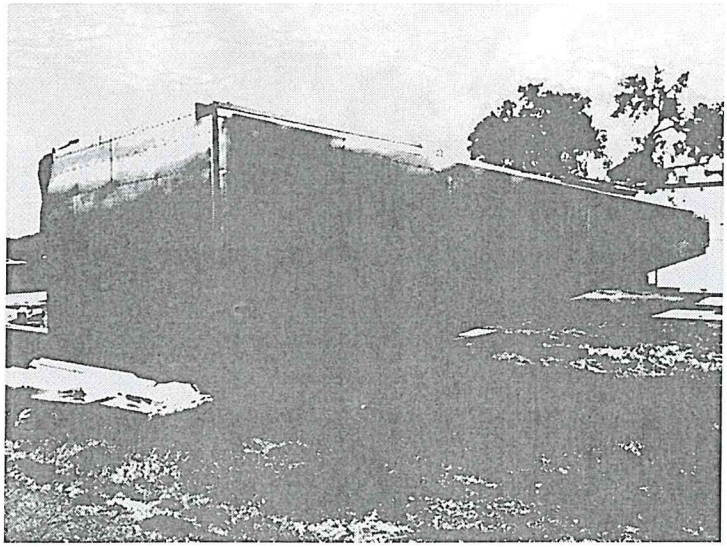
Quench Tower and Instrumentation

Return to table



25,000 CFM Baghouse

Baghouse Housing



Baghouse Cages

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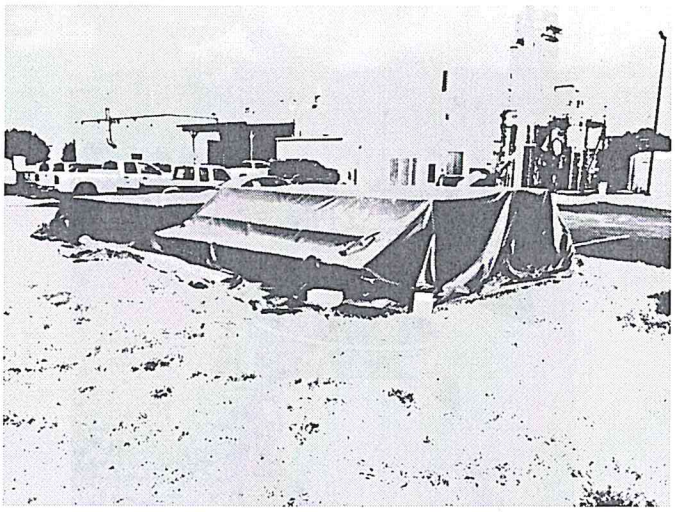

Baghouse Support Frames

Inlet-Outlet Bypass Dampers

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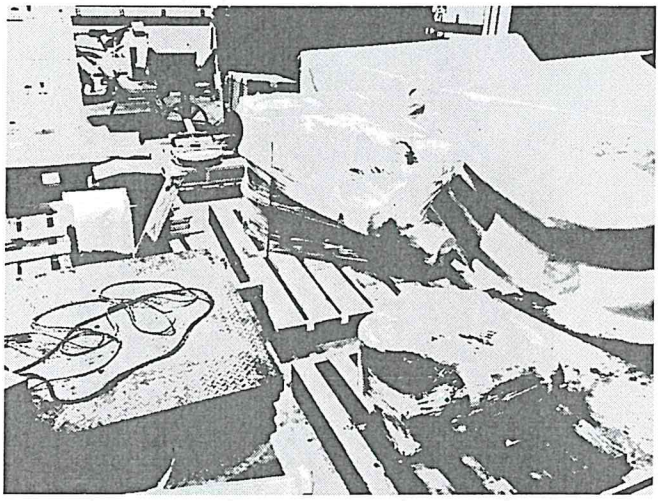
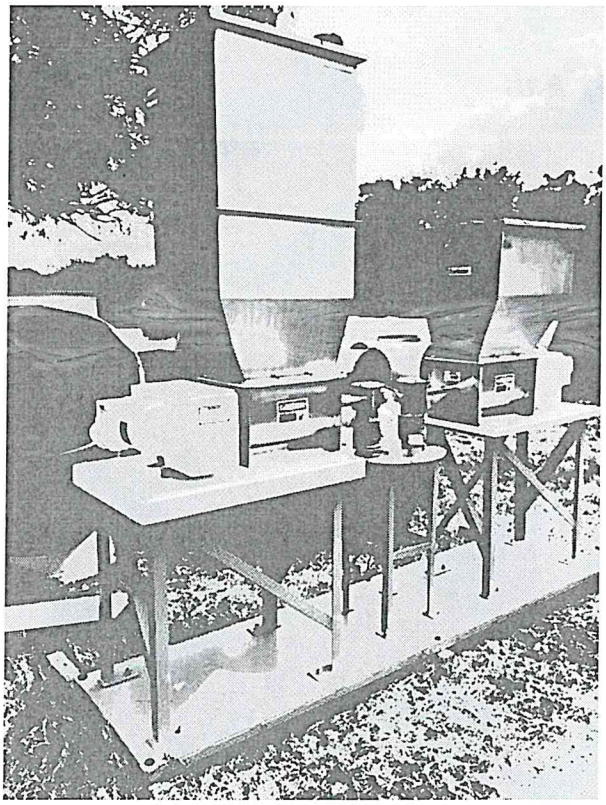


