

**SOXAL Combined SO<sub>x</sub>/NO<sub>x</sub> Flue Gas Control Demonstration**

Contract Number: DE AC 22-91 PC 91347

Contractor Name: AQUATECH Systems  
7 Powder Horn Drive  
Warren, NJ 07059-5191

Contract Period: 9/10/91 - 11/30/93

**1. Contract Objective: No Change****Summary of Work -**

AQUATECH Systems, a business unit of Allied-Signal Inc., proposes to demonstrate the technical viability and cost effectiveness of the SOXAL process a combined SO<sub>x</sub>/NO<sub>x</sub> control process on a 3 MW equivalent flue gas slip stream from Niagara Mohawk Power Corporation, Dunkirk Steam Station Boiler #4, a coal fired boiler. The SOXAL process combines 90+% sulfur dioxide removal from the flue gas using a sodium based scrubbing solution and regeneration of the spent scrubbing liquor using AQUATECH Systems' proprietary bipolar membrane technology. This regeneration step recovers a stream of sulfur dioxide suitable for subsequent processing to salable sulfur or sulfuric acid.

Additionally 90+% control of NO<sub>x</sub> gases can be achieved in combination with conventional urea/methanol injection of NO<sub>2</sub> gas into the duct. The SOXAL process is applicable to both utility and industrial scale boilers using either high or low sulfur coal.

The SOXAL demonstration Program began September 10, 1991 and is approximately 26 months in duration.

During the 6 months of scheduled operations, between January and July of 1993, data was collected from the SOXAL system to define:

- a. SO<sub>2</sub> and NO<sub>x</sub> control efficiencies
- b. Current efficiency for the regeneration unit.
- c. Sulfate oxidation in the absorber.
- d. Make-up reagent rates.
- e. Product quality including concentrations and compositions.
- f. System integration and control philosophy.
- g. Membrane stability and performance with respect to foulants.

The program is expected to be concluded in November 1993.

**2. Technical Approach Changes: No Change****3. Contract (by reporting element):**

Task 1: Program Definition - Complete

Task 2: Engineering, Design and Construction - Complete

MASTER

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QUARTERLY REPORT: JULY - SEPTEMBER '93

Task 3: Shakedown, Parametric Testing, and Disassembly

Sub task 3.1: Shakedown - Complete

Sub task 3.2: Parametric Tests

The final parametric and continuous process tests were completed in July. Analysis and evaluation of samples and data were mostly completed during August and September. A final report is currently being prepared.

Sub task 3.3: Disassembly

All equipment has been inventoried and the Completion Inventory Report is being prepared. All equipment and piping has been flushed for plant deconstruction.

Task 4: Conceptual Design and Economic Analysis

As provided by Contract Modification A006 (6/15/93), these tasks will not be performed.

Clifford M. Denker  
Program Manager

CMD:cmd

Attachments:

Milestone Schedule - September 1993

Parametric Testing Summary - July 1993

|  |                           |                     |      |                          |   |                  |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |                         |  |  |     |     |     |  |  |  |
|--|---------------------------|---------------------|------|--------------------------|---|------------------|---|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|-------------------------|--|--|-----|-----|-----|--|--|--|
| 1. TITLE   |                           | 2. REPORTING PERIOD |      | 3. IDENTIFICATION NUMBER |   |                  |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |                         |  |  |     |     |     |  |  |  |
| Combined SOx/NOx Control via SOXAL™ Process:<br>Electrodialytic Regenerative Wet Scrubbing Process |                           | September 1993      |      | DE AC 2291 PC 91347      |   |                  |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |                         |  |  |     |     |     |  |  |  |
| 4. PARTICIPANT NAME AND ADDRESS  |                           | 5. START DATE       |      | 6. COMPLETION DATE       |   |                  |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |                         |  |  |     |     |     |  |  |  |
| Allied-Signal Inc., AQUATECH Systems<br>7 Powder Horn Drive<br>Warren, NJ 07059-5191               |                           | September 10, 1991  |      | November 1993            |   |                  |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |                         |  |  |     |     |     |  |  |  |
| 7. ELEMENT   | 8. REPORT-<br>ING ELEMENT | 9. DURATION         |      | Page 1 of 4              |   |                  |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |                         |  |  |     |     |     |  |  |  |
|  |                           | Fiscal Year 1993    |      | Fiscal Year 1994         |   | Fiscal Year 1995 |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |                         |  |  |     |     |     |  |  |  |
|  |                           | O                   | N    | D                        | J | F                | M | A | M | J | J | A | S | O | N | D | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | 95 | 96 | a. | b. | 10. PERCENT<br>COMPLETE |  |  |     |     |     |  |  |  |
| 1.1  | Cost Management Plan      | 1992                | 1993 |                          |   |                  |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |                         |  |  |     | 100 | 100 |  |  |  |
| 1.2  | Test Plan/Design Basis    |                     |      |                          |   |                  |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |                         |  |  |     | 100 | 100 |  |  |  |
| 2.1  | Engineering Contract      |                     |      |                          |   |                  |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |                         |  |  |     | 100 | 100 |  |  |  |
| 2.2  | Procurement               |                     |      |                          |   |                  |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |                         |  |  |     | 100 | 100 |  |  |  |
| 2.3  | Site Work                 |                     |      |                          |   |                  |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |                         |  |  | 100 | 100 |     |  |  |  |
| 2.4  | Installation              |                     |      |                          |   |                  |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |                         |  |  | 100 | 100 |     |  |  |  |
| 3.1  | Shutdown                  |                     |      |                          |   |                  |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |                         |  |  | 100 | 100 |     |  |  |  |
| 3.2  | Parametric Test           |                     |      |                          |   |                  |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |                         |  |  | 100 | 100 |     |  |  |  |
| 3.3  | Disassembly               |                     |      |                          |   |                  |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |                         |  |  | 100 | 25  |     |  |  |  |
| 4.1  | Conceptual Design         |                     |      |                          |   |                  |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |                         |  |  | 100 | 0   |     |  |  |  |
| 4.2  | Economic Analysis         |                     |      |                          |   |                  |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |                         |  |  | 0   | 0   |     |  |  |  |
| 11. SIGNATURE OF PARTICIPANT'S PROJECT MANAGER AND DATE  |                           | 10/15/93            |      |                          |   |                  |   |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |                         |  |  |     |     |     |  |  |  |

