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OFFICE OF ENERGY, ENVIRONMENT, AND TECHNOLOGY
USAID/MEXICO

IN COLLABORATION WITH
Comision Federal de Electricidad, Mexico
Instituto de Investigaciones Electricas, Mexico

PRELIMINARY ENGINEERING FOR A FABRIC FILTER/ALKALI INJECTION PILOT PLANT FOR CONTROL OF SO_3 EMISSIONS AT MANZANILLO I UNIT 3 IN MEXICO

Final Report

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CONTENTS

Section	Page
BACKGROUND	1
PROJECT DESCRIPTION	2
Contribution of Sulfuric Acid Mist to High Plume Opacity at Manzanillo	2
Fabric Filter/Alkali Injection SO_3 Emissions Control Process	3
Objectives of the Pilot Plant Tests	3
PROJECT OBJECTIVES	4
ENGINEERING DESIGN OF A FABRIC FILTER/ALKALI INJECTION PILOT PLANT	5
Item 1, 2, and 8: Flue Gas Scoops and Installation Instructions	5
Items 3, 4, 5, 6, and 14: Siting, Elevation and Plan Drawings, Supports	7
Items 7, 9, and 10: FF System, FF Operation, Materials List	7
Fabric Filter Plant	7
Alkali Injection System	11
Fabric Filter and Alkali Injection Operation	11
Materials List	12
Items 11, 12, and 13: Fabrication, Erection, and Test Schedules	14
COST ESTIMATE	18
Task 2 - Procurement, Fabrication, and Erection Services	18
Task 3 - Operation and Testing	18
Task 4 - Results and Documentation	19

DRAWING PACKAGE ATTACHED

Drawing No. 1 - Design of the Extraction/Return Scoop Assembly
Drawing No. 2 - Design of the Scoop Mounting Plate
Drawing No. 3 - Installation Instructions for the Scoop Assembly
Drawing No. 4 - General Arrangement Elevation and Plan View
Drawing No. 5 - Pulse-Jet Fabric Filter General Arrangement

Background

In 1994, Mexico's Instituto de Investigaciones Electricas (IIE) and Comision Federal de Electricidad (CFE) initiated a collaborative project with the United States Agency for International Development (USAID) Center for Environment, Office of Energy, Environment, and Technology (the Center) and USAID/Mexico to address environmental problems at the Manzanillo Power Station. CFE is Mexico's state-owned utility company that owns and operates the Manzanillo Power Station, and IIE is the research and development agency for CFE. The goal of the project was to develop an environmental control strategy to meet proposed 1998 regulations for NOx, SO_2, and particulate matter (PM) emissions, and to reduce plume opacity. Recognizing that the Manzanillo Power Station (MPS) was producing emissions which were potential contributors to global climate change, USAID responded by initiating the Mexico Emissions Control Project (hereafter referred to as the Project).

Improving air quality in Mexico, and specifically in Manzanillo, is important to the indigenous population and the regional economy due to the large number of tourists which visit Mexico's west coast beaches in the vicinity of the plant. In this regard, the Manzanillo Power Station is located near the world's renown Las Hadas resort on the Pacific coast. The MPS is one of the Mexico's largest and most efficient utility plants for electricity generation, and has six units with a total generating capacity of 1900-MW. The plant provides electricity for the development of a vast region of this key part of the country. Although the MPS is a relatively new station, the units are not equipped with modern technologies required to control particulate matter (PM), NOx, and SOx (i.e., SO_2 and SO_3) emissions.

For Phase I of the Project, USAID assembled a project team consisting of the Electric Power Research Institute (EPRI), Electric Power Technologies, Inc. (EPT), Radian Corporation, and Bechtel Corporation. The objectives were to perform an engineering study to: (1) identify the causes for high plume opacity at the Manzanillo Power Station, (2) recommend potential solutions, and (3) evaluate the technical, economic, and commercial feasibility of each alternative. The results of the work were described in the report "*Retrofit Air Pollution Control for Heavy Fuel Oil Thermal Electric Power Stations in Mexico*" issued by USAID on February 28, 1995. As described in the report, the factors responsible for high plume opacity were: (1) excessive unburned carbon emissions from poor combustion, and (2) emissions of condensed sulfuric acid (i.e., sulfuric acid mist). The high unburned carbon emissions resulted from incomplete combustion of the fuel oil caused by the type of combustion equipment used in combination with the characteristics of the fuel oil. The sulfuric acid mist originated from oxidation of SO_2 contained in the flue gas to SO_3, and subsequent condensation of the SO_3 upon reaching the acid dew point temperature (typically before the stack exit).

Two approaches were recommended to achieve a clear stack plume at the Manzanillo Power Station. First, advanced oil combustion equipment referred to as Reduced Emissions and Advanced Combustion Hardware, or REACH, should be installed to reduce unburned carbon emissions. REACH is designed for retrofit to existing burners to solve a variety of site-specific boiler problems related to poor combustion conditions, and should reduce unburned carbon emissions by up to 60 percent, and decrease in-stack opacity from 40-50 percent to 5-10 percent.

The second approach consisted of a pilot plant demonstration of fabric filters with dry alkali injection to remove gaseous SO_3 and sulfuric acid mist. The pilot plant test would establish that fabric filters can achieve the degree of SO_3 removal desired with high reliability before committing to a full-scale system.

Subsequently, USAID, CFE, and IIE reached a mutual decision to retrofit REACH combustion hardware on one 300-MW unit at the Manzanillo Power Station (Phase II of the project). The unit selected for REACH was Manzanillo I Unit 3. In parallel, a preliminary engineering study was performed to define the requirements for a pilot plant demonstration of fabric filters with dry alkali injection at Manzanillo I Unit 3. This report presents results from the Phase II preliminary engineering study which USAID can use to solicit bids from contractors for detailed design, procurement, and installation of the fabric filter/alkali injection pilot plant.

Project Description

Contribution of Sulfuric Acid Mist to High Plume Opacity at Manzanillo

A major contributor to high plume opacity at the Manzanillo Station is droplets of sulfuric acid (sulfuric acid mist). Unlike unburned carbon emissions, which are the direct result of poor combustion conditions in the boiler and can be minimized by optimization of the combustion process, control of sulfuric acid emissions[1] is a more formidable problem because the sulfuric acid concentration in the flue gas is directly dependent upon the sulfur content of the fuel oil.

Measurements performed by Salt River Project at Manzanillo I Unit 3 before the REACH retrofit showed that SO_3 emissions at maximum load varied from 64 to 93 ppm depending upon excess oxygen[2]. The SO_3 emissions levels were quite high (SO_3 emissions of 50 ppm are considered high for oil-fired utility boilers), and were the combined result of the high sulfur (3.9 percent) and vanadium (340 ppm) contents in the fuel oil. The vanadium in the fuel oil oxidizes in the combustion zone to form complex vanadium compounds which deposit on boiler heat transfer surfaces and

[1]In this document, sulfuric acid refers to gas phase SO_3 and condensed droplets of H_2SO_4.

