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COMMERCIAL DEMONSTRATION OF THE NOXSO SO_2/NO_x REMOVAL FLUE GAS CLEANUP SYSTEM

DOE/PC/90549--5

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Project Definition Phase

U.S. DOE Patent Clearance Is Not Required Prior to the Publication of this Document

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1.0 INTRODUCTION

The NOXSO Process is a dry, post-combustion flue gas treatment technology which uses a regenerable sorbent to simultaneously adsorb sulfur dioxide (SO_2) and nitrogen oxides (NO_x) from the flue gas of a coal-fired utility boiler. In the process, the SO_2 is reduced to elemental sulfur and the NO_x is reduced to nitrogen and oxygen. It is predicted that the process can economically remove 90% of the acid rain precursor gases from the flue gas stream in a retrofit or new facility.

Details of the NOXSO Process are described with the aid of Figure 1. Flue gas from the power plant is drawn through a flue gas booster fan which forces the air through the fluid bed adsorber and centrifugal separator before passing to the power plant stack. Water is sprayed into the flue gas as required to lower the temperature by evaporative cooling. The fluid bed adsorber contains active NOXSO sorbent. The NOXSO sorbent is a 1.6 mm diameter γ-alumina bead impregnated with 5.2 weight % sodium. The centrifugal separator separates sorbent which may be entrained in the flue gas and returns it back to the adsorber.

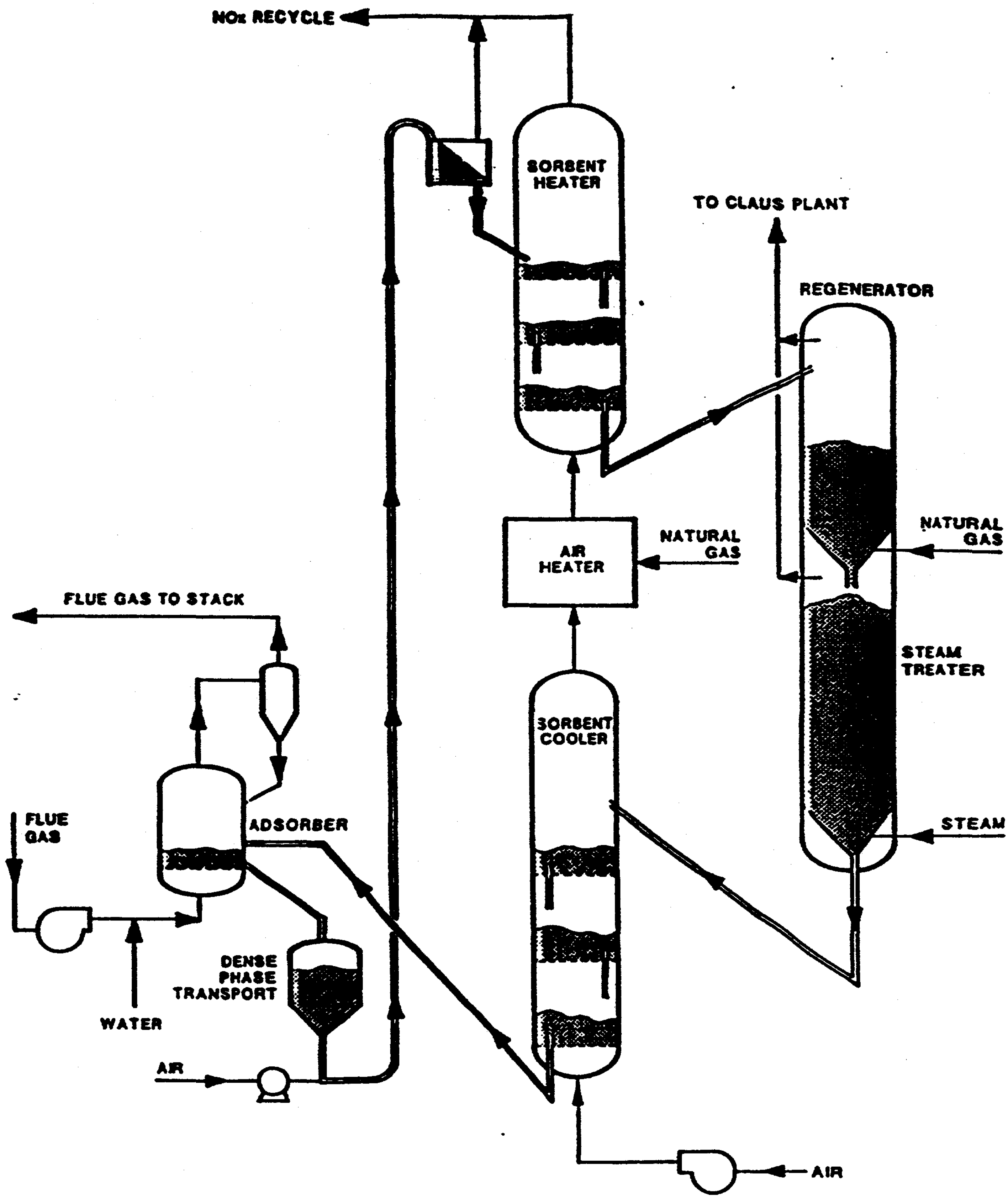
Spent sorbent from the adsorber flows into a dense-phase conveying system which lifts the sorbent to a disengaging vessel. From the disengaging vessel the sorbent flows by gravity to the top bed of the sorbent heater. The sorbent flows through the multi-stage fluidized bed sorbent heater counter to the heating gas which heats the sorbent to the regeneration temperature of approximately 1200°F.

