United States
Environmental Protection
Agency

Research and Development

Air and Energy Engineering
Research Laboratory
Research Triangle Park NC 27711

EPA/600/S7-85/029 Jan. 1986

EPA

# Project Summary

# Alkaline and Stretford Scrubbing Tests for $H_2S$ Removal from In-situ Oil Shale Retort Offgas

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**Two mobile pilot-plant scrubbers (one alkaline, the other Stretford) were evaluated for removing reduced sulfur compounds from the offgas of an in-situ retort at Geokinetics. The alkaline scrubber efficiency varied inversely with selectivity: at high solution concentration in the tower, 94 percent removal was achieved at a selectivity of 9; and at low concentration in the venturi, the removal was 50 percent and the selectivity was 79. The Stretford achieved 99+ percent removal with the packed tower and 95 percent with the venturi. A computer model of the alkaline scrubber based on the penetration theory was developed and agrees well with the observed performance. Based on this model, it appears possible to design an alkaline scrubber system including a Claus plant which can achieve 95 percent $H_2S$ removal at a selectivity of 37.**

***This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).***

## Introduction

Removing hydrogen sulfide ($H_2S$) and other reduced sulfur compounds (carbonyl sulfide, carbon disulfide, mercaptans, thiophenes, etc.) from shale oil retort offgas with a wet scrubber requires a process that will selectively react with the sulfur compounds and react as little as possible with the carbon dioxide ($CO_2$) which is present in much larger amounts than the $H_2S$. Typically the $CO_2$ concentration in retort gas is 20 percent, while the $H_2S$ concentration ranges from 0.1 percent (1000 ppm) to 4 percent, depending on the retorting process used. This report covers the tests performed on a direct-fired, in-situ (under the ground) retort for which the lower $H_2S$ concentration applies.

Since both $H_2S$ and $CO_2$ are acid gases, it is the objective of any scrubbing system to selectively remove as much $H_2S$ and other sulfur compounds as possible while minimizing the reaction with the accompanying $CO_2$. The reasons for this selectivity are to conserve the scrubbing chemicals and to concentrate the sulfur compounds so that they can be economically converted to a solid recoverable (or safely disposable) form.

Two liquid scrubbing concepts were evaluated, alkaline and Stretford. The tests were conducted on the offgas from a horizontal in-situ oil shale retort at the Geokinetics, Inc. (GKI) site in Eastern Utah during the spring of 1984.

Objectives of the GKI tests were:

1. For the Alkali Scrubber Pilot Plant
   - Shake down the equipment.
   - Investigate the influence of operating parameters (e.g., pH, gas/liquid contact time, and scrubbing agent) on the selectivity and removal efficiency associated

with scrubbing reduced sulfur compounds in the presence of high $CO_2$ concentration.

2. For the Stretford Pilot Plant
   - Duplicate on retort gas the 99+ percent removal efficiency attained in a previous test of offgas from a coal gasifier.
   - Upon achieving that, explain the low removal efficiency on the 1982 test at GKI by deliberately introducing upsetting changes in the plant chemistry, then returning to the 99+ percent performance.

## Site and Process Description

The GKI retort offgas is brought to the surface for processing where it is treated in four steps, shown schematically in Figure 1, before it is discharged to the atmosphere: (1) gas passage through a condenser/demister, upstream of the two blowers; (2) ammonia absorption; (3) sulfur recovery; and (4) incineration. Steps 2, 3, and 4 are performed in series, with the treatment units arranged so that the desired treatment configuration can be obtained by bypassing one or more process steps. Expected operations during the scrubber test were to bypass the ammonia absorber and treat the gas in the sulfur recovery unit and the incinerator. A maximum of 10 $Sm^3/s$ of gas at a maximum temperature of 82°C can be treated in the GKI gas processing operation.

## Findings

### *Alkaline Scrubber*

The alkaline scrubber system was operated using both the tray tower and the venturi as the gas/liquid contactor. After relocating the main blower, the equipment performed satisfactorily.

The alkaline scrubber was operated in a simple blowdown process where the alkali solutions were mixed to a specific concentration and fed into either the tray tower or venturi contactors. In a commercial process unit, the scrubber solution would be cycled through a stripper where the absorbed $H_2S$ and $CO_2$ would be removed. Then the solution would be returned to the original mixing tanks and recycled into the contactor. No significant alkali addition would be required in that case. Since a stripper was not included as part of the EPA pilot plant, the scrubbing solution was used on a once-through basis, then discharged to the GKI pond.

The experimental results for the alkaline scrubber are summarized in Table 1 and Figure 2. The runs were conducted using alternately the tower then the venturi at the same solution concentration. Three different solution concentrations were used for each alkali except for the last four runs (No. 31-34) where only the tower was used to make two high concentration runs for both NaOH and KOH.

To analyze these data, a computer model of an alkaline scrubber was developed employing the comprehensive penetration theory. Penetration theory treats the gas/liquid mass transfer to allow contact time to be a significant factor. Other models (e.g., the two-plane theory) have implicit assumptions of equilibrium and cannot account for the contact time difference between a tower and a venturi. The results predicted by the penetration theory agree with the experimental results.