[2]The work was summarized in the report *"Retrofit of REACH Combustion Equipment at Manzanillo I Unit 3 in Mexico"* submitted by EPT to USAID in February 1997.

effectively catalyze SO_2 to SO_3. Upon reaching the acid dew point (estimated to be between 150 and 160°C), the SO_3 condenses into a mist of submicron-sized, sulfuric acid droplets. The submicron acid droplets are extremely effective at scattering light, thereby contributing significantly to plume opacity even in the absence of particulate matter. At Manzanillo, an "attached" sulfuric acid plume was visible at the top of the stack under virtually all operating conditions, which indicated that the flue gas reached the acid dew point in the ductwork or stack.

Fabric Filter/Alkali Injection SO_3 Emissions Control Process

The SO_3 emissions control process described in this document consists of the injection of dry alkali compounds upstream of a fabric filter (baghouse). In the process, small quantities of alkali materials such as pulverized limestone, hydrated lime, sodium-based compounds, or magnesium-based additives may be continuously injected upstream of the fabric filter. The alkali compounds build a uniform dust layer on the bags (and internal surfaces of the fabric filter casing) which will react with SO_3 and sulfuric acid as the flue gases follow a tortuous path through the dust layer, thereby removing the sulfuric acid from the flue gas and achieving a clear stack plume. The reaction products are alkali sulfate salts which are not sticky or corrosive. A unique characteristic of fabric filters is the excellent gas-solids contact which occurs as flue gas passes through the dust layer on the bags. This feature promotes high-efficiency removal of SO_3 and sulfuric acid, and distinguishes fabric filters from other dust collectors such as electrostatic precipitators which have much poorer gas-solids contact characteristics. Another positive aspect of the process is high-efficiency removal of particulate matter emissions (i.e., unburned carbon, fuel additive compounds, ash, sediments, and deposits dislodged by sootblowing) by the fabric filter. In this regard, fabric filters are extremely efficient collectors of fine particles, and will assure compliance with any future particulate matter regulations to control fine particles (i.e., PM_{10} and $PM_{2.5}$) and condensed-phase air toxics.

Objectives of the Pilot Plant Tests

To confirm the application the fabric filter/dry alkali injection process for acid plume control on oil-fired, utility boilers, a pilot-scale project will be performed at Manzanillo to demonstrate: (1) 95+% removal efficiency of sulfur trioxide (SO_3) and condensed sulfuric acid, (2) 99+% removal efficiency of fine particulate matter and condensed air toxics, and (3) a clear stack plume (i.e., plume opacity < 5 percent).

Specific objectives of the project are:

- Design, fabricate, and erect a fabric filter/alkali injection pilot plant at Manzanillo I Unit 3. The size of the pilot plant will be approximately 3,500 acfm (~ 1 MW).

- Conduct pilot-scale demonstration tests of the fabric filter/alkali injection sulfuric acid removal process on a slipstream of flue gas at Manzanillo for a sufficient time period to produce engineering design specifications and operating guidelines which can be used to design and operate full-scale systems. Tests will be performed using full-scale baghouse technology (e.g., bag length and diameter, pulse pressure, number of bags per pulse pipe, temperatures, etc.) such that the results will be readily applicable to a full-size system.

- Demonstrate the capabilities of the technology for PM and opacity control and alleviate technical concerns associated with application of fabric filters to oil-fired boilers. Demonstrating these objectives at pilot-scale (with full-scale components in a single compartment) will build confidence in the technology to support consideration for full-scale installations.

- Determine the reagent(s) of choice for the process and optimum feed rates and byproduct quantities. Also, quantitatively analyze samples of the byproduct to determine potential commercial uses.

- Provide a conceptual design of a fabric filter/alkali injection system for a full-scale system.

- Produce capital and operating cost estimates for a full-scale system.

Project Objectives

The objective of the work was to produce a preliminary engineering package which could be used by USAID to solicit bids for installation of a fabric filter/alkali injection pilot plant at the Manzanillo Station. Work performed consisted of the following items and services:

1. Design, fabricate, and deliver flue gas extraction and return scoops to Manzanillo I Unit 3.
2. Design, fabricate, and deliver required shutoff dampers, blank flanges, and supports for the extraction and return scoops.
3. Evaluate three possible sites for the fabric filter (FF) system.
4. Prepare elevation and plan view drawings for the complete FF system as installed at the recommended location.
5. Prepare a preliminary schedule for site work/foundations for installation of the FF system.
6. Design structural steel supports for flue gas extraction and return scoops, flue gas ductwork, and the FF system.
7. Determine the FF system and induced draft fan control interfaces.
8. Develop detailed instructions for installation of the flue gas extraction and return scoops in the boiler ductwork.

9. Develop detailed instructions for operation of the FF and dry alkali injection systems.
10. Provide a complete materials list of equipment to be furnished with the FF system.
11. Provide detailed schedules for fabrication and erection of the FF system.
12. Provide a detailed schedule for site restoration.
13. Develop a detailed test schedule.
14 Assist CFE in developing options for erection of the FF system at Manzanillo I Unit 3.

Descriptions of each task are presented in the following section of this report. Attached to the report is a packet containing the referenced drawings.

Engineering Design of a Fabric Filter/Alkali Injection Pilot Plant

A process flow diagram for the fabric filter/alkali injection pilot plant is shown in Figure 1. Dirty flue gas is extracted from the boiler ductwork downstream of the air heaters at Manzanillo I Unit 3 through an "intake" scoop. The gas is directed through ductwork to the inlet of a pulse-jet fabric filter. A small quantity of dry alkali (e.g., calcium hydroxide) is injected into the gas stream before the gas enters the fabric filter. Clean flue gas is pulled through the fabric filter by an induced draft (ID) fan, and is returned to the boiler duct through the "return" scoop. The ID fan will be equipped with a flow control damper. Solids collected in the fabric filter are discharged through a rotary valve to a removable hopper for subsequent disposal.

Descriptions of the items and services performed to design the fabric filter/alkali injection pilot plant are presented below.