In the process of heating the sorbent, the NO_x is driven from the sorbent and carried to the power plant boiler in the NO_x recycle stream. The NO_x recycle replaces a portion of the combustion air. The presence of NO_x in the combustion air reduces the formation of NO_x in the boiler resulting in a net destruction of NO_x.

The heated sorbent enters the regenerator where it is contacted with a methane reducing gas. Through a series of chemical reactions, the sulfur on the sorbent combines with the methane and forms SO_2 and H_2S. Additional regeneration occurs in the steam treater when the sorbent is contacted with steam converting the remaining sulfur on the sorbent to H_2S.

The regenerator and steam treater off-gas streams are combined and directed to a Claus plant where the H_2S and SO_2 are converted to liquid elemental sulfur. Tail gas from the sulfur plant will be incinerated and recycled back through the adsorbers to remove any sulfur compounds.

High temperature sorbent exiting the steam treater passes to the multi-stage fluidized bed sorbent cooler. The sorbent flows counter to the ambient air which cools the sorbent. Regenerated sorbent exits the cooler at 250°F. It is directed to the adsorber completing the sorbent cycle.



NOXSO PROCESS FLOW DIAGRAM

FIGURE 1

Ambient air which is forced through the sorbent cooler by the heater-cooler fan exits the sorbent cooler at approximately 800°F. This preheated air then enters the air heater where it is heated to approximately 1350°F so it is capable of heating the sorbent exiting the sorbent heater to 1200°F.

2.0 PROJECT DESCRIPTION

The objective of the NOXSO Demonstration Project is to design, construct, and operate a flue gas treatment system utilizing the NOXSO Process at Ohio Edison's Niles Plant Unit #1. The effectiveness of the process will be demonstrated by achieving significant reductions in emissions of sulfur and nitrogen oxides. In addition, sufficient operating data will be obtained to confirm the process economics and provide a basis to guarantee performance on a commercial scale. Ohio Edison's Niles Plant Unit #1 generates 115 MW of electricity and 275,000 scfm of flue gas while burning 3.5% sulfur coal.

3.0 PROJECT STATUS

The project is presently in the project definition and preliminary design phase. This phase was included in the project to allow completion of process studies and preliminary activities which could be conducted in parallel with NOXSO's pilot plant project being conducted at Ohio Edison's Toronto Power Plant.

Prior to this reporting period, activity on the Demonstration Project was limited while awaiting data from the pilot plant. During this reporting period, significant adsorption and regeneration data was obtained. This information is being used to develop the Demonstration Plant design basis.

NEPA Compliance

A draft EIV and EA had been prepared before this contract was awarded. Due to the reduction in activity on the project during the last year, no progress was made. During this reporting period, the EIV preparation has been re-initiated. Specifically, the EIV is being reviewed and reorganized based on recent policies for preparation of the EIV and EA.

Items of particular concern which must be investigated include:

- Disposition, fate, and toxicity of attrited sorbent.

Attrited sorbent can exit the system in the bottom ash, fly ash, and flue gas. The quantity and impact on the environment of the attrited sorbent must be assessed.

- Location and classification of the ash ponds.

The ash ponds location relative to the local flood plains must be determined. There is also uncertainty whether the ash ponds are classified as wetlands. This determination impacts the degree of analysis and reporting required for the project.

Preliminary Engineering

Expectations of the plant with regard to pollutant removal efficiency and availability have been discussed with Ohio Edison. Of significant interest is the most economical removal efficiency, i.e. to remove the most SO_2 and NO_x at the minimum normalized cost. Required NOXSO plant availability has a direct impact on the requirement for equipment sparing and consequently capital cost.

The regenerator at the pilot plant is constructed from alonized stainless steel due to the high temperature and corrosive environment. Due to the physical size of the oven used for alonizing material, an alonized regenerator for the Demonstration Plant must be constructed of pieces limited in size to 6½ feet by 21 feet. The regenerator size is estimated to be 15 feet in diameter by 50 feet long including the head and cone section.

Nitrogen Oxide Studies

NO_x destruction testing for the DOE project "An Experimental Study of NO_x Recycle in the NOXSO Flue Gas Cleanup Process", DE-AC22-91PC91337, continued at the B&W research facility in Alliance, Ohio. The series of NO injection tests into the primary or secondary combustion air have been completed. Some of the tests involving simultaneous injection of NO into both the primary and secondary combustion air as well as NO_2 injection have been completed. About 70% average NO_x reduction efficiency has been achieved when NO is injected into the primary air duct. The reduction efficiency was not affected by the NO injection flowrate, the furnace load or exit O_2 concentration. When NO is injected into the secondary air duct, the NO_x reduction efficiency ranges from 46% to 60% with dependance on the exit O_2 concentration. The NO simultaneous injection tests showed that the NO_x reduction efficiency increases with the percentage of total NO injected into the primary air duct. About 67% average NO_x reduction efficiency was demonstrated with injection of NO_2 into the secondary air duct, which is higher than that with injection of NO at the same test conditions.

Process Studies

Pilot Plant

At the completion of this reporting period, the POC pilot plant had been operated for a total of approximately 1200 hours in a hot inert mode (normal operating temperatures without flue gas) and 1600 hours with flue gas. Availability for this reporting period was 75%.