## PARAMETRIC TESTING SUMMARY - JULY 1993

### June 28 - July 4, 1993

On June 28, the test at 60 ppm NO<sub>2</sub> was aborted after two hours due to a leak from a diaphragm valve serving the HCl Absorber. During this short duration, an oxidation rate of 68% was observed, with 69% of the NO<sub>2</sub> absorbed. On Tuesday and Thursday, this test was repeated, however precise control of the NO<sub>2</sub> concentration was difficult. Absorption of SO<sub>2</sub> was unchanged. Absorption of NO<sub>2</sub> averaged 84%, with an observed oxidation rate of 108%-126%. At the end of Tuesday's test, the injection of NO<sub>2</sub> was halted, and the absorption/oxidation characteristics rapidly changed toward baseline observations. This seemed to indicate that the increased oxidation only occurs in the presence of NO<sub>2</sub>. An additional test during this week, performed at an elevated SO<sub>2</sub> concentration and no NO<sub>2</sub> confirmed previous results.

### July 5 - July 11, 1993

A variety of tests were performed this week, all with 30 ppm NO<sub>2</sub> in the flue gas. The first test was performed at baseline conditions. High SO<sub>2</sub> removal (99.9%) was observed, with 58% oxidation.

| <u>NO<sub>2</sub> Concentration</u> | <u>SO<sub>2</sub> Absorption</u> | <u>SO<sub>2</sub> Oxidation</u> | <u>NO<sub>2</sub> Absorption</u> |
|-------------------------------------|----------------------------------|---------------------------------|----------------------------------|
| 30 ppm                              | 99.9%                            | 58%                             | 60%                              |
| 60                                  | 99.9%                            | 110%                            | 82%                              |
| 150                                 | 99.9%                            | 190%                            | 65%                              |

Three tests were performed at elevated levels of SO<sub>2</sub>. The first resulted in higher absorption of NO<sub>2</sub> (89%) and lower oxidation (33%). The second test, run with less sodium in the absorbent feed, showed slightly lower SO<sub>2</sub> absorption (99.4%) and similar NO<sub>2</sub> absorption (76%) and oxidation (44%). The third test combined 30 ppm NO<sub>2</sub>, elevated SO<sub>2</sub>, and decreased recycle rates (45 gpm vs. 90 gpm). Absorption and oxidation characteristics were unchanged (99.8% SO<sub>2</sub> absorption, 86% NO<sub>2</sub> absorption, and 44% oxidation). Therefore, changes in sodium concentration and recycle rate had little effect in the presence of NO<sub>2</sub>. However, higher concentrations of SO<sub>2</sub> (~2000 ppm) appears to inhibit oxidation.