Items 1, 2, and 8: Flue Gas Scoops and Installation Instructions

Drawing No. 1 and No. 2 show designs for the extraction/return scoop assembly and the scoop mounting plate furnished for Manzanillo, respectively. Drawing No. 3 presents installation instructions for the scoop assembly. The materials supplied included the following items which are noted in Drawing No. 3:

- Inlet/return mounting plate
- Inlet/return scoop assembly
- Inlet gasket, neoprene
- 355.6 mm(14-inch) diameter pipe saddle.
- 355.6 mm(14-inch) flange gaskets
- 355.6 mm(14-inch) butterfly valves, manual, with drop chain
- 355.6 mm(14-inch) blind flange
- Various assembly bolts

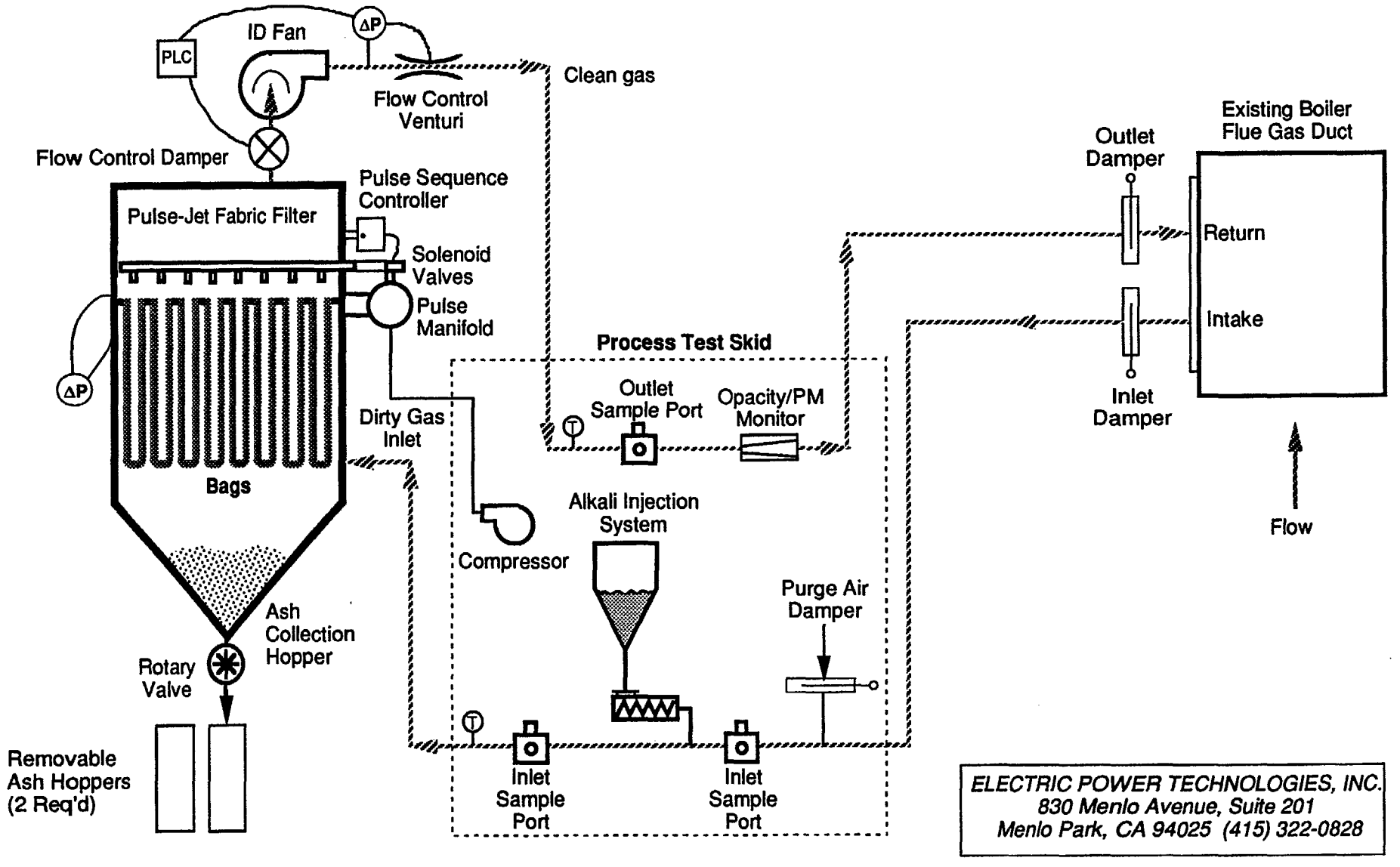


Figure 1. Process flow diagram for the Pulse-Jet Fabric Filter w/Alkali Injection for SO3 Control at Manzanillo I Unit 3.

The scoop assembly was delivered to the Manzanillo Station in September 1996, and was installed during the fall 1996 maintenance outage. Figure 2 shows the scoop assembly installed in the ductwork at Manzanillo I Unit 3.

Items 3, 4, 5, 6, and 14: Siting, Elevation and Plan Drawings, Supports

At the recommendation of Instituto de Investigaciones Electricas (IIE) and CFE, EPT subcontracted with Millares Construcciones En General in Veracruz, Mexico to provide preliminary design engineering for the fabric filter, alkali injection skid, and ductwork (as part of EPT's cost sharing). A Mexican engineering company was selected because they are familiar with construction requirements in Mexico, they have ready access to the Manzanillo plant site, and they can communicate readily with plant personnel.

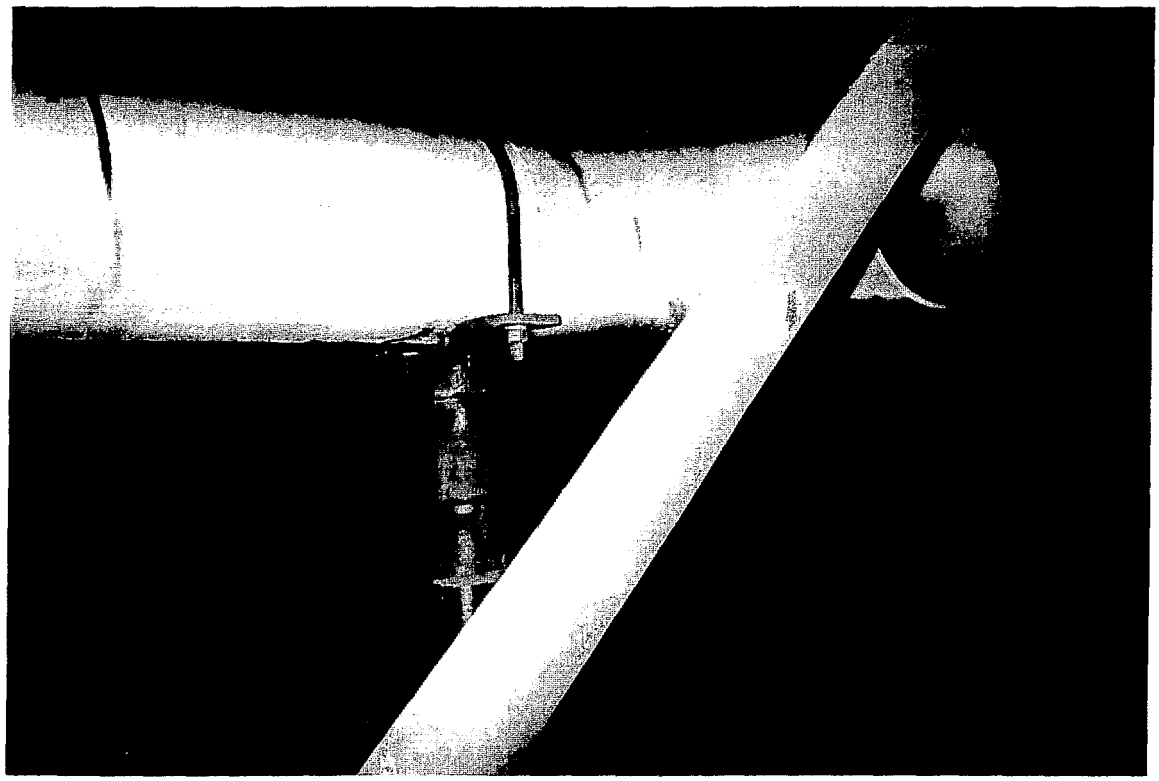
Several locations were considered for locating the pilot plant the Manzanillo Station. The location shown in Drawing No. 4 "General Arrangement Elevation and Plan View" was selected as best. Other sites considered included: (1) the opposite side of the duct between Units 2 and 3, and (2) twenty meters to the west (left) of the selected location. These locations were eliminated because of interferences with access routes to plant equipment.