A series of tests were conducted to determine the minimum temperature required for regeneration. The initial design called for the bottom bed of the sorbent heater to be operated at 1225°F. It was determined that regeneration could be successfully completed with the bottom bed at 1150°F. The result of this test reduces the incentive to use reformed natural gas as the reducing gas since the motivation for using reformed gas is to lower the regeneration temperature. Tests with reformed gas are, however, still scheduled.

NO_x and SO_2 removal efficiencies of greater than 90% have been demonstrated as shown in Figure 2. Reducing sorbent circulation rate and adsorber bed depth (adsorber bed ΔP) causes the removal efficiencies to decrease as seen by comparing Figures 2 and 3. The inlet pollutant concentration varies significantly as a function of power plant load and coal composition. As shown in Figure 4, the SO_2 concentration ranges between 1800 and 2600 ppm while the NO_x concentration ranges from 200 to 500 ppm.

Sorbent surface area is of major concern and is measured regularly. After 350 complete cycles, the sorbent surface area has stabilized at approximately 160 m^2/g. The initial surface area was 250 m^2/g. These results are consistent with previous laboratory studies.

Sorbent attrition rate is also a major concern. Prior to the project, the attrition rate was estimated to be 4.3 lb/hr. The experimentally determined rate based on sorbent makeup is 3.0 lb/hr. The impact of this result is to reduce the sorbent operating cost by 29%.

Demonstration Plant

A study was done to optimize the number of sorbent heater and cooler stages. As can be seen from Figures 5 and 6, as the number of stages increase, the air heater natural gas consumption and sorbent cooler/heater gas flowrate decrease. Figure 7 shows the fan power consumption as a function of number of stages. Figure 8 shows the impact of number of stages on the exit gas temperatures. As the number of stages increases, the sorbent heater exit gas temperature decreases while the sorbent cooler exit gas temperature increases. An economic analysis including operating and capital costs concluded 5 stages was the optimum number.

Work began to prepare a preliminary process flow diagram, heat and material balances, and stream data. A computer simulation of the NOXSO process is being developed to allow efficient inclusion of POC data into the design. Adsorption and regeneration models used in the simulation are being modified based on POC results.

Conversation was initiated with a potential sulfur plant vendor to obtain a preliminary sulfur plant design. The H_2S to SO_2 ratio obtained at the pilot plant is lower than expected and desired. The optimum ratio is 2 for the Claus reaction. Values from the pilot plant range from 0.2 to 1.0.

