DOE/PC/88889--T16

PROOF OF CONCEPT TESTING OF THE ADVANCED NOXSO FLUE GAS CLEANUP PROCESS

CONTRACT NUMBER: DE-AC22-89PC88889

Quarterly Technical Progress Report for the Period April - July 1989

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1.0 INTRODUCTION AND SUMMARY

This project is being performed by MK-Ferguson Company for the U.S. Department of Energy Pittsburgh Energy Technology Center. The project is a pilot plant scale up from laboratory testing of the NOXSO flue gas cleanup process. The process simultaneously removes both sulfur and nitrogen oxides from the flue gas.

The objective of this project is to prove the NOXSO Process can achieve the same SO_2 and NO_x removal efficiencies under field conditions as achieved in laboratory tests.

The project is a scale-up of previous laboratory tests. The project will be built at Ohio Edison's Toronto Station a coal fired power plant located in Toronto Ohio. The pilot plant will process a 12000 SCFM slip stream of flue gas from the power plant.

The project is divided into 6 tasks. The purpose of Task 1 is to establish a work plan that covers in detail all the activities related to the successful completion of the project. Task 2 consists of the design and construction of the pilot plant. Task 3 consists of an experimental program to define both operating conditions and performance data to support Task 4. Task 4 primary activities to conduct a long duration test which attains continuous 90% sulfur dioxide and nitrogen oxide removal rates. Task 5 will be the conceptual design of a 500MW including an economic evaluation of the conceptual design. Task 6 will be the demolition of the pilot plant and restoration of the site.

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2.0 OBJECTIVES

The objective of this project is to demonstrate the potential for application of the NOXSO Flue Gas Treatment (FGT) technology to coal-fired utility boilers in the 1990's. To accomplish this, the NOXSO team will design, construct, operate, and test a proof-of-concept-scale NOXSO test facility at Ohio Edison's Toronto Station. The goal of the proof-of-concept test is to obtain the engineering data required to prepare a cost effective design of a commercial scale NOXSO process module at an acceptable level of technical risk. A secondary goal of the test program is to optimize process performance, i.e., achieve 90% removal of SO_2 and NO_x from the flue gas at the lowest possible cost, while maintaining the high level of system reliability dictated by the utility market.

3.0 ACCOMPLISHMENTS

3.1 Task 1: Accomplishments

The site access agreement between MK-Ferguson and Ohio Edison has been executed.

The NOXSO Corp. has submitted the Work Plan narratives.

The DOE has scheduled the kick-off meeting for July 26, 1989.

The Work Plan was submitted on June 30, 1989.

Elements of the Project Description section of the Work Plan are included as Attachment 1 to provide an understanding of the project tasks and goals.

4.0 PLANS FOR NEXT QUARTER JULY 20 - OCTOBER 20, 1989

4.1 Task 1:

DOE approval of the Work Plan is expected. The sorbent Transport Study will be done. The design phase of the engineering studies by Pemm-Corp. for the fluid bed design for the adsorber and heater/cooler and the design for the non-mechanical valves will be started.

4.2 Task 2:

Task 2 engineering will be started. The primary activities will be developing the Process Flow Diagram, starting system P & ID drawings, starting the General Arrangement Drawings and the major equipment specifications will be started.

NOXSO will start Task 2.2, developing the Detailed Test Plan for Tasks 3 and 4. The Detailed Test Plan is required to establish the process control philosophy and the type and location of the instrumentation required to monitor and control the process.

ATTACHMENT 1

1.0 Task 1 - Program Definition

This task entails submittal of the work plan which covers in detail all activities related to the successful completion of the project. The technical approach discussed herein is a part of the work plan, as is the project schedule, budget, and work chart.

The revised Work Plan will be submitted to the DOE in near future. A binding agreement from Ohio Edison for the use of the Toronto Station as the project host site.

2.0 Task 2 - Design, Procurement, Assembly, and Shakedown Tests

The NOXSO team will design, construct, and operate a proof-of-concept (POC) test facility at Ohio Edison's Toronto Station treating a slipstream of flue gas generated by burning Ohio's high sulfur (3.5%) bituminous coal.