Items 7, 9, and 10: FF System, FF Operation, Materials List

For reasons described in the USAID report *"Retrofit Air Pollution Control for Heavy Fuel Oil Thermal Electric Power Stations in Mexico"* described previously, a pulse-jet fabric filter was selected for the fabric filter/dry alkali injection process. For this preliminary engineering study, EPT solicited a quotation for a pulse-jet fabric filter pilot plant from Brandt Filtration Group (BFG) in Norcross, GA. Brandt was selected because of their experience building pulse-jet fabric filters, and their extensive efforts to develop appropriate bag fabrics for applications such as the project at Manzanillo. A description of the pulse-jet fabric filter is provided below.

Fabric Filter Pilot Plant. The pulse-jet fabric filter pilot plant will be a one-piece modular design featuring removable roof doors over the compartment tubesheet for access to the filter bags and cages. Included with the pilot plant will be system control components, shop insulation of the casing, induced draft fan with motor and drive, flow control damper, and other auxiliary items. Design criteria were:

- Volumetric flow rate: 3,500 acfm @ 250/350°F
- Bag dimensions (nominal): 6-inch OD x 14-feet long
- Filter area/bag: 22.4 ft^2
- Array: 1 compartment/4 rows/10 bags
- Total no. of bags: 40
- Total cloth area: 896 ft^2
- Air-to-cloth ratio (gross): 3.9 $acfm/ft^2$



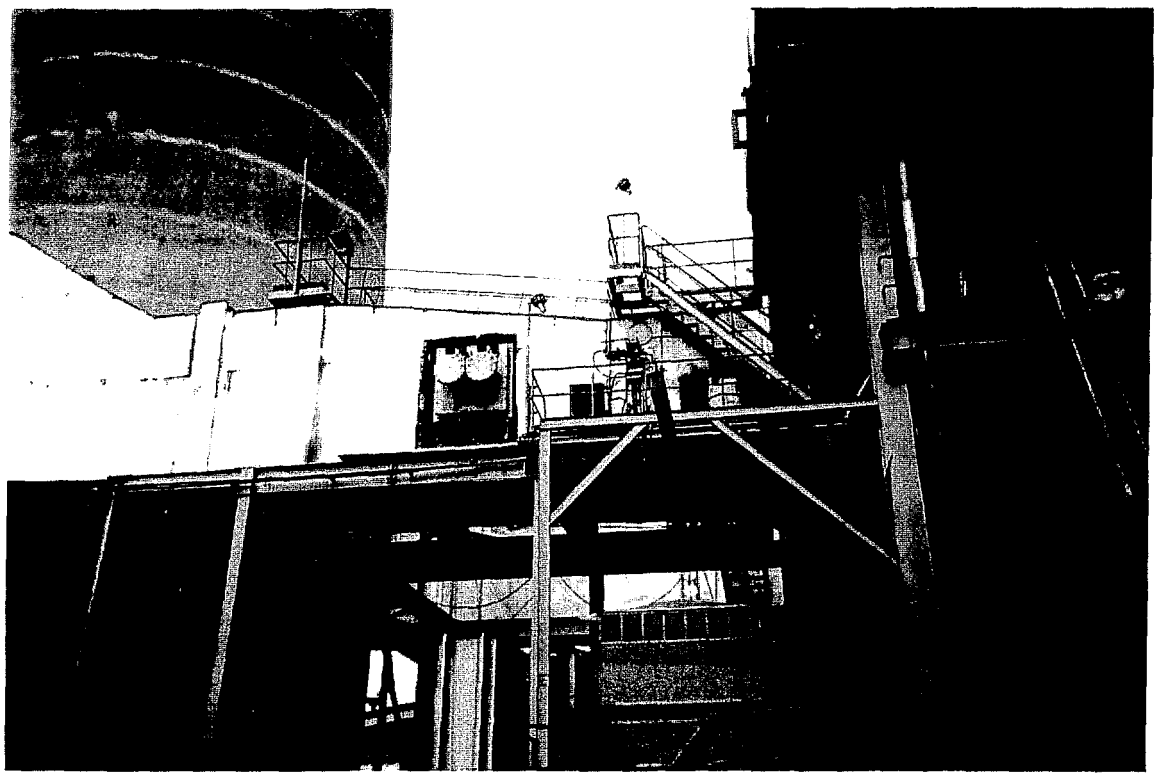


Figure 2. Photographs of the flue gas extraction and return scoops installed at Manzanillo I Unit 3. The top photograph shows the intake scoop inside the flue gas ductwork. The bottom photograph shows an external view of the intake (right) and return (left) scoops.

The fabric filter compartment will be shipped as a one-piece modular assembly (the hopper, bag compartment with tubesheet, and removable roof covers). The compartment will be constructed of Type A36, 3/16-inch plate carbon steel. The tubesheet will be 3/16-inch thick Type A36 steel, and will be precision die-punched to receive the filter bags. The bags will be spaced on 8-inch centers with 3-inches clearance with the side walls. The blowpipes will be 1-1/2-inches in diameter and will be drilled with variable orifices to equalize the distribution of cleaning energy to the bags.

The blowpipes will be connected by compression fittings to a 1-1/2-inch nipple that will be seal welded through the outer wall of the compartment. The nipple will be connected via a flexible, temperature-insulated hose to a high-capacity (Cv = 50) 1-1/2-inch diameter Goyen RCA45T pulse valve. The pulse valves will be shop installed on the on the high-volume air supply manifold. Mounting brackets will be provided on the outer walls of the compartment for easy installation of the manifold. The pilot solenoids and pulse card will be shop assembled into NEMA 4 boxes.