Based on the experimental results and the computer model, an alkaline

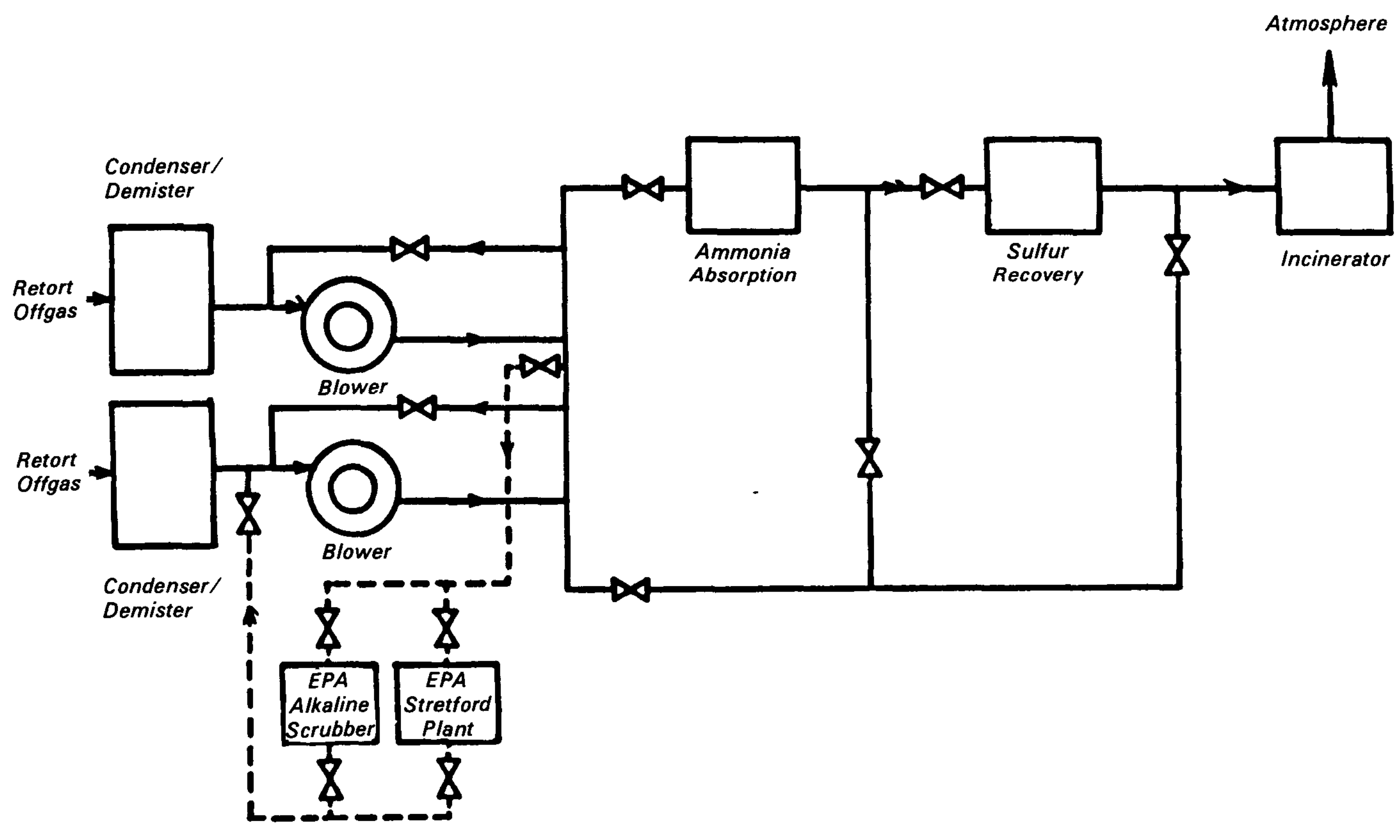


*Figure 1. Pilot plant installation in the Geokinetics process.*

scrubbing system design concept is suggested which could achieve an $H_2S$ removal efficiency of 95 percent with a selectivity approaching 40. This is a two-stage scrubber with a venturi-contactor first stage and a tray-tower second stage. The first stage removes 50 percent of the $H_2S$ in a highly selective manner. The second stage removes 90 percent of the remaining $H_2S$ at a lower selectivity. Summarized, these performance values are:

TWO-STAGE ALKALINE SCRUBBER - CONCEPT I

| Stage No | I | II | Combined |
|---|---|---|---|
| Contactor | Venturi | Tray Tower | |
| Selectivity | 110 | 40 | 37 |
| Removal Efficiency, % | 50 | 90 | 95 |

Another concept, employing a two-stage tray tower scrubber which results in a higher removal efficiency but a lower selectivity, is summarized as:

ALKALINE TOWER SCRUBBER - CONCEPT II

| Stage No | I | II | Combined |
|---|---|---|---|
| Contactor | Tray Tower | Tray Tower | |
| Selectivity | 40 | 40 | 23 |
| Removal Efficiency, % | 90 | 90 | 99 |

This two-stage tray tower scrubber can be combined into a single tower of double length.

