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CARBON DIOXIDE FOR pH ADJUSTMENT
100-K REACTORS

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CARBON DIOXIDE FOR pH ADJUSTMENT
100-K REACTORS

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CARBON DIOXIDE FOR pH ADJUSTMENT
100-K REACTORS

The sulfuric acid used to obtain 6.6 pH process water costs approximately \$260,000 annually for the 100-K Reactors. Carbon dioxide is available at each reactor in the boiler house stack gas. This carbon dioxide might be used for pH adjustment if an economical method could be found for introducing it into the reactor process water. In addition to reducing the cost of sulfuric acid, use of recovered carbon dioxide might reduce the radioactivity of the reactor effluent and the corrosivity of the process water. The sulfur in the sulfuric acid may be a source of the P-32 in the reactor effluent, and carbonate solutions are less corrosive for aluminum in some cases than are sulfate solutions.

This report presents the results of a recent analysis to determine if there is a practical method for using carbon dioxide for pH adjustment at the 100-K Reactors.

SUMMARY AND CONCLUSIONS

Carbon dioxide could be recovered from the boiler stack gas and introduced into the K Reactor process water. The approximately \$240,000 installation cost would be repaid in about one year by the reduction of sulfuric acid costs.

The proposed system would consist of a blower, a purification system, and a distribution system for conducting the gas from the boiler house stacks to spargers in the process water clearwells. The blower would draw gas from the boiler stacks and then blow it successively through the purification system and the distribution system. The purified gas, consisting primarily of carbon dioxide, oxygen, and nitrogen, would bubble up through the water in the clearwells, where the carbon dioxide would be absorbed by direct contact with the water.

The development work necessary before the use of carbon dioxide can be recommended consists primarily of in-reactor single tube tests followed by a half-reactor test. These tests are necessary to show the effects of carbon dioxide on aluminum corrosion, effluent activity, and reactor hydraulics. The single tube tests already have been started. The half-reactor tests probably will start in CY-1965 if no adverse effects are observed during the single tube tests.

Satisfactory completion of the development tests is expected early in CY-1966. The necessary installation work could be started before the end of FY-1966.

RECOMMENDATIONS

It is recommended that emphasis be placed on completing development of the use of carbon dioxide for pH control at the 100-K Reactors. A half-reactor test should be started as soon as ample data is available from the current single tube tests to show that no adverse effects are expected to occur.

DISCUSSION

Use of carbon dioxide for adjusting the pH of the reactor process water has been

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considered for several years. These efforts did not result in active investigation of reactor effects because sufficient justification could not be found for the necessary installation cost. The primary justification, elimination of sulfuric acid costs, was not adequate before CY-1961 because substantially less acid was required for operation at 7.0 pH in comparison to the current 6.6 pH. A study of a carbon dioxide installation for the B, C, D, DR, F, and H Reactors at 6.6 pH showed that the \$1,100,000 installation cost would be repaid by the reduced sulfuric acid cost in four to six years.¹

Recent emphasis on reducing operating costs and reactor effluent activity renewed interest in the use of carbon dioxide. One of the important radioisotopes in the reactor effluent is phosphorus-32. The precursors of P-32 are believed to be sulfur and phosphorus in the reactor process water. A significant source of sulfur is the sulfuric acid used for pH adjustment. Substitution of carbon dioxide for the sulfuric acid would eliminate that source of sulfur and possibly would reduce the amount of P-32 in the reactor effluent. An exact statement cannot be made as to whether or not the amount of P-32 would be reduced because the amount of parent isotope absorbed by and the hold-up times on the film formed by carbonate treated coolant are not known. The actual reduction of P-32 by use of carbon dioxide will have to be determined by reactor tests.

Use of carbon dioxide for pH adjustment was investigated with the assistance of the Process Engineering Development group of the Hanford Laboratories. Because prior investigations had shown that the installation cost could not be justified for the small reactors, decision was made to study only the use of carbon dioxide at the K Reactors. The carbon dioxide requirements for each of those reactors would be over twice as large as for a small reactor, thereby providing the economic advantage of larger installations. In addition, the transport distances from the boiler stacks to the point of introduction of the carbon dioxide into the process water could be less than half the distance for a small reactor. Also, the current uncertainty concerning future operation of the small reactors creates the possibility that they will not operate long enough to repay necessary installation costs.

All studies of the use of carbon dioxide have been based on recovery of carbon dioxide from the boiler house stack gasses. The cost of purchased carbon dioxide (currently \$40 per ton) is not expected to be less than the cost of sulfuric acid (currently about \$15 per ton) even if large quantities are purchased. The carbon dioxide cost must be less than \$10 per ton if a significant cost savings is to be realized.

Three methods for recovering the carbon dioxide from the stack gas and introducing it into the process water were investigated:

1. Absorption of the carbon dioxide in a water stream by use of an absorption column and then mixing this water stream with the process water.