The compartment/hopper assembly will be provided with removable roof doors for access to the tubesheet level. One (1) 24-inch diameter hinged cam-lock door will be provided.

The bag compartment will be provided with flow diffuser plates and anti-reentrainment vanes located between the inlet duct and the bag compartment. Inlet and outlet connecting flanges will be provided as shown in Drawing No. 5. This design will minimize upward velocity between the rows of filter bags, eliminate "vortexing" of the flue gas, and provide better gas distribution within the compartment, thus minimizing overall pressure drop and abrasion of filter bags.

The pyramid compartment hopper will have a minimum 68 degree slope and 55 degree valley angle, and will be equipped with a covered poke hole, heavy-duty pounding anvil, and 12-inch square discharge flange. The hopper discharge will be fitted with a chain-driven "Rotolok" maximum duty, high-temperature rotary airlock and TEFC 1.15 SF motor. The hopper will be structurally designed to support both a full load of dust up to the bottom of the inlet at 80 pounds/ft^2 and the loads imposed by the dust removal system components. The hopper will be equipped with a hopper heater to maintain the dust above the acid dew point (approximately 150-160°C).

The entire fabric filter casing, including the removable roof doors, will be furnished with 3-inch thick semi-rigid fiberglass insulation covered by 22 gauge flat embossed galvanized lagging to achieve an effective protective barrier to minimize heat loss and prevent contact with hot surfaces by plant personnel. All exterior surfaces of the fabric filter casing will be power-tool cleaned (SSPC-SP3) and coated with high-temperature primer before application of the insulation and lagging. Interior

surfaces will be coated with an effective rust inhibitor. All structural steel components will be commercially blast cleaned (SSPC-SP6) and coated with industrial quality primer.

The filter bags will be nominal 6-inch OD x 14-feet long and constructed from 18 oz/yd^2 non-singed, plain self-supported Ryton felt. The bag cages will be fabricated from heavy duty, 11 gauge steel, and will have 20 vertical wires with horizontal wires on 8-inch centers. BFG high-capacity venturis will be included.

Structural supports providing a clearance of 5 feet to grade, a caged ladder, grating platform, and handrails at the cleaning system manifold will also be provided.

The induced draft (ID) fan will be a Chicago blower or equal fan size with a 135Q Radial Blade wheel design, and SISW arrangement 9-belt drive complete with:

- Floor-mounted motor base welded to extended fan base rails
- Punched flanged inlet and outlet
- Bolted access door
- Drain connection
- Shaft seal
- OSHA shaft and bearing guard
- Inlet vane damper for flow control with PLC controller
- Shaft cooler with OSHA belt guard
- 15 HP constant speed V-belt drive with 15 HP TEFC 1.15 SF motor
- Performance: 3,500 acfm at 12-inches static pressure and gas density of 0.052 lb/ft^3, 11.9 BHP operation at 300°F

The fan will be assembled and run before shipping to assure proper balance and alignment. The fan will be located on top of the fabric filter to minimize the footprint area.

A NEMA 4 control box equipped with a slave timer/controller will be furnished. The controller will be activated by a dual set point pressure switch complete with pressure indicator designed to automatically activate and deactivate the module cleaning cycle based on pressure drop. High and low pressure drop set points for activation and deactivation will be adjustable through a nominal range of zero (0) to ten (10) inches of water column. The pressure drop indicator will be visible from outside the NEMA enclosure. The timer/controller will have adjustable pulse interval (time between pulse) control. The span of adjustment will range from one (1) to thirty (30) seconds. The capability for pulse duration (length of pulse) adjustment will be incorporated into the timer/controller. Pulse duration adjustment will have a range of from one-twentieth (1/20) to one-half (1/2) second. Also furnished will be: (1) one air pulse control card, (2) air pulse control pilot

solenoids, and (3) photohelic-type dual set point pressure switch to display differential pressure and to initiate and interrupt cleaning.

The total weight of the FF with fan, bags, cages, and full hopper will be 4,600 kg (10,120 lb).

Alkali Injection System. The alkali injection system will be skid mounted and will include the items shown in Figure 1 and Drawing No. 4:

- Purge air intake and damper.
- Inlet sample port (upstream of alkali injection).
- Alkali (reagent) storage silo with bin vent filter, bin activation, and slide gate.
- Load cells on the storage silo for accurate measurement of reagent mass flow.
- Low level alarm/FF trip and "no flow" alarm/FF trip on reagent injection system for protection of bags in the fabric filter.
- Alkali (reagent) volumetric screw feeder.
- Inlet sample port (downstream of alkali injection).
- Outlet sample port.
- Opacity/continuous particulate matter monitor.

The reagent storage silo will have a capacity of 925 pounds (approximately 17 ft^3), which should provide 14 days operation at 24 hr/day (and 100 ppm SO_3). The silo will be filled manually with reagent through a roof door. The primary reagent to be evaluated will be calcium hydroxide ($Ca(OH)_2$), furnished in bags with an average particle diameter of 20μm. Contractors will investigate the need for a pneumatic conveying system to inject the alkali reagent at the inlet to the fabric filter as an alternative to the injection system shown in Figure 1 and Drawing No. 4 if particle dropout is a problem.

Fabric Filter and Alkali Injection Operation. Startup, checkout, and initial parametric tests of the pilot plant will require approximately two weeks of operation (the pilot plant will be operated 24-hours a day).

Before starting up the fabric filter, the following checks will be made:

1. <u>Mechanical Checks and Air Load to Verify:</u> ID fan operation and control, flue gas/purge air dampers, pulse system, pressure transmitters, alkali screw feed system, and data logger performance. Initially, the fabric filter will be operated on air only. This will be accomplished by starting up the ID fan with the inlet and outlet dampers closed. The purge air damper will then be opened, followed by the outlet damper (refer to Figure 1 and Drawing No. 4). Air flow will be increased to operate the fabric filter at an air-to-cloth ratio of approximately 4.0 acfm/ft^2 until all systems are checked out and performing to specification.

2. Alkali Precoat the Bags on Air: The pilot plant will be operated on purge air at the design flow rate of 4 acfm/ft^2. The alkali injection feeder will be operated without alkali to insure proper operation. A small quantity of alkali reagent will then be injected to "precoat" the bags with a protective dust layer. Pressure drop will be allowed to increase to 3 inches of water, at which time the bags will be cleaned. Precoating will continue through a number of cleaning cycles until ΔP after cleaning is 0.5 to 1 inches of water. The fabric filter will then be shut down to visually inspect the surface of the bags for uniform coating of alkali.