The alkaline scrubber showed little removal of the organic sulfur compounds. This is similar to previous results reported in the literature.

## Stretford Plant

The Stretford operated for over 200 hours. Table 2 gives available measurements of $H_2S$ removal efficiency and pertinent process data taken in conjunction with the removal efficiency. For 140 hours, the plant operated with a venturi contactor, modified from that used in previous tests in that the throat area could be adjusted to handle variable gas flow rates. In this test, the throat was adjusted to the smallest throat area, 7.1 in. (18 cm), and held constant during most of the testing.

The maximum $H_2S$ removal efficiency measured while using the venturi alone was 95 percent, which was maintained only briefly. Over the period of operation with this contactor alone the removal efficiency averaged 80 percent. A brief attempt was made to experiment with increasing the venturi throat area. When no effect on removal efficiency was observed, the throat area experiment was discontinued.

Because of the failure of the plant to achieve the 99+ percent removal efficiency objective observed in the previous coal gasifier test, a field-fabricated, packed-column contactor was added in series with and downstream of the venturi. This device increased the removal efficiency to the 99+ percent range during its period of operation. Because of the makeshift nature of this field modification, there was no instrumentation to measure the flow rate of the scrubber liquid through the tower. Thus, it was not possible to optimize liquid distribution between the venturi and the tower.

**Table 1.** *Summary of Alkali Scrubbing Results*

| Contactor | Alkali | $OH^-$ Conc. gmole/liter | Removal Efficiency, % | Measured Selectivity[a] | Run No. |
|---|---|---|---|---|---|
| Venturi | NaOH | 0.012 | 52 | 79 | 21 |
| Venturi | KOH | 0.012 | 53 | 71 | 28 |
| Venturi | NaOH | 0.023 | 48 | 60 | 24 |
| Venturi | KOH | 0.023 | 48 | 51 | 30 |
| Venturi | NaOH | 0.045 | 70 | 84[b] | 19 |
| Venturi | KOH | 0.046 | 71 | 21 | 26 |
| Venturi | $NH_4OH$ | 0.049 | 60 | 71 | 15 |
| Venturi | $NH_4OH$ | 0.29 | 62 | 56 | 17 |
| Venturi | $NH_4OH$ | 2.0 | 67 | 11 | 13 |
| Tower | NaOH | 0.012 | 52 | 52 | 20 |
| Tower | KOH | 0.012 | 54 | 43 | 27 |
| Tower | NaOH | 0.023 | 54 | 41 | 22 |
| Tower | KOH | 0.023 | 59 | 49 | 29 |
| Tower | NaOH | 0.045 | 83 | 36 | 18 |
| Tower | KOH | 0.046 | 88 | 41 | 25 |
| Tower | $NH_4OH$ | 0.049 | 64 | 29 | 14 |
| Tower | $NH_4OH$ | 0.29 | 91 | 29 | 16 |
| Tower | $NH_4OH$ | 2.0 | 93 | 9 | 12 |
| Tower | KOH | 0.89 | 94 | N/A[c] | 31 |
| Tower | NaOH | 1.25 | 93 | N/A | 33 |
| Tower | KOH | 1.79 | 92 | N/A | 32 |
| Tower | NaOH | 2.5 | 94 | N/A | 34 |

[a]*Selectivity is a measure of the preferential removal of $H_2S$ over $CO_2$, taking into account the relative difference in concentration between the two gases. In this report, selectivity is the ratio of percent removal of $H_2S$ to percent removal of $CO_2$.*
[b]*Data are suspected to be erroneous.*
[c]*Selectivity value was not available because the spent scrubbing solution was not analyzed.*

## Conclusions

Based on the findings reported here, the following conclusions were reached:

1. For shale oil retort offgas similar in composition to that from the GKI process, the alkaline scrubber, in combination with a stripper and a Claus plant, could be a viable means of $H_2S$ removal. This overall conclusion is based on the following conclusions.
2. For GKI-type process offgas and based on these tests, the performance of an alkaline scrubber with a tray tower contactor similar to that in the EPA pilot plant can achieve an $H_2S$ removal efficiency of at least 90 percent with a selectivity of approximately 30. Under the same conditions a single venturi contactor in place of the tray tower would remove only 50 to 60 percent $H_2S$, but with a selectivity of 70 to 80.
3. Based on the computer model developed to analyze these test results, the removal efficiencies and selectivity above are applicable to offgas with lower $H_2S$ concentrations than found at GKI. This suggests a concept of multiple scrubbing actions to increase the $H_2S$

removal. Because this increased removal efficiency is accompanied by a reduced selectivity which could present a problem for the Claus plant, the cost effectiveness of this concept requires a design study.