Figure 2 NOXSO PILOT TEST

POLLUTANT REMOVAL EFFICIENCIES

5/15/92 - 5/22/92

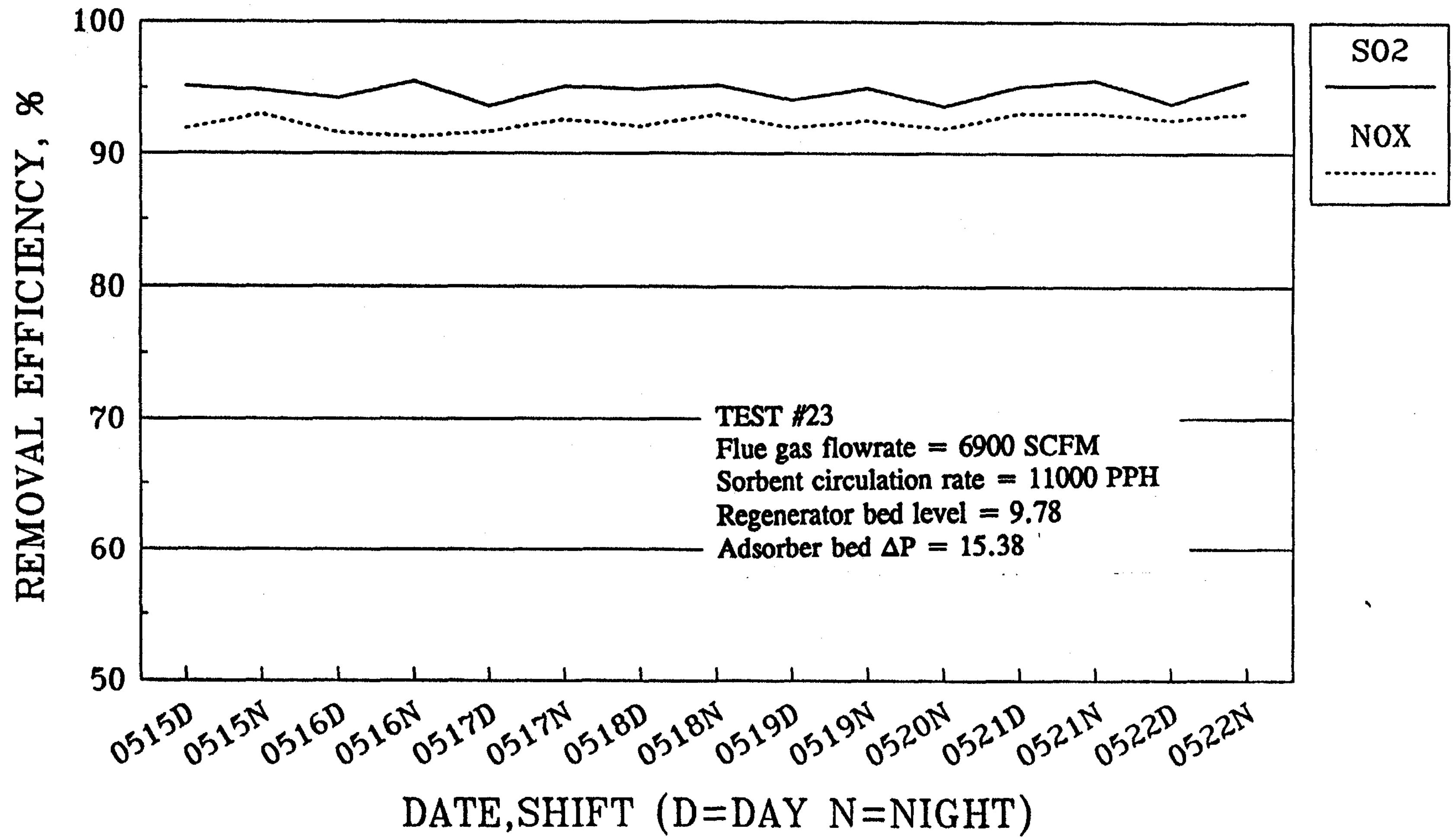


Figure 3 NOXSO PILOT TEST

POLLUTANT REMOVAL EFFICIENCIES

5/25/92–5/30/92