### July 12 - July 18, 1993

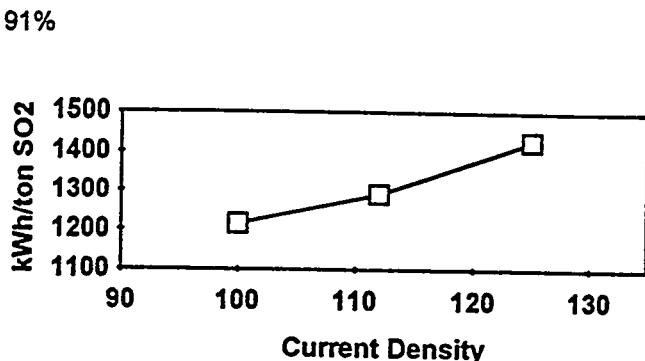
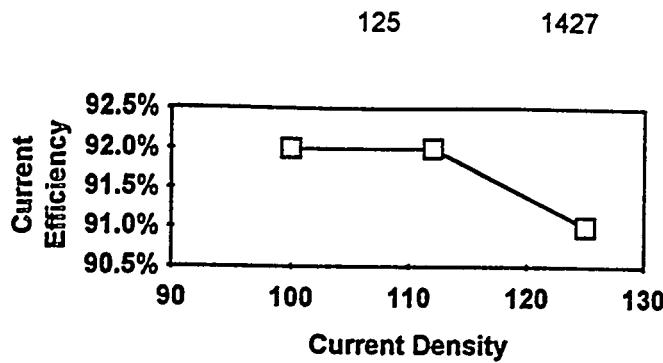
During this week, we operated both the absorption and regeneration processes simultaneously and continuously on a 24 hour, 5 day schedule. During this period, we recycled a portion of the recovered SO<sub>2</sub> to produce flue gas with 1800 - 2200 ppm SO<sub>2</sub>. Test data was taken during the same eight-hour time frame used during the decoupled tests. Absorption of SO<sub>2</sub> averaged 99.8%, with 5.9% oxidation. Regeneration at baseline conditions yielded a current efficiency of 93%, consuming 1217 kWh/ton SO<sub>2</sub>. These results match closely with those of the related parametric tests.

### July 19 - July 25, 1993

During this week, we operated both the absorption and regeneration processes simultaneously and continuously on a 24 hour, 5 day schedule. During this period, we recycled a portion of the recovered SO<sub>2</sub> to produce flue gas with 1900 - 2100 ppm SO<sub>2</sub>. Test data was taken during the same eight-hour time frame used during the decoupled tests. Absorption of SO<sub>2</sub> averaged 99.8%, with 8.2% oxidation. Regeneration during this week was performed at 100 ASF (baseline condition), 112 ASF, and 125 ASF. Current efficiency for all tests averaged 92%, with little variance. However, power consumption varied between 1200 - 1500 kWh/ton SO<sub>2</sub>. These results are similar to those of the related parametric tests. These measurements of current efficiency are considered more reliable than the tests during early June.

| <u>Current Density</u> | <u>kWh/ton SO<sub>2</sub></u> | <u>Current Efficiency</u> |
|------------------------|-------------------------------|---------------------------|
| 100 ASF                | 1214                          | 92%                       |
| 112                    | 1291                          | 92%                       |

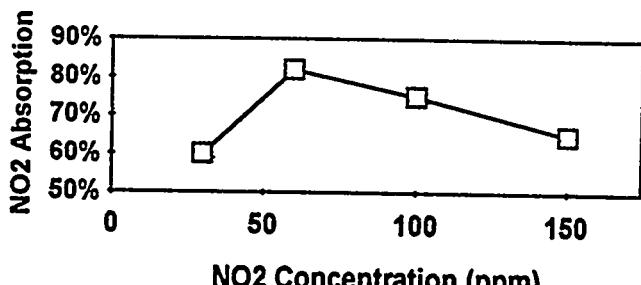
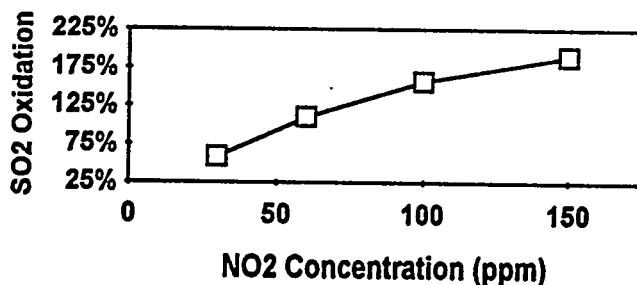
## PARAMETRIC TESTING SUMMARY - JULY 19-3



### July 26 - July 30

During the final week of testing, we investigated the effectiveness of using EDTA to inhibit NO<sub>2</sub>-induced oxidation. These tests were performed with continuous operation at baseline conditions, except that the first day we used recycled SO<sub>2</sub> to obtain 1920 ppm in the flue gas (vs. 1013 - 1751 for the remainder). The first test two tests were performed without injected NO<sub>2</sub>. The results for SO<sub>2</sub> absorption (99.7% and 99.3%) and oxidation (7.9% and 20.3%) indicate little effect from the presence of EDTA. Upon addition of 100 ppm NO<sub>2</sub> oxidation rose to 157%. Another test, run with double the concentration of EDTA, yielded 156% oxidation. Therefore, EDTA had no measurable effect on oxidation via the presence of NO<sub>2</sub>.

| NO <sub>2</sub> Concentration | SO <sub>2</sub> Absorption | SO <sub>2</sub> Oxidation | NO <sub>2</sub> Absorption |
|-------------------------------|----------------------------|---------------------------|----------------------------|
| 30 ppm                        | 99.9%                      | 58%                       | 60%                        |
| 60                            | 99.9%                      | 110%                      | 82%                        |
| EDTA and 100                  | 99.9%                      | 157%                      | 75%                        |
| 150                           | 99.9%                      | 190%                      | 65%                        |



On July 30 (elapsed time = 2195 hours), cell stack modules 2-3 and 3-2 were removed after 490 hours of operation. These membranes will be analyzed at AQUATECH.