4. Based on a three gas component ($H_2S$, $NH_3$, and $CO_2$) analysis by the computer program, the principal reactant for the $H_2S$ in the retort offgas is the $NH_3$ in that same offgas. In that $NH_3$ is present in the GKI offgas in similar molar quantities to that of the $H_2S$, the scrubber performance observed on these tests may not be applicable to retort offgas with little or no $NH_3$. This suggests that water with just the $NH_3$ in the gas stream would be an effective scrubbing agent. Scrubbing in this manner would certainly improve the selectivity; but, the effect on removal achievable is uncertain.
5. The alkaline scrubber removal efficiency and selectivity seemed to have little dependency on the alkali used. This is consistent with the above concept that it is the $NH_3$ in the offgas itself that is reacting the $H_2S$. Since the $NH_3$ and $H_2S$ concentrations are variable, it is likely that some of the $H_2S$ is reacted by the alkali. Therefore, it is likely some alkali will always be needed. However, the choice of scrubbing alkali may be made on such factors as cost, maintenance, safety, availability, and crew comfort (rather than performance).
6. The absorption of $H_2S$ and $CO_2$ in the alkaline solution appears to be fully reversible by distillation. The sulfur in the scrubber solution is primarily in the form of sulfide. The sulfate or sulfite level determined in the scrubbing solution was equal to that in the water supply. The sulfide will distill off as $H_2S$ (along with $CO_2$) while the sulfate will not.
7. With an adequate contactor the Stretford process can obtain $H_2S$ removal efficiencies of 99 percent. These tests suggest that, if adequate $H_2S$ removal cannot be achieved with a venturi, a packed tower is a workable option for improving performance.
8. To ensure continued satisfactory performance of a Stretford plant in processing retort offgas, it is important to effectively remove the hydrocarbon mist and other particulate matter from the gas before it enters the plant.