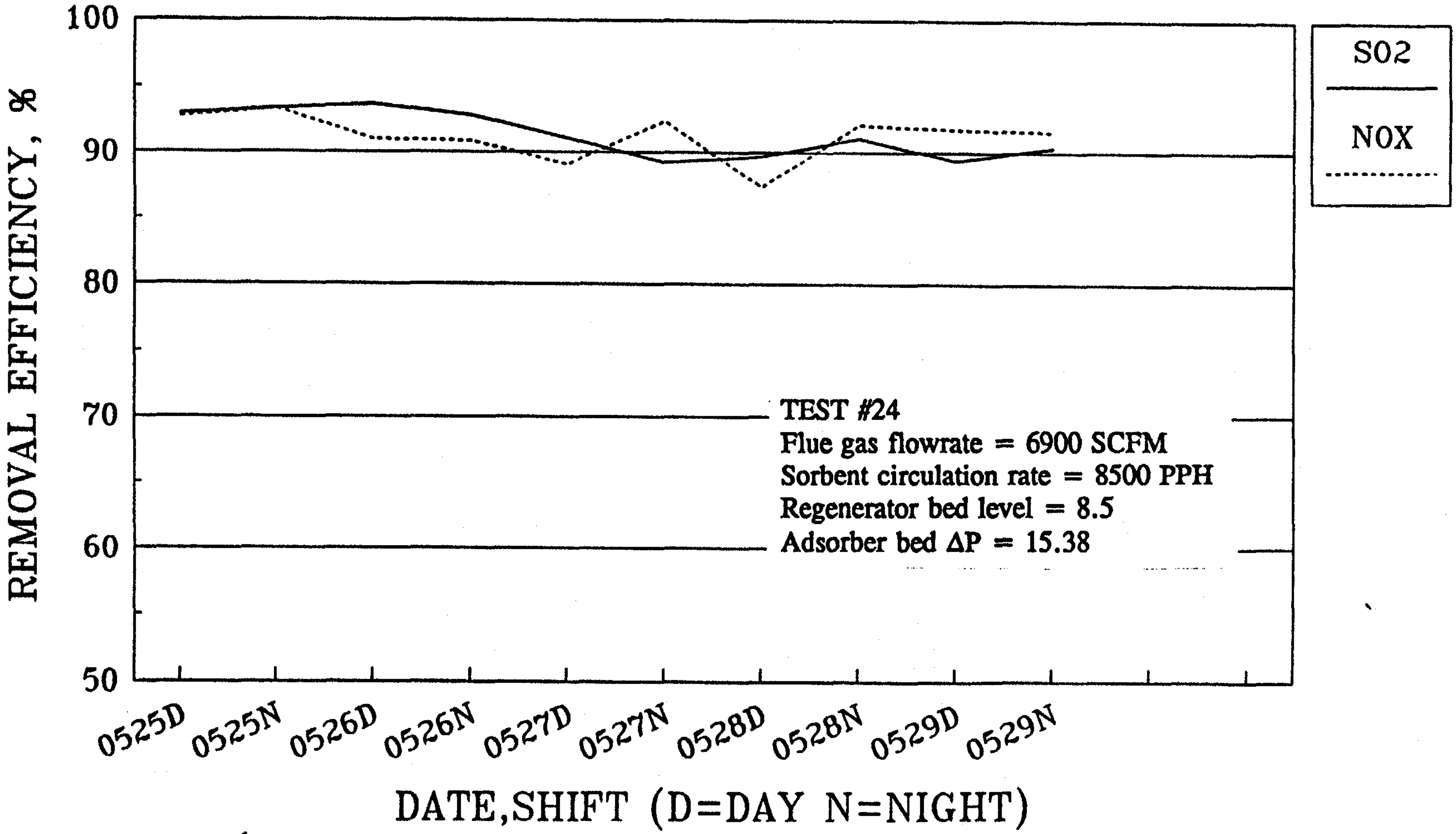


Figure 4 NOXSO PILOT TEST
FLUE GAS COMPOSITION
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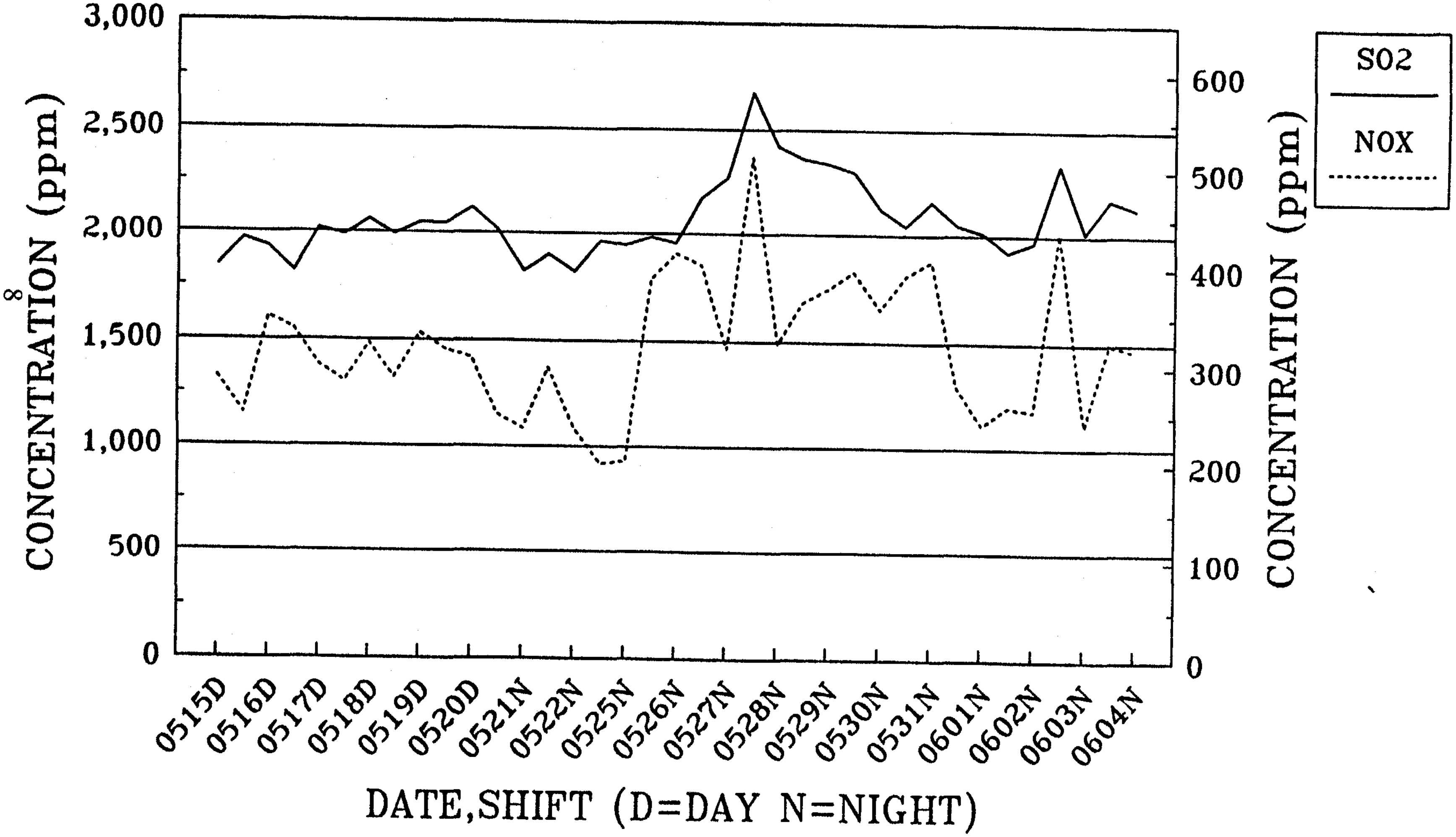