1. HW-74047, "Utilization of Carbon Dioxide Recovered From Boiler Stack Gas For Reactor pH Control", R. J. Nicklas, June 29, 1962.

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2. Absorption of the carbon dioxide in a monoethanolamine solution, desorbing and purifying the carbon dioxide, and then introducing the pure gas into the bottom of the clearwells.
3. Removing particulate and oily impurities from a portion of the stack gas and then blowing this purified gas into the bottom of the clearwells.

Absorption of the carbon dioxide in a water stream by use of an absorption column was rejected because of the high installation and operating costs. Calculations showed that the necessary absorption tower would be approximately thirty feet in diameter and approximately twenty feet high for a K Reactor. Through this tower would pass a water stream equal to between twenty and fifty percent of the total reactor coolant flow. This flow range results from the annual variation in the water temperature. By inspection, it became apparent that this system would require more equipment and installation cost than would the third system studied. Both the first and third systems would require the same gas purification system. Both would require a gas blower of about equal capacity. The first system would require installation of the absorption tower in a separate, new building, whereas the third system uses existing buildings and a simple sparger system at the bottom of the clearwell. In addition, the first system requires a water pumping station large enough to pump half of the reactor coolant flow.

Use of a monoethanolamine (MEA) solution also was rejected because of the high installation and operating cost. In this system, the stack gas would be blown through an absorption tower through which an MEA solution passes. The MEA absorbs the carbon dioxide and flows to a desorbing column where the carbon dioxide is removed from the MEA by heating. The crude carbon dioxide stream then passes through a series of purification processes to remove any undesirable materials. A preliminary estimate by a vendor of package MEA installations shows an installation cost of approximately \$325,000 for a facility large enough for one K Reactor.² The estimated operating cost is \$6.67 per ton of carbon dioxide. In addition to the installation cost for the package facility is the cost of the piping for transporting the carbon dioxide to a process pipe and introducing it into the process water. Since the annual savings from reduction of the use of sulfuric acid would be a maximum of \$130,000 per reactor, it is apparent that the installation cost would not be repaid within two years, the current maximum desirable repayment period.*

Analysis of the third proposed system, blowing purified stack gas into the clearwells, showed that this is the most attractive system studied and that the repayment period is less than two years.

The system is simple and easily adapted to the K Reactors. Stack gas would be pulled from the boiler stacks by a gas blower and then blown through a venturi

2. Letter, O. R. Matzner to W. J. Van Slyke, "DeMarkus Carbon Dioxide Manufacturing Systems", September 3, 1964.

* See Appendix for detailed economic analyses.

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scrubber, an electrostatic precipitator, a pipeline to the clearwells, and finally through a distribution system in the clearwells. The venturi scrubber and the electrostatic precipitator would remove oily and particulate materials and also provide some gas cooling because of water used in the venturi scrubber. The purified gas would contain about thirteen percent carbon dioxide and the remainder would be primarily nitrogen and oxygen with traces of sulfur dioxide, carbon monoxide, and particulate material. The impurities are expected to be in low enough quantity that they would not have a detrimental effect on the reactor operation.

The estimated cost for this system is approximately \$240,000 installation cost for the two K Reactors plus an estimated \$32,000 annual operating cost.*

The annual cost savings for operation at 6.6 pH is \$264,000 from reduction of sulfuric acid consumption, resulting in a net annual savings of \$232,000. The repayment period for the installation cost is approximately one year.

Several aspects of the use of carbon dioxide as proposed must be investigated before adoption can be recommended. These are:

1. The effect of carbon dioxide on process tube and fuel element corrosion.
2. The effect of carbon dioxide on reactor effluent activity.
3. The effect of carbon dioxide on the reactor water system hydraulics.
4. Design of the distribution system for introducing the gas into the clearwells.
5. Health hazards from the inert atmosphere in the clearwell buildings.
6. Effect of impurities in the gas on clarity of the service water.

The first three aspects involve reactor effects and can be determined only by reactor tests. Engineering analysis and laboratory tests can give general indications of the expected effects, but reactor technology is not refined enough to permit accurate prediction of in-reactor effects on the basis of ex-reactor tests.

Reactor testing has been started by Research and Engineering Section with a two tube test at KE Reactor.³ This test will give general indications of the aluminum corrosion rate and effluent activity. If no undesirable effects are observed, the next step is a half-reactor test, which will provide sufficient data for determination of

* See Appendix for installation cost estimate.

3. HW-83116-B, "Production Test IP-520, Supplement B, In-Reactor Testing With Water Prepared in the Water Treatment Pilot Plant", P. R. Prevo, August 11, 1964.

The test started October 24, 1964, and is scheduled for one year duration.

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corrosion rates, effluent activity, and hydraulic effects. Large quantities of corrosion data can be obtained from a half-plant test by measurement of fuel elements and process tubes; the effluent activity effect can be determined by comparison of the activity of the two sides of the reactor; and hydraulic effects can be determined by comparison of pressure drops and the downcomer water levels.