3. Startup on Flue Gas. The pilot plant will be placed in operation on air only with alkali injection as in Steps 1 and 2. The flue gas outlet damper will then be opened and the purge air damper closed. The alkali injection rate will be set to achieve a reagent ratio of 1.0 (i.e., Ca/S molar ratio) based on measurements of SO_3 performed prior to startup.

NOTE: Reagent should always be injected when the fabric filter is on-line filtering flue gas. Interruption of reagent injection for several hours could result in damage to the bags (this will be quantified in the tests).

4. Initial Measurements. Sulfuric acid and PM will be measured at the inlet and outlet of the pilot plant. The Controlled Condensation Method will be used for SO_3 and USEPA Method 17 for PM to determine the baseline SO_3 and PM concentrations, and removal across baghouse. Also, the SO_3 data will be used to finalize the reagent injection rate.

5. Fabric Filter Shutdown. A controlled shutdown should be performed as follows. With the unit filtering flue gas, the purge air damper should be opened. The inlet damper should then be closed. The fabric filter should be operated for approximately 30 minutes with alkali injection to purge flue gas from the compartment and to "dry" the bags. Alkali injection should be discontinued after 30 minutes. The outlet damper should then be closed, followed by the purge air damper. The ID fan can then be removed from service and the fabric filter isolated from the flue gas.

For a boiler trip, the fabric filter should be isolated from the flue gas and purged with air as quickly as possible.

Materials List. A detailed materials list will be incorporated following completion of preliminary engineering. A preliminary list is presented in Table 1.

Table 1

Materials List for the Fabric Filter/Alkali Injection Pilot Plant at Manzanillo

Equipment No.	Service	Quantity	Equipment Description
1	Inlet and Outlet Ductwork (approximately 200 ft)	1	Material: 1/4" A242 Diameter: 15-inch
2	Inlet Damper	1	Type: Butterfly, cast body, EPDM seat Diameter: 14-inch
3	Outlet Damper	1	Type: Butterfly, cast body, EPDM seat Diameter: 14-inch
4	Reagent Storage Silo w/Bin Vent Filter, Bin Activation, & Slide Gate	1	Capacity: 925 lbs Storage: 14 days @ 24 hr/day Material: Carbon steel Cone Angle: 60° Diameter: 2-ft 0-inches Height: 8-ft 0-inches Volume: 17 ft^3
5	Volumetric Screw Feeder	1	Rate: 20 lb/hr (maximum)
6	Pulse-Jet Fabric Filter	1	Supplier: Brandt Filtration Group Size: 3,500 acfm, A/C = 4 $acfm/ft^2$ No. Bags: 40
7	Induced Draft Fan	1	Type: Chicago blower, 15 HP Performance: 3,500 acfm @ 12-inches SP
8	Removable Hopper	2	TBD
9	Hopper Discharge	1	Type: "Rotolok" rotary airlock
10	Pulse Air Compressor	1	Requirements: 30 scfm (free air), 80 psig
11	Filter Bags	50	Type: Ryton felt, 18 oz/yd^2, 6-inch OD
12	Bag Filter Cages	50	Type: Steel, 11 gauge, 20 vertical wires
13	Opacity/PM Monitor	1	Type: BHA Group CPM 5000 PM Monitor
14	Flow Venturi	1	Material: Carbon steel
15	Alkali Reagent	1	Type: Hydrated lime (20 µm) Quantity: 5 tons (nine months supply)

Items 11, 12, and 13: Fabrication, Erection, and Test Schedules

Figure 3 presents a preliminary fabrication schedule for the fabric filter/alkali injection pilot plant equipment. For purposes of this document, it was assumed that a fabric filter contract can be awarded by May 30, 1997. In any event, the pulse-jet fabric filter can be fabricated and shipped to Manzanillo 16 weeks after placement of the order. Similarly, the alkali injection skid can be designed and fabricated in approximately 14 weeks. Most of the alkali injection skid, including all ductwork, can be fabricated in Mexico. This approach would reduce the cost and shipping time for the components and is recommended for USAID consideration.
A preliminary erection schedule is presented in Figure 4. Using a local Mexican contractor, all work can be completed by December 1997. The work will be scheduled such that upon arrival at the plant, the fabric filter can be lifted off a flatbed truck with a crane and immediately installed on the foundation. Equipment checkout would be performed in late November-early December 1997.

A preliminary test schedule is shown in Figure 5. Startup of the fabric filter/alkali injection pilot plant would be performed in December before the Holiday Season. It was assumed that calcium hydroxide ($Ca(OH)_2$) will be the alkali reagent of choice. The unit would be operated through late January at calcium-to-sulfur (Ca/S) ratio of approximately 1.0 using the SO_3 emissions data from the REACH tests. Particulate matter (PM) emissions at the outlet of the pulse-jet fabric filter and pressure drop across the bags will be continuous recorded by the data logger during this period.

Initial PM/SO_3 emissions measurements using USEPA Reference Methods would be performed at the start of the long-term tests. The results from these measurements will define the SO_3 inlet concentration and the removal efficiency across the fabric filter. The Ca/S will be adjusted as needed to achieve 95% removal of SO_3. The unit will be then be operated (and monitored remotely by modem) for approximately six months to obtain long-term pressure drop data and to allow the bags to achieve quasi-equilibrium (i.e., relatively stable duct layer). PM and SO_3 measurements will be performed twice during the long-term tests.

After the six-month operating period, alternative reagents (e.g., MgO), and fabric filter operation at increased air-to-cloth ratio (e.g., 6 acfm/ft^2) will be evaluated. All waste collected in the baghouse hopper will be stored on site. The waste will be analyzed to determine long-term storage characteristics and the potential for reuse.

Current plans call for the pilot plant to be removed from the site in late 1998. However, it may be appropriate to consider further tests to evaluate alternative bag fabrics or other reagents. Once removed from the site, the pilot plant can be moved to another plant for testing, or stored at Manzanillo.