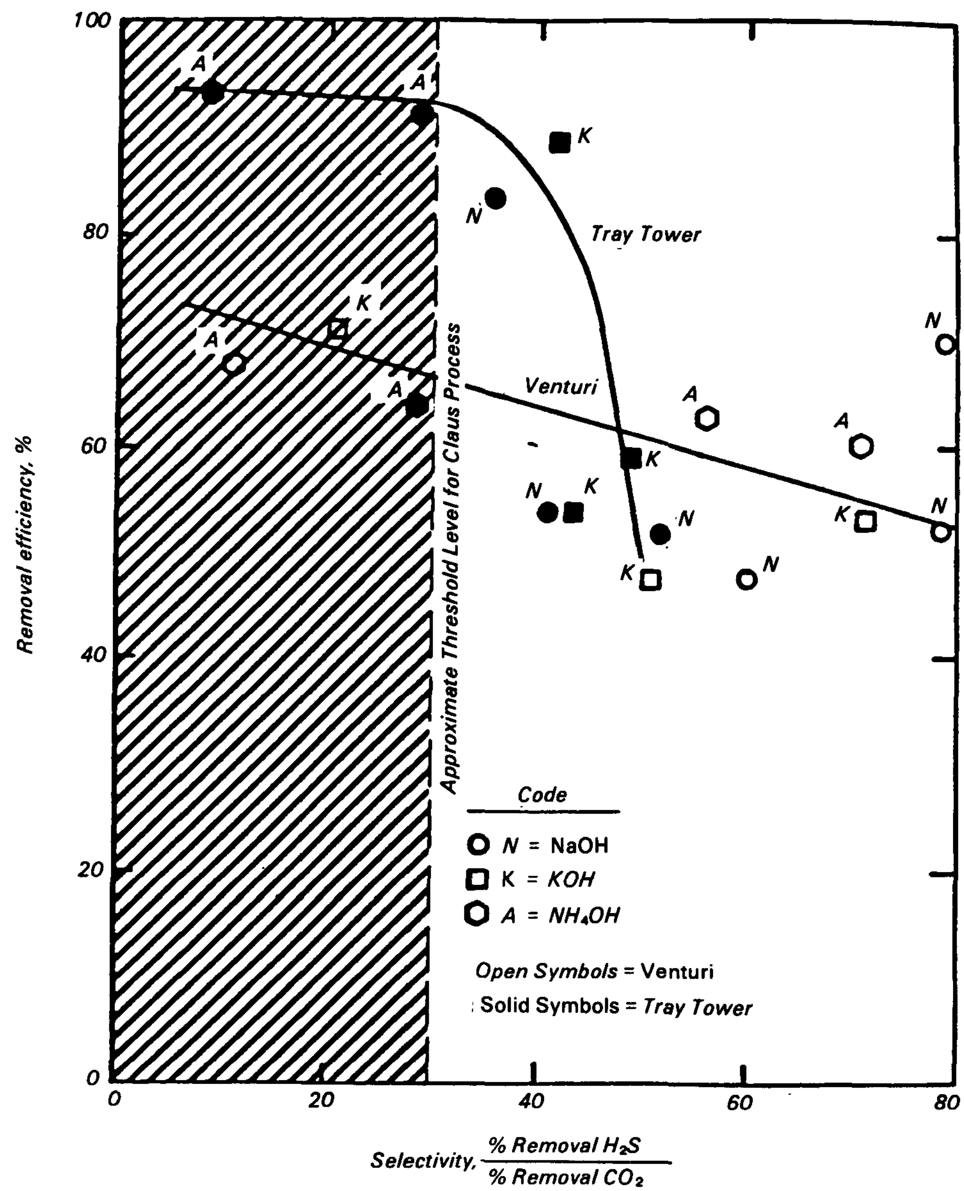


*Figure 2. Removal efficiency vs. selectivity for alkaline scrubber.*

**Table 2.** *Stretford Operating Conditions and Removal Efficiency During GKI Test Program*

| Date 1984 | Time | Gas Contct Device | Removal Eff % | Gas Flow Rate $Sm^3/s$ | Gas Out Temp °C | Gas Inlt Pres mm Hg | Inlt $H_2S$ Conc ppmV | Out $H_2S$ Conc ppmV | Sol Flow Rate S1/s | Sol Htr T in °C | Sol Htr T out °C | Oxidizer Air Flow $Sm^3/s$ | Oxidizer Motor Curr amps | ADA Conc $kg/m^3$ | Van. Conc $kg/m^3$ | Carb. Conc $kg/m^3$ | Thio-sul. Conc $kg/m^3$ | pH | Oxidation Potential mV |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5/5 | 18:05 | V | 75.2 | 0.190 | 40 | 27.8 | 1617 | 401 | 1.93 | 43 | 40 | 0.036 | 7.5 | 7.5 | 2.3 | 16.8 | 0.2 | 10.8 | +38 |
| | 18:55 | V | 74.7 | 0.255 | 41 | 30.4 | 1579 | 400 | 1.91 | 43 | 43 | 0.035 | 7.3 | 7.5 | 2.2 | 16.4 | 0.2 | 10.5 | +19 |
| | 20:30 | V | 73.7 | 0.233 | 43 | 30.4 | 1633 | 429 | 1.79 | 44 | 44 | 0.029 | 7.4 | 7.5 | 2.2 | 15.8 | 0.2 | 10.2 | 0 |
| | 21:45 | V | 62.1 | 0.256 | 40 | 30.4 | 1571 | 595 | 1.77 | 43 | 43 | 0.029 | 7.4 | 8.7 | 2.5 | 15.3 | 0.2 | 9.9 | −21 |
| | 22:35 | V | 51.7 | 0.269 | 43 | 30.4 | 1322 | 639 | 1.86 | 46 | 44 | 0.026 | 7.3 | 8.7 | 2.4 | 14.9 | 0.2 | 9.9 | −15 |
| | 23:30 | V | 61.3 | 0.269 | 44 | 32.9 | 1618 | 626 | 1.54 | 47 | 47 | 0.026 | 7.3 | 8.7 | 2.4 | 14.5 | 0.2 | 9.9 | −8 |
| 5/6 | 00:30 | V | 72.7 | 0.272 | 44 | 29.3 | 1623 | 443 | 1.60 | 47 | 47 | 0.026 | 7.3 | 8.7 | 2.4 | 14.1 | 0.2 | 9.8 | −2 |
| | 01:30 | V | 79.5 | 0.192 | 38 | 29.9 | 2169 | 444 | 1.48 | 47 | 41 | 0.026 | 7.4 | 8.6 | 2.4 | 13.7 | 0.2 | 9.8 | +5 |
| | 02:30 | V | 90.3 | 0.327 | 44 | 24.3 | 2018 | 195 | 1.48 | 46 | 46 | 0.025 | 7.4 | 8.6 | 2.3 | 13.3 | 0.2 | 9.1 | +4 |
| | 03:30 | V | 93.4 | 0.254 | 45 | 30.4 | 1886 | 125 | 1.51 | 46 | 46 | 0.024 | 7.3 | 8.6 | 2.3 | 12.9 | 0.2 | 8.4 | +2 |
| | 04:25 | V | 94.3 | 0.189 | 46 | 30.4 | 1741 | 100 | 1.48 | 47 | 47 | 0.024 | 7.3 | 8.5 | 2.3 | 12.5 | 0.3 | 7.7 | +1 |
| | 05:30 | V | 93.7 | 0.189 | 47 | 30.9 | 1590 | 101 | 1.50 | 48 | 47 | 0.026 | 7.3 | 8.5 | 2.2 | 12.0 | 0.3 | 7.0 | 0 |
| 5/7 | 21:21 | V | 63.0 | 0.276 | 46 | 60.1 | 763 | 282 | 1.67 | 46 | 46 | 0.039 | 7.5 | 10.0 | 3.3 | 16.0 | 0.5 | 10.0 | −50 |
| | 22:02 | V | 70.4 | 0.206 | 43 | 65.8 | 1157 | 343 | 1.64 | 47 | 46 | 0.038 | 7.4 | 9.9 | 3.3 | 15.9 | 0.5 | 9.9 | −37 |