Figure 5
Air Heater Natural Gas Consumption as a Function of Fluid Bed Stages

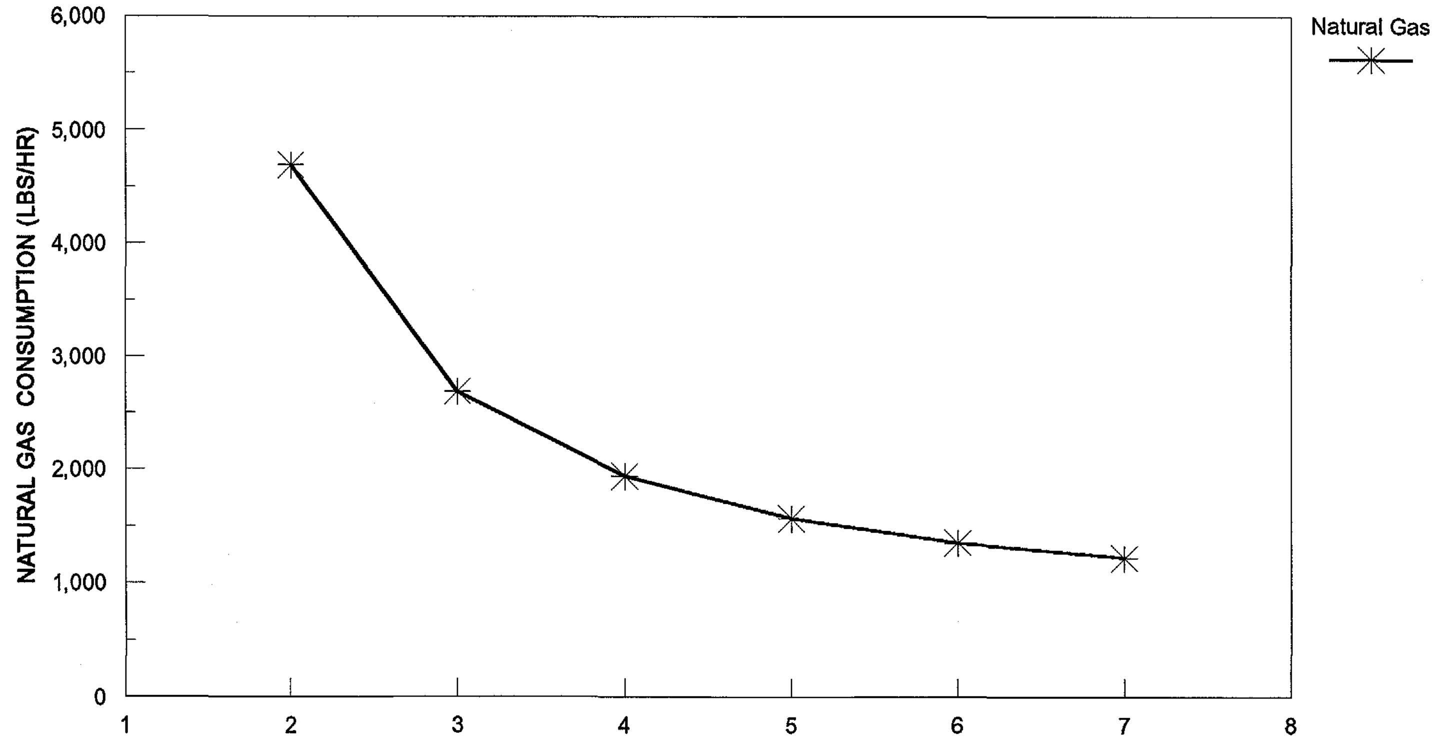

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Figure 6

Air Flow Rate through Sorbent Cooler/Heater Train as a Function of Fluid Bed Stages

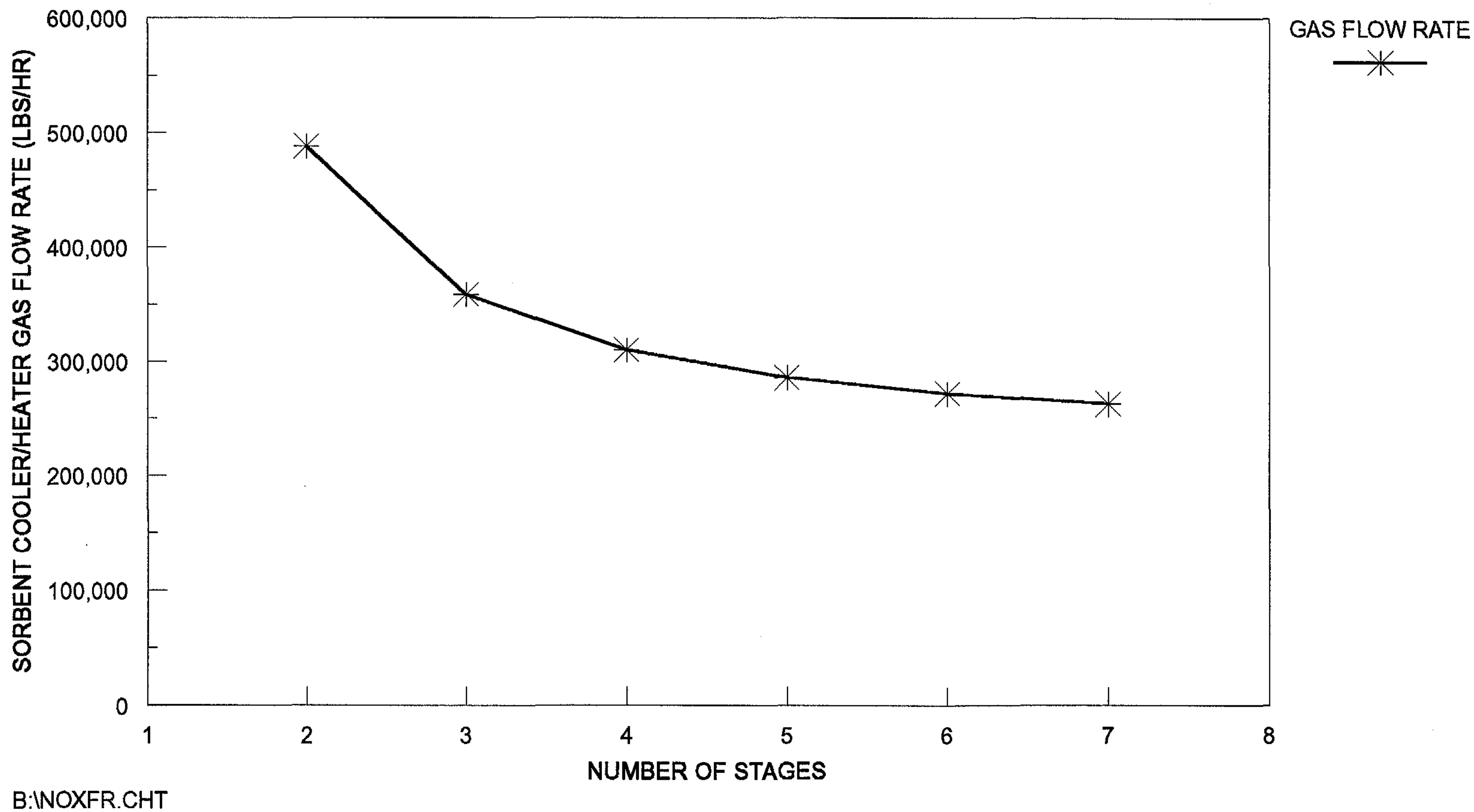


Figure 7 Sorbent Cooler/Heater
Blower and Adsorber Fan Power
Requirements as a Function of Fluid Bed Stages