Figure 5. Fabric Filter/Alkali Injection Pilot Plant Test Schedule and Site Restoration

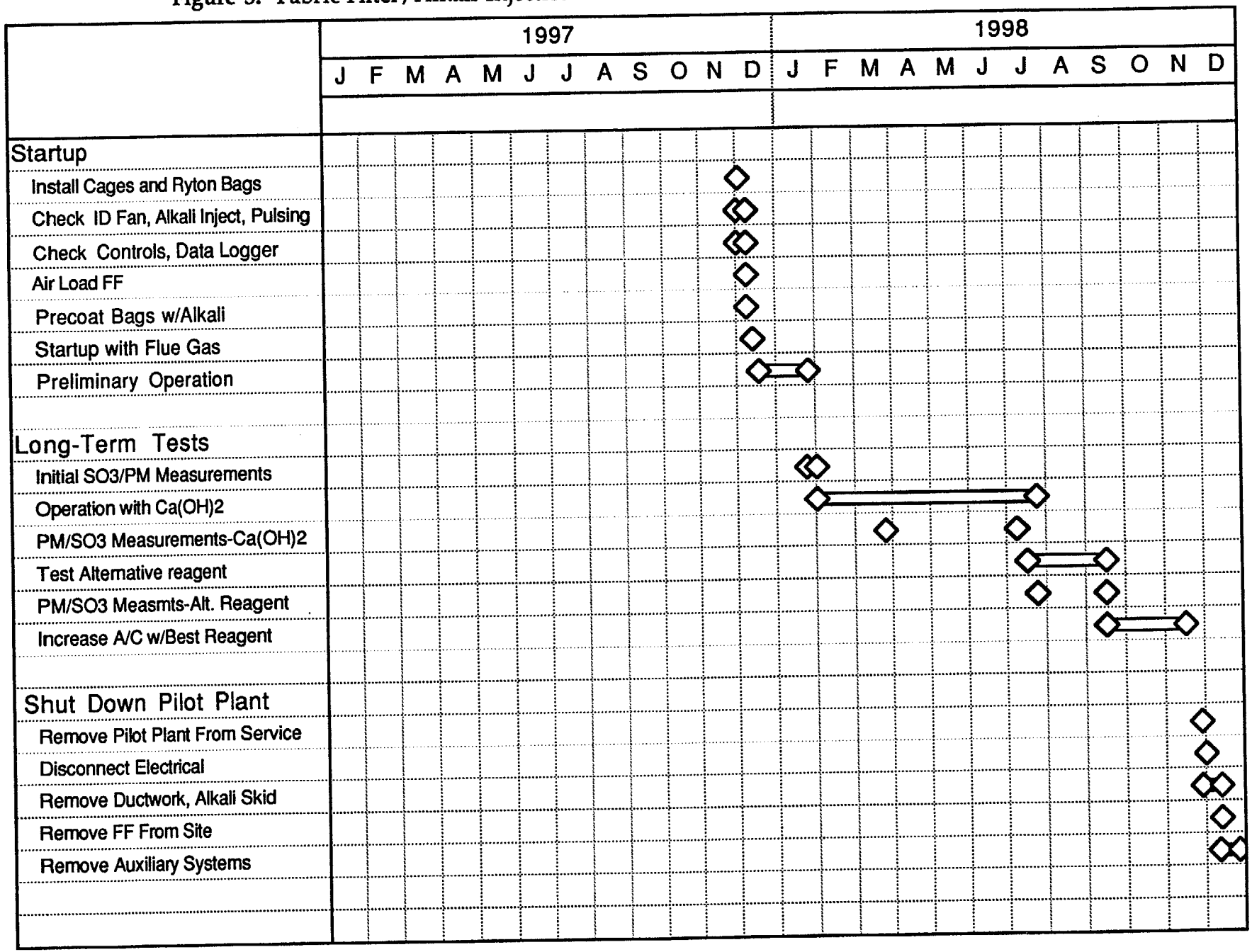


Figure 4. Fabric Filter/Alkali Injection Pilot Plant Erection Schedule

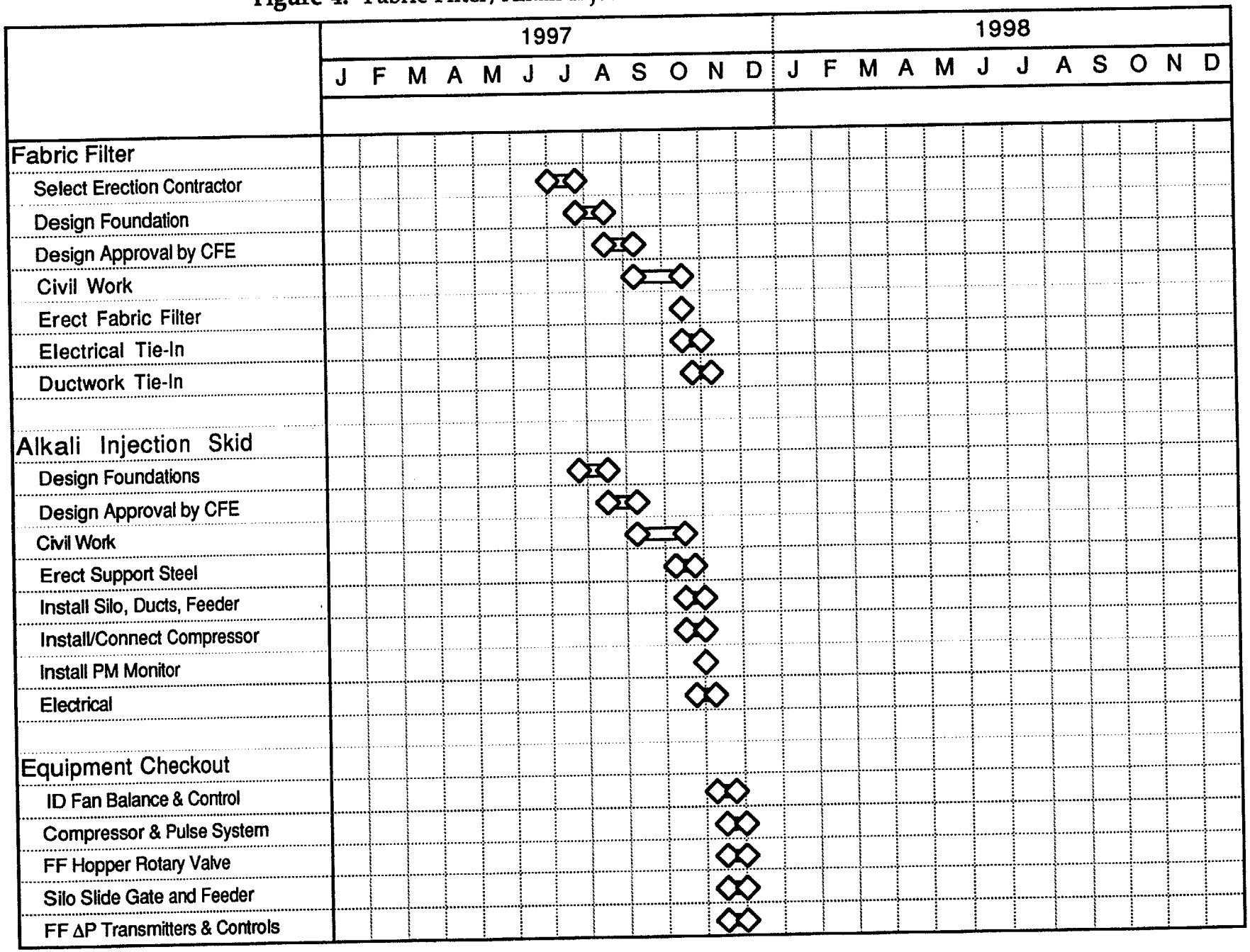
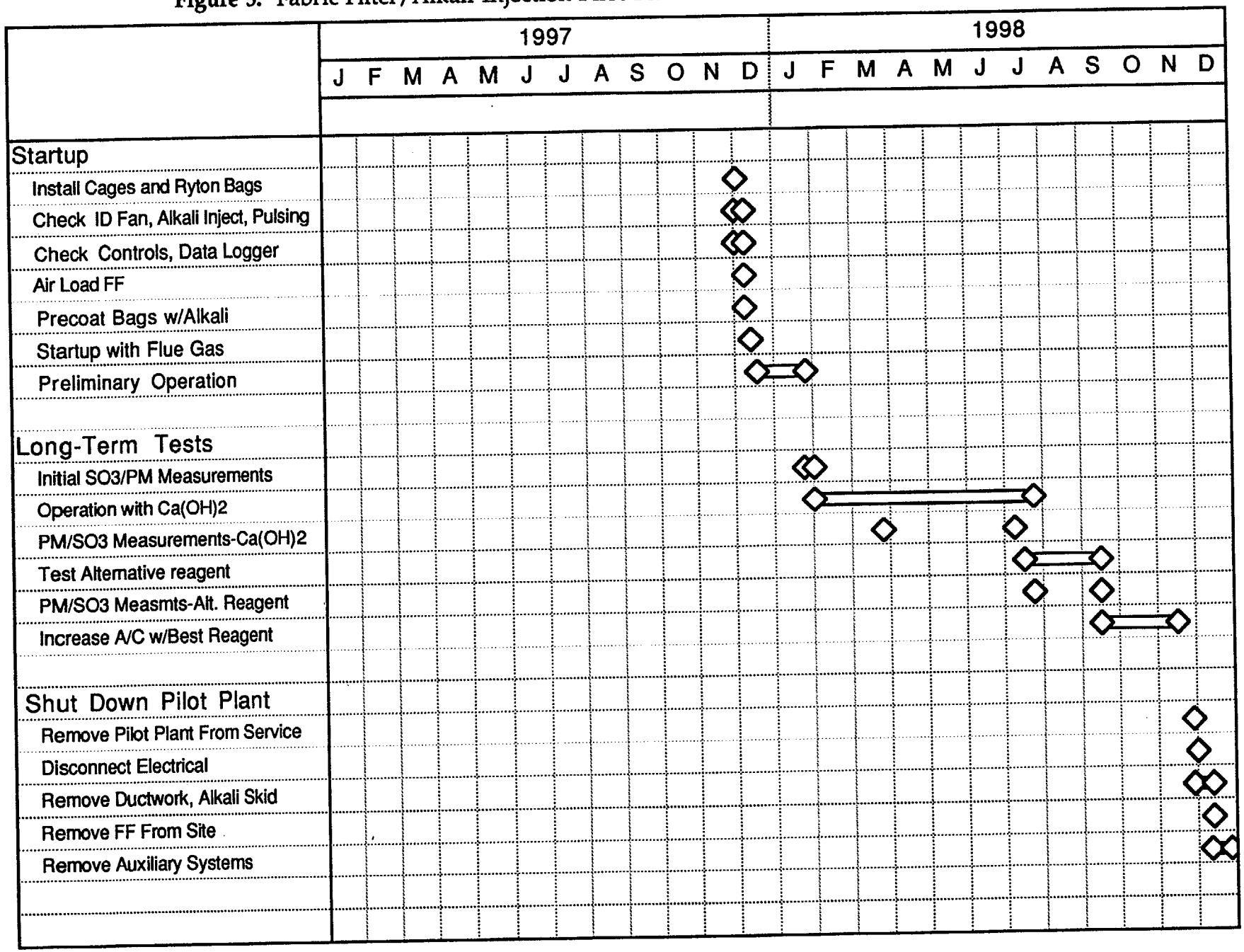


Figure 5. Fabric Filter/Alkali Injection Pilot Plant Test Schedule and Site Restoration



Cost Estimate

The fabric filter/alkali injection pilot plant project originally consisted of four tasks:

Task 1 - Preliminary Engineering and Design and Fabrication of Flue Gas Scoops
Task 2 - Procurement, Fabrication, and Erection Services
Task 3 - Operation and Testing
Task 4 - Results and Documentation

Work performed in Task 1 was reported herein. To assist USAID in budgeting, cost estimates to complete the project (Tasks 2-4) per the work scope and schedules described previously are summarized below. The costs include shipping and assume local Mexican labor will be used for erection services at Manzanillo.

Task 2 - Procurement, Fabrication, and Erection Services

Item	Cost, $US
Design, Procurement, and Shipping of the Fabric Filter Pilot Plant (with Compressor and All Controls)	84,000
Procurement and Shipping of Instrumentation	32,000
Design and Procurement of Reagent Skid Including all Ductwork, Feeders, Load Cells, Foundations, etc.	64,000
Erection Including Civil, Mechanical, Electrical	50,000
Sub-Total - Task 2:	**$230,000**

Task 3 - Operation and Testing (Including Travel and Expenses)

Item	Cost, $US
Alkali Reagents	5,500