| 5/8 | 18:23 | V | 84.5 | 0.280 | 42 | 43.0 | 1369 | 212 | 1.80 | 43 | 41 | 0.034 | 7.5 | 8.2 | 3.3 | 30.0 | 0.6 | 7.4 | −39 |
| | 20:00 | V | 94.5 | -- | -- | -- | 1372 | 75 | -- | -- | -- | -- | -- | 8.0 | 3.3 | 30.2 | 0.6 | 7.4 | −33 |
| | 22:05 | V | 76.8 | -- | -- | -- | 1378 | 320 | -- | -- | -- | -- | -- | 7.7 | 3.3 | 30.4 | 0.6 | 7.4 | −27 |
| | 22:17 | V | 81.1 | 0.483 | 37 | 53.1 | 1392 | 263 | 1.74 | 39 | 36 | 0.030 | 7.4 | 7.6 | 3.3 | 30.4 | 0.6 | 7.4 | −21 |
| | 23:12 | V | 80.2 | 0.489 | 37 | 70.8 | 1395 | 276 | 1.71 | 39 | 34 | 0.034 | 7.4 | 7.5 | 3.3 | 30.5 | 0.6 | 7.8 | −21 |
| | 23:45 | V | 80.8 | 0.443 | 37 | 60.7 | 1398 | 269 | 1.73 | 39 | 34 | 0.034 | 7.4 | 7.4 | 3.3 | 30.6 | 0.6 | 8.2 | −21 |
| 5/9 | 00:45 | V | 81.4 | 0.443 | 36 | 65.8 | 1399 | 260 | 1.72 | 39 | 35 | 0.034 | 7.3 | 7.3 | 3.3 | 30.7 | 0.6 | 8.9 | −21 |
| | 16:10 | V | 85.6 | 0.208 | 42 | 140.2 | 1689 | 243 | 1.81 | 43 | 43 | 0.039 | 7.3 | 4.6 | 3.2 | 30.1 | 0.7 | 9.1 | −69 |
| | 16:30 | V | 82.8 | 0.218 | 42 | 146.7 | 1700 | 293 | 1.82 | 43 | 43 | 0.038 | 7.3 | 4.6 | 3.2 | 30.1 | 0.7 | 8.9 | −78 |
| | 18:02 | V | 86.1 | 0.215 | 42 | 126.5 | 1818 | 253 | 1.82 | 43 | 43 | 0.038 | 7.4 | 4.6 | 3.2 | 29.9 | 0.7 | 8.6 | −87 |
| | 20:20 | V | 82.7 | 0.205 | 42 | 126.5 | 1768 | 306 | 1.90 | 43 | 43 | 0.038 | 7.4 | 4.6 | 3.2 | 29.6 | 0.7 | 9.9 | −75 |
| 5/10 | 00:30 | V | 82.9 | -- | 39 | 32.9 | 1761 | 301 | 1.93 | 43 | 39 | 0.030 | 7.4 | 5.5 | 3.5 | 31.5 | 0.7 | 9.7 | −42 |
| | 17:16 | V | 80.7 | 0.189 | 38 | 15.2 | 1362 | 263 | 1.36 | 41 | 39 | 0.025 | 7.7 | 9.9 | 3.4 | 30.1 | 0.8 | 9.4 | −54 |
| | 17:48 | V | 80.8 | 0.247 | 38 | 15.2 | 1330 | 255 | 1.36 | 41 | 39 | 0.024 | 7.7 | 9.9 | 3.4 | 29.9 | 0.8 | 9.4 | −48 |
| | 18:27 | V | 80.9 | 0.190 | 37 | 15.2 | 1305 | 249 | 1.36 | 40 | 39 | 0.024 | 7.7 | 9.8 | 3.4 | 29.8 | 0.8 | 9.5 | −42 |
| | 19:30 | V | 81.1 | 0.267 | 40 | 15.2 | 1283 | 243 | 1.35 | 41 | 42 | 0.024 | 7.7 | 9.7 | 3.4 | 29.5 | 0.8 | 9.5 | −46 |
| | 20:15 | V | 81.1 | 0.298 | 40 | 15.2 | 1270 | 240 | 1.36 | 41 | 42 | 0.020 | 7.7 | 9.7 | 3.3 | 29.3 | 0.8 | 9.4 | −51 |
| | 21:28 | V | 80.9 | 0.189 | 40 | 15.2 | 1259 | 240 | 1.36 | 42 | 42 | 0.019 | 7.7 | 9.6 | 3.3 | 28.9 | 0.8 | 9.4 | −55 |
| | 22:15 | V | 81.3 | 0.220 | 41 | 17.7 | 1255 | 235 | 1.36 | 43 | 43 | 0.019 | 7.8 | 9.5 | 3.3 | 28.7 | 0.8 | 9.5 | −51 |