AC & DS Injection System

Hopper



Loader

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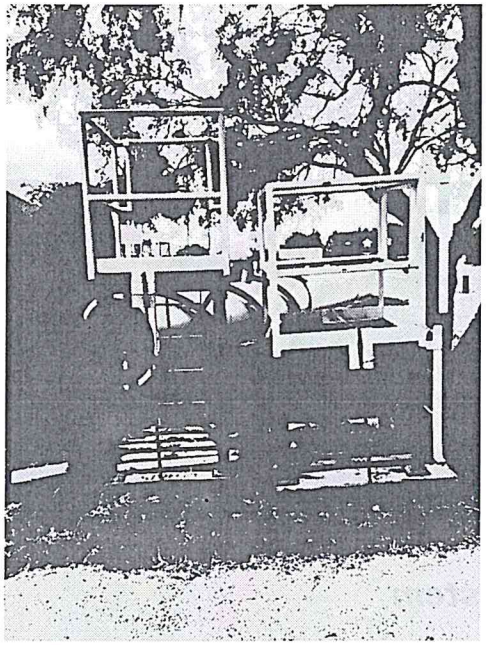
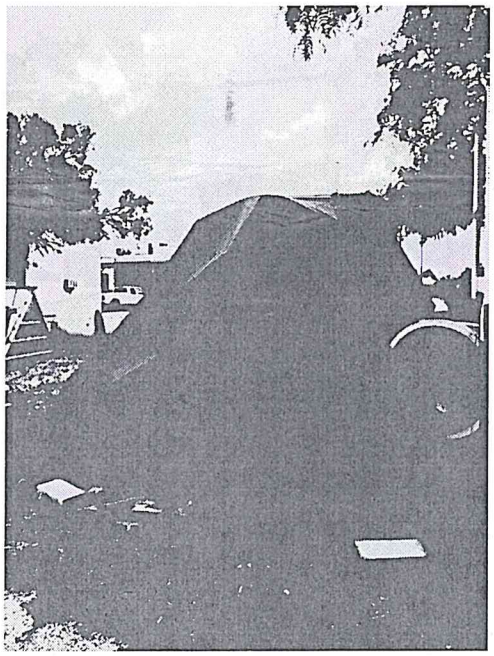


Induced Draft (ID) Fan



Stand Alone Stack

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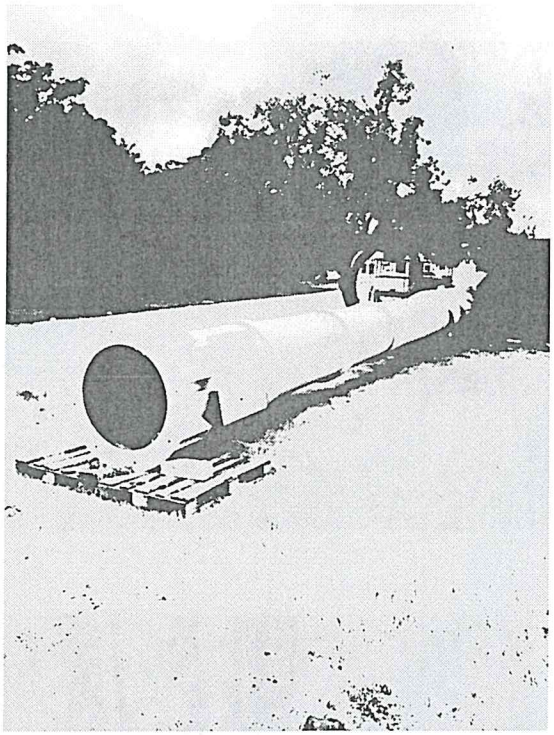
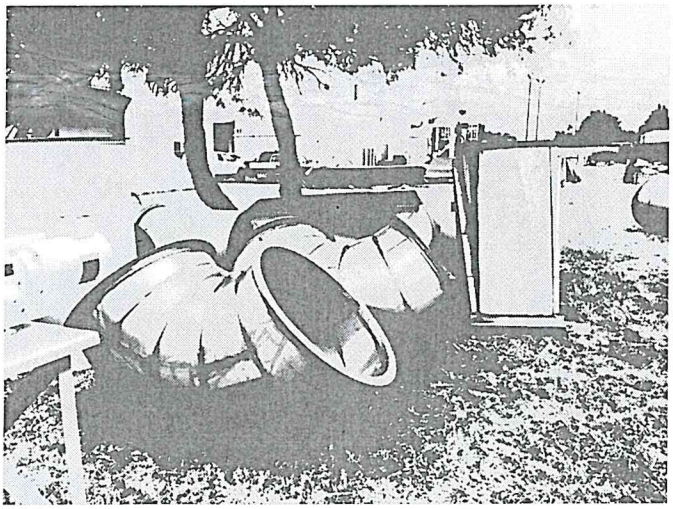