2.1 Process Design

The design phase of Task 2 begins with process design. NOXSO Corporation will be responsible for preparing a process design package which will consist of a POC test facility process flow diagram, energy and material balance, equipment list, equipment specifications, and plot plan. The process flow diagram shows the flow of gas and solids (sorbent) through the system and the arrangement of all of the pieces of equipment in the POC test facility. The POC test facility will treat 12,000 SCFM of flue gas containing 2500 ppmd SO_2 and 365 ppmd NO_x. The POC test facility will integrate absorption and regeneration process steps such that there will be a continuous flow of sorbent from the adsorber to the sorbent heater to the sorbent regenerator to the sorbent cooler and back to the adsorber.

2.2 Detailed Test Plan

The second phase of the design effort is the preparation of the detailed test plan. The test plan will be submitted to DOE and OCDO for review and approval prior to the start of work on the final design (discussed below). The test plan is an important part of the design effort because the design must be consistent with the types and ranges of process variables to be studied. For example, the specifications for the fan that extracts the slipstream of flue gas from the power plant ductwork and moves it through the NOXSO adsorber will depend on the range of adsorber bed heights to be studied. For this reason, the test plan must be completed before work on the final process design begins. The test plan will contain a comprehensive description of the series of experiments to be run in the POC test facility. The test plan will include:

- Number, sequencing, and duration of test runs
- Specified operating conditions for each run
- Schedule for all tests
- Data acquisition requirements for each run
- Number and type of samples to be taken manually for each run
- Detailed description (with scale drawings) of any design changes or equipment modifications to be made over the course of the test program
- Examples of how the data for each run will be analyzed
- List of reporting requirements

The test plan will be divided into two major parts: parametric tests and the long duration test. The series of parametric tests are intended to evaluate process performance, identify important operating variables, optimize process operation, and provide data to serve as input to the conceptual design and economic evaluation (Task 5). Simply stated, the objective is to define the process in a form that produces the maximum efficiency at the lowest possible cost.

Previous tests on the NOXSO process have identified certain key operating parameters that determine efficiency and cost. These are:

- o SO_2/NO_x inlet concentration
- o Sorbent feed rate
- o Sorbent bed height
- o Sorbent bed temperature (adsorber)
- o Regeneration temperature
- o Composition and amount of reducing gas

2.3 Final Detailed Design

Before the final design can begin, the completed process design with analyses, process flow diagram, material and energy balances, equipment list, equipment sizes, and a plot plan will be submitted to the DOE and OCDO Project Manager. Following the appropriate approvals, Final Detailed Design will begin. The following states the work which will be accomplished as a part of this effort:

General

- o Complete design, ancillary equipment sizing, drawings, specifications, and other supporting efforts to the degree of detail that can clearly determine manufacturing and construction work requirements.
- o Prepare calculations as required for design decisions, equipment and material selection, and preparation of construction drawings.
- o Prepare final drawings of equipment arrangement for DOE and OCDO review and comment, and final arrangement drawings for construction.
- o Prepare construction drawings to include the following:
  - Plant/site arrangements including equipment maintenance areas - Foundations

- Structural steel, platforms, and stairs - Water supply
- Equipment location
- Piping
- Fire protection system
- Electrical diagrams
- Electrical schematic and interconnection diagrams
- Underground utilities
- Control panel arrangements

o Surveys and Exploration - Provide engineering information and specifications for the procurement of subsurface foundation explorations and soils investigations if required for the project.

o Site Arrangement - Evaluate site topography, access, utility location, and other applicable site conditions in order to develop an efficient, economical site arrangement.

o Equipment Specifications - Specifications shall be prepared for equipment, instrumentation except bulks, electrical equipment and electrical specialties (including cable and trays), piping specialties (strainers, traps, gauges, valves, hangers, expansion joints, etc.) and breeching (including dampers and expansion joints).

o Construction Specifications - Develop construction work packages suitable for fixed price bidding and prepare construction specification. Each contract can be subdivided as necessary for this project after a firm definition of construction contracts is established.

2.4 Procurement

MK-F will award the bid packages upon DOE approval.

The project schedule will be reviewed and adjusted as required where vendor delivery schedules differ from those planned.

MK-F shall monitor each vendor for its progress against the scheduled dates.

2.5 Construction

- Prior to construction, a schedule of engineering procurement, delivery, construction and start-up will be developed and a copy submitted to OCDO. This schedule shall consider design activities, procurement lead times, delivery and erection requirements. Prior to construction, a meeting shall be held with OCDO to review the schedule. (See Attachment)

- The NOXSO team will coordinate construction and installation of the facility at the host utility site, and shall be responsible for disposal of all the waste materials produced from the process during construction and subsequent testing in accordance with all applicable laws and regulations.