| | 23:21 | V | 81.0 | 0.189 | 42 | 17.7 | 1250 | 237 | 1.38 | 44 | 44 | 0.019 | 7.7 | 9.5 | 3.3 | 28.4 | 0.8 | 9.7 | −48 |
| 5/11 | 00:30 | V | 81.2 | N/A | 42 | 12.7 | 1248 | 235 | 1.36 | 43 | 44 | 0.024 | 7.7 | 9.4 | 3.3 | 28.1 | 0.8 | 9.8 | −44 |
| | 01:30 | V | 79.7 | N/A | 39 | 12.7 | 1134 | 230 | 1.36 | 43 | 41 | 0.019 | 7.7 | 9.3 | 3.3 | 27.8 | 0.8 | 10.0 | −41 |
| | 02:30 | V | 80.7 | N/A | 39 | 12.7 | 1250 | 241 | 1.36 | 43 | 41 | 0.027 | 7.7 | 9.2 | 3.3 | 27.5 | 0.8 | 10.1 | −37 |
| | 03:30 | V | 80.6 | N/A | 39 | 12.7 | 1232 | 239 | 1.38 | 43 | 41 | 0.017 | 7.7 | 9.1 | 3.3 | 27.3 | 0.8 | 9.9 | −23 |
| | 04:35 | V | 81.8 | N/A | 40 | 12.7 | 1242 | 226 | 1.67 | 42 | 42 | 0.017 | 7.7 | 9.1 | 3.2 | 27.0 | 0.8 | 9.6 | −10 |
| | 05:30 | V | 81.3 | N/A | 40 | 10.1 | 1240 | 232 | 1.53 | 42 | 41 | 0.021 | 7.7 | 9.0 | 3.2 | 26.7 | 0.8 | 9.4 | +4 |
| | 06:35 | V | 84.3 | N/A | 39 | 10.1 | 1236 | 194 | 2.12 | 43 | 41 | 0.021 | 7.7 | 8.9 | 3.2 | 26.7 | 0.8 | 9.4 | 0 |
| 5/12 | 13:30 | V&T | 99.1 | N/A | 38 | 19.5 | 1024 | 9 | 1.63 | 42 | 42 | 0.026 | 7.8 | 7.5 | 3.0 | 30.9 | 1.0 | 9.3 | +2 |
| | 14:30 | V&T | 99.2 | N/A | 41 | 19.5 | 1036 | 8 | 1.64 | 43 | 45 | 0.027 | 7.8 | 7.5 | 3.0 | 30.7 | 1.0 | 9.3 | −15 |
| | 15:30 | V&T | 99.1 | N/A | 38 | 18.2 | 985 | 9 | 1.60 | 42 | 42 | 0.029 | 7.7 | 7.4 | 2.9 | 30.4 | 1.0 | 10.1 | −15 |
| | 16:22 | V&T | 98.8 | N/A | 38 | 25.3 | 1001 | 12 | 1.59 | 42 | 43 | 0.029 | 7.5 | 7.3 | 2.9 | 30.2 | 1.0 | 10.8 | −16 |
| | 17:19 | V&T | 98.7 | N/A | 38 | 22.8 | 1138 | 15 | 1.61 | 42 | 42 | 0.029 | 7.7 | 7.3 | 2.9 | 30.0 | 1.0 | 11.6 | −16 |
| | 18:25 | V&T | 98.8 | N/A | 39 | 22.8 | 1199 | 14 | 1.62 | 42 | 43 | 0.027 | 7.7 | 7.2 | 2.8 | 29.7 | 1.0 | 12.3 | −17 |
| | 19:19 | V&T | 99.1 | N/A | 39 | 25.3 | 1171 | 11 | 1.69 | 42 | 43 | 0.031 | 7.7 | 7.1 | 2.8 | 29.5 | 1.0 | 11.5 | −22 |
| | 20:18 | V&T | 99.0 | N/A | 38 | 25.3 | 1218 | 12 | 1.70 | 42 | 42 | 0.031 | 7.7 | 7.1 | 2.7 | 29.3 | 1.0 | 10.7 | −27 |
| | 21:25 | V&T | 99.3 | N/A | 39 | 25.3 | 1237 | 9 | 1.86 | 42 | 42 | 0.033 | 7.6 | 7.0 | 2.7 | 29.0 | 1.0 | 9.9 | −32 |
| | 22:24 | V&T | 99.4 | N/A | 100 | 27.8 | 1232 | 8 | 1.96 | 43 | 41 | 0.035 | 7.5 | 6.9 | 2.6 | 28.7 | 1.0 | 9.8 | −23 |
| | 23:21 | V&T | 99.4 | N/A | 39 | 25.3 | 1228 | 7 | 2.05 | 42 | 41 | 0.035 | 7.6 | 6.8 | 2.6 | 28.5 | 1.0 | 9.6 | −13 |