Ductwork and supports

Elbows



Ducts

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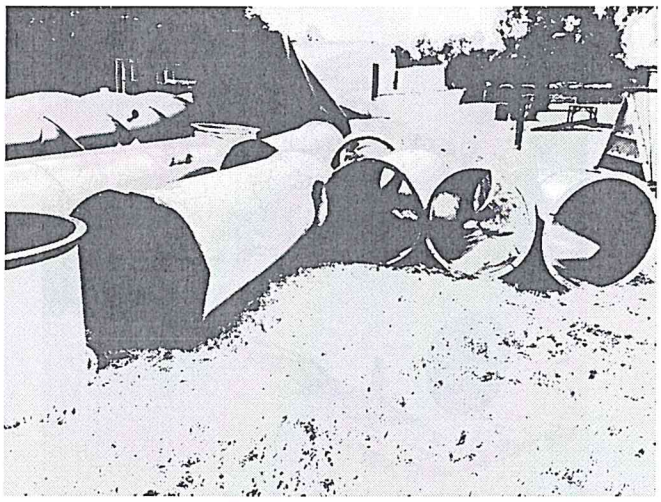
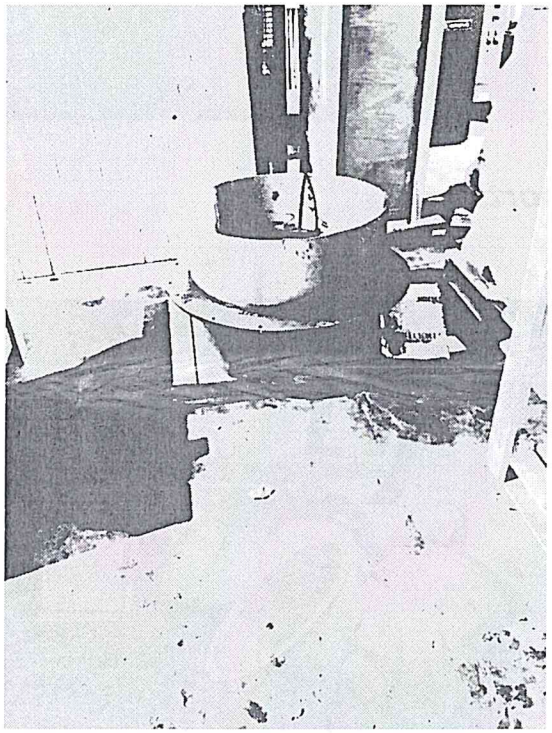


Flanges



Supports

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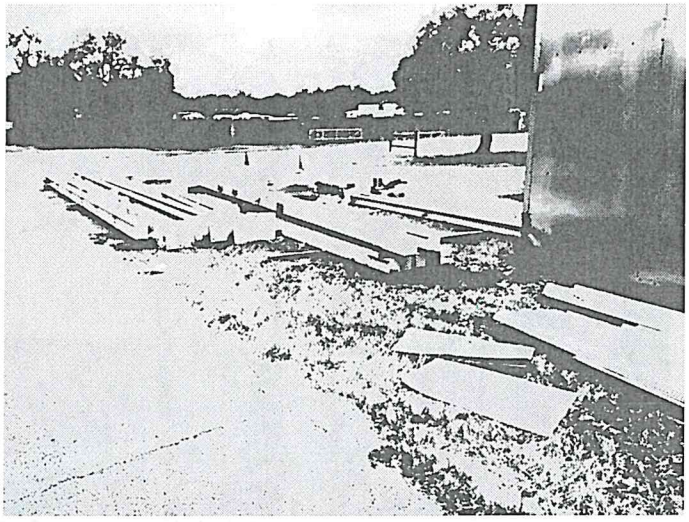
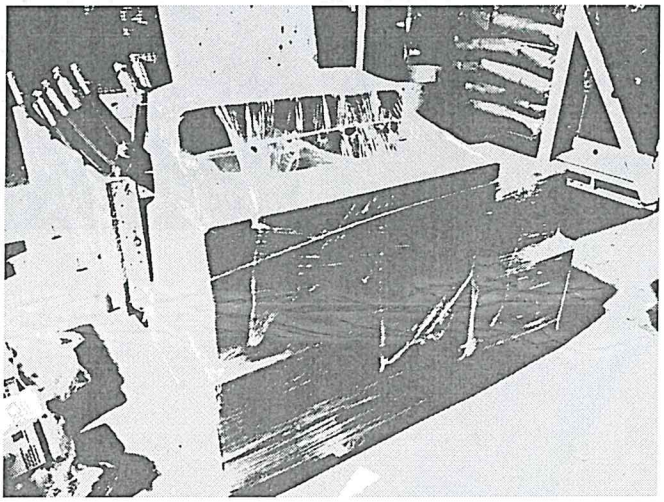


Control System and Panels



Variable-Frequency Drive (VFD)

Return to table