Equipment Checkout, Startup, Initial Measurements of SO_3 and Particulate Matter	22,000
Periodic SO_3/PM Emissions Tests (4 Separate Test Periods)	49,000
Analysis of SO_3/PM samples, Data Transfer Analysis	19,000
On-Site Training of CFE/IIE Personnel	4,000
Sub-Total - Task 3:	**$99,500**

Task 4 - Results and Documentation (Including Travel and Expenses)

Item	Cost, $US
Data Analysis (PM, SO_3, Fabric Filter, Alkali Injection)	21,000
Document Preparation and Technical Briefings in Mexico	6,000
Reporting	12,000
Preliminary Design of a Full-Scale System at Manzanillo	6,000
Sub-Total - Task 4:	**$45,000**
Total - Tasks 2-4:	**$374,500**

In summary, the project can be conducted for approximately $374,500 in accordance with the schedules shown in Figures 3-5. Due to uncertainties regarding schedule, labor and material costs in Mexico, and exchange rates the cost estimates have an accuracy of ± 15 percent. If CFE was able to cost share the erection services, the total cost to USAID would be reduced to approximately $324,000. Lower costs are likely by competitive bidding for equipment procurement, and design and erection services. Further, EPT would seek to identify commercial partners to cost share supply of the fabric filter, alkali injection equipment, and evaluate the reuse potential of waste products collected in the fabric filter. In this regard, the waste will have a high concentration of vanadium, which has commercial value (the plant currently sells vanadium-rich bottom ash removed from the furnace during maintenance outages).