**Table 2.** *(Continued)*

| Date 1984 | Time | Gas Contct Device | Removal Eff % | Gas Flow Rate $Sm^3/s$ | Gas Out Temp °C | Gas Inlt Pres mm Hg | Inlt $H_2S$ Conc ppmV | Out $H_2S$ Conc ppmV | Sol Flow Rate S1/s | Sol Htr T in °C | Sol Htr T out °C | Oxidizer Air Flow $Sm^3/s$ | Oxidizer Motor Curr amps | ADA Conc $kg/m^3$ | Van. Conc $kg/m^3$ | Carb. Conc $kg/m^3$ | Thio-sul. Conc $kg/m^3$ | pH | Oxidation Potential mV |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5/13 | 15:30 | V* | 86.9 | N/A | 38 | 20.0 | 990 | 130 | 1.88 | 39 | 41 | 0.042 | 7.6 | 7.6 | 2.1 | -- | 1.1 | 9.9 | −9 |
| | 16:12 | V* | 84.3 | N/A | 39 | 25.3 | 797 | 125 | 1.86 | 41 | 41 | 0.043 | 7.6 | 9.7 | 2.8 | -- | 1.1 | 10.1 | −19 |
| | 17:17 | V* | 83.3 | N/A | 39 | 25.3 | 749 | 125 | 1.79 | 42 | 42 | 0.044 | 7.6 | 9.7 | 2.7 | -- | 1.1 | 10.4 | −28 |
| | 18:57 | V* | 85.4 | 0.250 | 39 | 25.3 | 940 | 137 | 1.82 | 40 | 41 | 0.043 | 7.6 | 9.7 | 2.6 | -- | 1.1 | 10.6 | −23 |
| | 19:32 | V* | 86.2 | 0.251 | 38 | 25.3 | 1001 | 138 | 1.86 | 40 | 42 | 0.039 | 7.7 | 11.0 | 3.0 | -- | 1.1 | 10.7 | −18 |
| | 20:16 | V* | 86.9 | 0.251 | 38 | 25.3 | 1063 | 139 | 1.83 | 42 | 42 | 0.038 | 7.6 | | 3.0 | -- | 1.1 | 10.9 | −13 |
| | 21:13 | V* | 87.3 | 0.251 | 38 | 25.3 | 1094 | 139 | 1.83 | 43 | 43 | 0.037 | 7.6 | | 3.0 | -- | 1.1 | -- | -- |
| | 22:18 | V* | 87.4 | 0.250 | 39 | 26.3 | 1113 | 140 | 1.87 | 43 | 43 | 0.036 | 7.6 | | 2.9 | -- | 1.1 | -- | -- |
| | 23:25 | V* | 87.6 | 0.250 | 39 | 22.8 | 1119 | 139 | 1.82 | 44 | 43 | 0.036 | 7.6 | | 2.9 | -- | 1.1 | -- | -- |
| 5/14 | 00:00 | V* | 87.7 | 0.250 | 38 | 22.8 | 1125 | 138 | 1.83 | 44 | 43 | 0.036 | 7.6 | 11.0 | 2.8 | -- | 1.1 | -- | -- |
| | 01:00 | V* | 87.9 | 0.211 | 36 | 22.8 | 1133 | 137 | 1.80 | 40 | 38 | 0.033 | 7.6 | 11.0 | 2.8 | -- | 1.1 | -- | -- |
| | 02:00 | V* | 87.9 | 0.210 | 36 | 22.8 | 1133 | 137 | 1.77 | 40 | 41 | 0.031 | 7.6 | 11.0 | 2.7 | -- | 1.1 | -- | -- |
| | 03:00 | V* | 88.3 | 0.210 | 36 | 22.8 | 1128 | 132 | 2.02 | 41 | 42 | 0.031 | 7.6 | 11.0 | 2.7 | -- | 1.1 | -- | -- |
| | 04:00 | V&T | 95.1 | 0.210 | 37 | 22.8 | 1116 | 55 | 2.08 | 41 | 42 | 0.028 | 7.6 | 11.0 | 3.1 | -- | 1.1 | -- | -- |
| | 05:00 | V&T | 95.0 | 0.210 | 36 | 22.8 | 1127 | 56 | 2.05 | 38 | 37 | 0.031 | 7.6 | 11.0 | 3.0 | -- | 1.1 | -- | -- |
| | 06:00 | V&T | 94.5 | 0.210 | 37 | 22.8 | 1115 | 61 | 2.05 | 40 | 39 | 0.033 | -- | 11.0 | 3.0 | -- | 1.1 | -- | -- |
| | 07:00 | V&T | 94.4 | 0.192 | 37 | 22.0 | 1106 | 62 | 2.27 | 39 | 39 | 0.033 | 7.6 | 11.0 | 2.9 | -- | 1.1 | -- | -- |
| | 07:30 | V&T | 97.3 | 0.182 | 37 | 17.5 | 1101 | 30 | 2.26 | 39 | 39 | 0.034 | 7.7 | -- | -- | -- | 1.1 | -- | -- |
| | 08:15 | V&T | 98.7 | 0.182 | -- | 17.5 | 1091 | 14 | 2.26 | 39 | 39 | 0.034 | 7.7 | -- | -- | -- | 1.1 | | |

V = venturi.
V&T = venturi plus packed tower.

*On these tests, the packed tower was in place but no solution was flowing to it.

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**Edward R. Bates** is the EPA Project Officer (see below).
The complete report, entitled "Alkaline and Stretford Scrubbing Tests for $H_2S$ Removal from In-Situ Oil Shale Retort Offgas," (Order No. PB 85-246 965/AS; Cost: $22.95, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
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