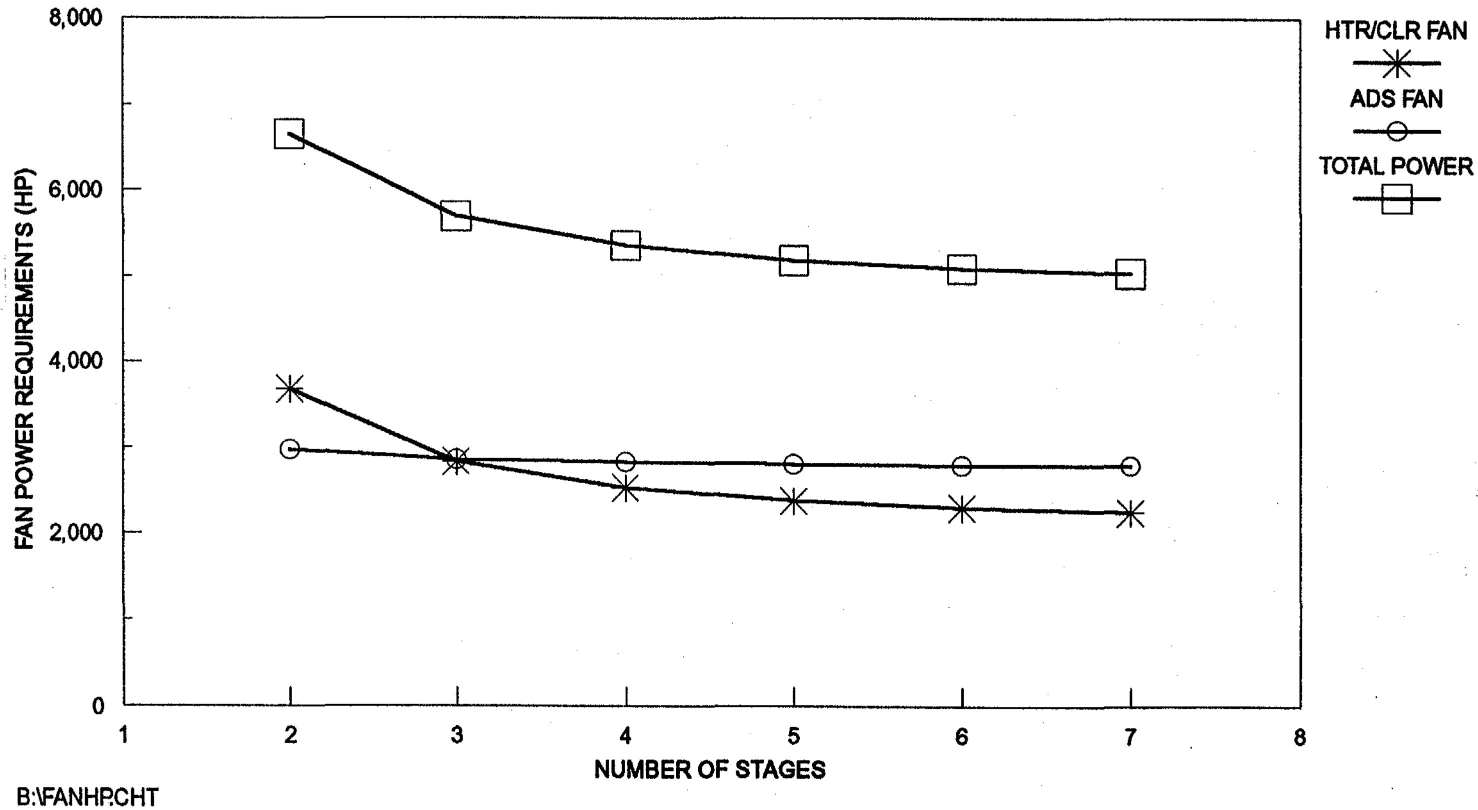
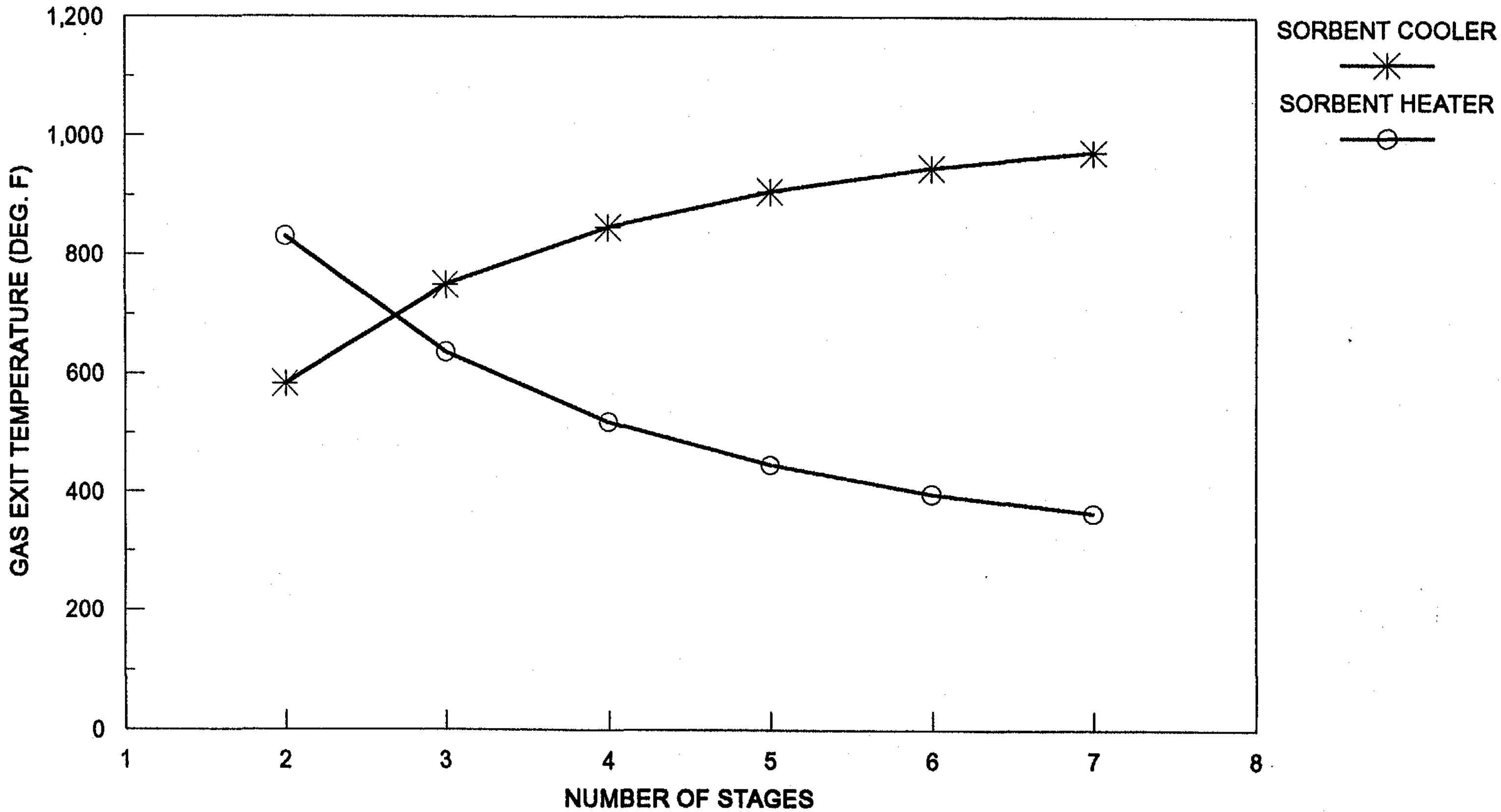