- The construction work has been divided into bid packages for the major elements of the work.

    - Civil
    - Structural
    - Mechanical & Piping
    - Electrical & I & C
    - Insulation

- MK-F intends to solicit subcontractor bids for some or all of the bid packages dependent upon schedule constraints and responsiveness of bidders. All work subcontracted will be first approved by the DOE.

- The construction activities will be monitored closely for compliance with the project schedule.

2.6 Shakedown Tests & Start-up

- The objective of the shakedown test is to ensure that the facility is ready for a safe start-up as soon as all required construction is complete. Shakedown activities are those checks, inspections, tests, and calibrations which are required to insure that all components are properly installed, prepared, and fully functional at start-up. Prior to start-up, a meeting will be held with OCDO to review construction, projection progress, and status of budget.

3.0 Task 3 - Experimental Program and Data Reduction

Upon completion of Task 2 activities (design, construction, shakedown, start-up), Task 3 testing of the proof-of-concept (POC) facility begins. The primary goal of Task 3 is to define both operating conditions and performance data to support both Task 4, long duration POC testing, and Task 5, conceptual design and economic evaluation activities for a commercial-scale process. The Task 3 secondary goal is determining optimized unit operating conditions (temperature, pressure, sorbent bed height/inventory) which ensures flue gas SO2 and NOx removal in an economic and reliable manner.

The host boiler for the POC demonstration produces a flue gas flowrate substantially greater than the maximum allowable quantity for treatment in the POC facility. In addition, the quantity of inlet flue gas to the POC facility makes component variations impractical. Therefore, tests conducted in Task 3 will primarily concern POC process variation and optimization for treatment of a uniform flue gas stream.

Baseline flue gas characterization, monitoring and data collection will be performed during Task 2 as part of NOXSO'S construction support activity. Monitoring and data collection will be conducted during a two-month period prior to starting Task 3 testing; a summary report for the flue gas monitoring and characterization efforts will be submitted to DOE and OCDO.

In evaluation of NOXSO process performance, primary concerns include the operation and parameter characterization of sorbent adsorption, heating, regeneration, and attrition conditions.

During adsorption, required SO_2 and NOx emission reductions in the flue gas must efficiently occur while practical, economic operating conditions are defined, maintained and monitored. Flue gas emission reductions are determined by the difference in the concentration of the adsorber flue gas inlet and outlet streams.

However, process economics indicate that an optimal sorbent circulation rate exists which minimizes operating cost. In addition, fluidization bed temperature strongly influences adsorption rates and must be maintained and controlled.

Sorbent heating occurs in a three stage adsorber; therefore, optimal bed heights and temperatures will be maintained to minimize the flowrate of inlet heated air. In addition, nitrogen oxide and trace sulfur dioxide mass flows desorbed in the heater require monitoring and analysis in support of Task 5 activities assessing NOx and combustion air recycle to the utility boiler. During regeneration, desorption of sulfur compounds is essential to sorbent circulation and adsorption operations.

Sorbent regeneration occurring at optimal and acceptable conditions minimizes sorbent inventories in unit operations and transport. Dependent upon regeneration operations, sulfur dioxide and nitrogen oxide adsorption capture is increased by improving sorbent reactivity, thereby reducing process capacity requirements and associated costs. Sorbent regeneration will be measured, monitored, and evaluated by two approaches. First, the mass flowrate of sulfur leaving the regenerator/steam treatment vessel in the exiting gas will be measured by continuously monitoring the flowrate and composition of these gas streams. Second, samples of sorbent into and out of the regenerator/steam treatment vessels will be periodically taken and analyzed for total sulfur content.

Sorbent attrition during fluidization and transport will be measured; evaluations will be conducted to define sorbent-related operating conditions influenced by process transients.

Evaluation of baghouse flyash indirectly determines sorbent attrition by monitoring sodium and alumina particulate contents. Defining attrition by sorbent make-up rate allows development of relationships between varying operating conditions and sorbent attrition.

Manual sampling of exiting gas particulate loading from unit operations allows evaluation of attrition rates in individual fluid and moving bed systems by established EPA standards and methods. A combined approach in evaluating sorbent attrition by the three methods will promote accurate and complementary analysis.