Design of the distribution system in the clearwells has an effect primarily on the size and cost of the gas blower and distribution system. The cost estimates of this report are based on the assumption that the carbon dioxide must be pumped to the bottom of the clearwells and introduced into the clearwells at the corners where the process water enters. Absorption calculations indicate that the carbon dioxide would be absorbed if introduced at a depth as shallow as ten feet. Also, it may be possible to introduce the gas into the water near the exit to the clearwells. These design changes would reduce appreciably the cost of the distribution system and of the gas blower. Since the blower represents over half of the installation cost, a significant reduction of its cost would cause a significant reduction of the total installation cost.

The proper design for the distribution system can be determined during half-plant tests of the use of carbon dioxide. It is predicted that such a test would be conducted by purchasing a tank car or truckload of pure carbon dioxide and then connecting it to a temporary distribution system in one clearwell. The position of this distribution system could be changed so that the effect on carbon dioxide absorption and distribution in the process water could be determined.

The health hazard from the inert atmosphere in the clearwell buildings does not appear to be a limitation on the use of carbon dioxide. Blowing the purified stack gas or pure carbon dioxide into the clearwells could result in displacement of the air above the water by nitrogen and/or carbon dioxide. An analysis of the building design and usage would have to be made to determine how and when personnel would be exposed to the inert atmosphere, and appropriate building seals, warning signs, and procedures must be adopted. Normally, personnel entry into the clearwells is rare and occurs only when the clearwells are drained. If the carbon dioxide system is shut off before a clearwell is drained, the process of draining should draw enough air into the clearwell to prevent exposure of personnel to an inert atmosphere.

Impurities in the gas blown into the clearwells could change the clarity of the service water. This could cloud the metal storage basins, making fuel handling more difficult. This problem will have to be studied prior to final design of the gas purification systems. It is possible that the venturi scrubber plus electrostatic precipitator may not remove enough impurities. In that case, additional purification equipment would be necessary or the gas may have to be blown into the sedimentation basins rather than into the clearwells. The additional cost is not expected to increase the total installation cost enough to increase the repayment period to more than two years.

ACKNOWLEDGEMENT

Appreciation is expressed to the Process Engineering Development Group of the Hanford Laboratories for their assistance during this analysis. In particular,

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W. J. Van Slyke provided the basic analyses and data concerning the various carbon dioxide recovery systems.

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APPENDIX I

INSTALLATION COST
100-K REACTOR CARBON DIOXIDE pH ADJUSTMENT

Basis:

Boiler house stack gas would be blown successively through a purification system, a distribution system, and then spargers located in the bottoms of the process water clearwells. The purification system would consist of a venturi scrubber, an electrostatic precipitator, and de-entrainment equipment. Each reactor would have an independent system.

Cost Estimate:

<u>Item</u>	<u>Labor and Material Cost</u>	<u>Total Cost</u>
100-KE Reactor		
Compressor - 400 HP, 3,500 cfm	52,000	
Purification equipment	10,350	
Piping and control equipment	16,500	
Miscellaneous materials and supplies	<u>1,150</u>	80,000
Equipment usage		3,700
Construction overhead		<u>9,000</u>
		92,700
100-KW Reactor		<u>92,700</u>
Total construction cost		185,400
Design Engineering		19,000
Contingency		<u>39,000</u>
Total project cost		243,400

Basis: Letter, "Stack Gas to Flocculation Basins, 100-KE and KW", N. C. Dresser to W. J. Van Slyke, dated September 16, 1964.

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APPENDIX II

ECONOMIC ANALYSIS
CARBON DIOXIDE FOR 100-K REACTOR pH ADJUSTMENT

Basis:

The carbon dioxide recovery system described in Appendix I. FY-1964 operation.

Basic Data:

1. Sulfuric acid consumption at the 100-K Reactors during FY-1964 was 14,200 tons.
2. Sulfuric acid costs \$15.50 per ton.
3. Electricity costs \$17.50 per kw year.
4. A 400 HP motor requires about 350 kw of electricity.
5. The annual maintenance cost for one carbon dioxide system is \$10,000.
6. Future annual sulfuric acid consumption for operation at 6.6 pH is expected to be twenty percent higher than in FY-1964 because of less extended reactor outages.

Calculations:

1. Annual savings

$$\begin{aligned} &= (\text{Reduction of acid cost}) - (\text{increased electricity and maintenance costs}) \\ &= (14,200 \text{ tons})(1.2)(\$15.50/\text{ton}) - (2)(350 \text{ kw})(\$17.50/\text{kw}) - (2)(\$10,000) \\ &= \$264,100 - \$12,200 - \$20,000 \\ &= \underline{\$231,900} \text{ annual savings} \end{aligned}$$

2. Repayment period

$$\begin{aligned} &= \frac{\text{Installation cost}}{\text{Annual savings}} \\ &= \frac{\$243,400}{\$231,900} = \underline{1.05 \text{ years}} \end{aligned}$$

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