Figure 8
Sorbent Heater and Cooler Gas Exit Temperature as a Function of Fluid Bed Stages



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Plant Characterization

A plant tour of the Niles power plant and specifically the combustion air system was conducted. From a practical point of view, injection locations for the NO_x recycle stream are limited. The NO_x recycle stream will have to be injection into the combustion air system before the stream is split to go to the individual burners and before it is split between primary, secondary, and tertiary air. This limits the injection choices to upstream of the forced draft fans, between the forced draft fans and combustion air preheater, or downstream of the combustion air preheater.

Gilbert/Commonwealth, who designed the Niles plant, has been issued a subcontract to investigate the impact of the NO_x recycle stream on the power plants performance. Additionally, they will identify any potential problems resulting from interfacing the power plant and NOXSO plant. They will provide recommendations for the optimum injection location of the NO_x recycle stream as well as input to control strategy for this stream and the flue gas booster fans.

Site Survey/Geotechnical Investigation

No site survey or geotechnical investigation was conducted this reporting period.

Permitting

Need for environmental permits has been reviewed with the Ohio Edison environmental staff. Modifications may be required to some permits as a result of attrited sorbent discharge streams. Of concern is the impact mixing attrited sorbent with fly ash will have on the "exempt" status fly ash currently enjoys. Discharges of attrited sorbent to the bottom ash and up the stack are not anticipated to be a problem because of the use of the material and the quantities released, respectively.

4.0 SUMMARY

A formal request was made to extend the completion of phase 1A from March 11, 1992 until March 11, 1993. The request was granted. The schedule is being modified to reflect this extension. Project definition and preliminary design phase activities have been accelerated this period as reflected by the expenditures of money and labor.

The EIV is being updated to reflect the current NEPA policies and design status. Some preliminary engineering activities which require early resolution have been initiated. NO_x studies which are being conducted as an independent project are yielding results which are consistent with similar projects conducted previously.

Data from the pilot plant is being provided to the Demonstration Plant design group on a regular basis. For the most part, the data is as expected. Theoretical studies have been initiated to evaluate various design options. These options will be incorporated in the design as appropriate.

Studies have been initiated to assure the NOXSO plant will have no adverse affect on the power plant operation. Potential permitting requirements have also been discussed with the appropriate Ohio Edison personnel.