Upon completion of Task 3 and prior to starting Task 4, a presentation will be made to DOE and OCDO on the test results that have been accumulated to verify the technical and economic viability of the process. A decision by DOE and OCDO will be made at that time to determine whether or not to proceed with Task 4 of the USDOE contract and/or OCDO grant agreement. Task 4 will not proceed until written approval from the DOE Contracting Officer and OCDO is obtained.

4.0 Task 4 - Long Duration Test

The primary Task 4 activity is to conduct a three-month duration test at the POC facility which attains continuous 90% sulfur dioxide and nitrogen oxide removal rates at a 90% process availability factor. The long duration test will confirm the NOXSO flue gas treatment process' ability to operate under conditions and periods closely simulating utility power plant operations.

Based on operating parameter optimization activities established in Task 3, long-term, steady-state operation will be performed to confirm process efficiency, reliability, and economic achievements. Specifically, long-term operating reliability of the sorbent transport non-mechanical valving is addressed in Task 4.

Task 4 process monitoring and data collection will be conducted by procedures defined in Task 3. All exiting gaseous streams and relevant operating parameters will be identified and maintained to promote optimal process performance. Data defining inlet/outlet stream compositions/flowrates and relevant process operating parameters will support Task 5 conceptual design activities. Process fluctuations occurring in response to unit transients during long-term operation will be monitored and assessed.

The Task 4 long duration test will confirm long-term, steady-state process operational feasibility; stability issues; transient and outage responsiveness; and process control logic design. Such information will support Task 5 conceptual commercial design activities.

The section narrative entitled "Reporting Requirements" defines all documentation responsibilities required for Task 4.

5.0 Task 5 - Conceptual Design and Economic Evaluation

The primary activities to be conducted in Task 5 are a 500MWe power plant (utilizing high sulfur coal) conceptual design and a subsequent economic evaluation of the conceptual design. Information necessary to perform the activities in Task 5 will be developed from documented assessments previously performed, applicable evaluations currently conducted, and relevant data produced in Tasks 3 and 4 of the Proof-of-Concept (POC) test.

Task 5 activities are based on the operation of the coal-fired (high sulfur coal case) power plant developed by EPRI and described in the following reports:

- "Economic Evaluation of FGD Systems," Vol. 5, EPRI CS-3342, October 1986
- "Coal-Fired Power Plant Capital Cost Estimates," EPRI PE-1865, May 1981
- "FGD Economic and Design Factors," EPRI CS-1428, April 1980

6.0 Task 6 - POC Unit Removal

The POC facility will be dismantled and removed from Ohio Edison's Toronto plant at the test plan's conclusion. Interim storage is located approximately 60 miles from the test site before resale or use at the Pittsburgh Energy Technology Center. The timeframe for POC equipment dismantling is dependent upon program approval of any follow-up demonstrations of unit operations evaluating performance improvements and system capital/operating cost reductions. Such concepts focus on transfer line adsorption, improved sorbent regeneration, and sorbent strength characteristics.

NOXSO CONTRACT NO. DE-AC22-89PC8889
KEY PRESONNEL REPORT FOR MAY, 25 1989 THU JULY 21, 1989

KEY PERSONNEL	TASK I		TASK II		TASK III		TASK IV		TASK V		TASK VI	
	PLANNED	ACTUAL	PLANNED	ACTUAL	PLANNED	ACTUAL	PLANNED	ACTUAL	PLANNED	ACTUAL	PLANNED	ACTUAL
R. L. GILBERT	100%	48%*	100%		10%		10%		100%		100%	
L. G. NEAL	100%	27%**	10%		100%		100%		20%		0%	
K. W. PLUMLEE	25%	0%	0%		10%		10%		10%		0%	
M. D. MORRELL	100%	67%*	100%		10%		3100%		100%		50%	
J. L. HASLBECH	100%	29%**	10%		100%		100%		10%		0%	
T. R. GOUKER	10%	0%	0%		100%		100%		0%		0%	
J. P. SOLAR	10%	0%	0%		100%		100%		0%		0%	
W. T. MA	100%	3%**	10%		100%		100%		10%		0%	

FOOT NOTES:
* CALCULATION BASED ON 504 AVAILABLE HOURS 04/26/89 THRU 07/21/89
** CALCULATION BASED ON 346 AVAILABLE HOURS 05/01/89 THRU 06/30/89