ENERGY CONSERVATION IN COAL CONVERSION

Alternate Acid Gas Removal System Study

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ABSTRACT

To reduce the reboiler steam required, we studied replacing the MEA (monoethanolamine) system proposed by the Ralph M. Parsons Co. with a DEA (diethanolamine) acid gas removal system. Steam consumption is reduced by 16,000 lbm/hr which is 1% of the total steam generated in the Oil/Gas Complex or $317,000 per year. In addition, there is an annual savings of $88,000 for chemicals. The additional capital costs and operating expenses for the DEA system are negligible since the process plants are equivalent. It is therefore recommended that a DEA system replace the MEA system as Process Unit 17 of the Oil/Gas Complex.

ACKNOWLEDGEMENTS

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INTRODUCTION

In the Ralph M. Parsons Oil/Gas Conceptual Design, the acid gas removal system uses MEA (monoethanolamine) to strip the dissolver gas of H_2S and CO_2. Since the MEA system has a high steam consumption, 190,300 lbm/hr, we examined the feasibility of using a DEA (diethanolamine) which uses less steam.
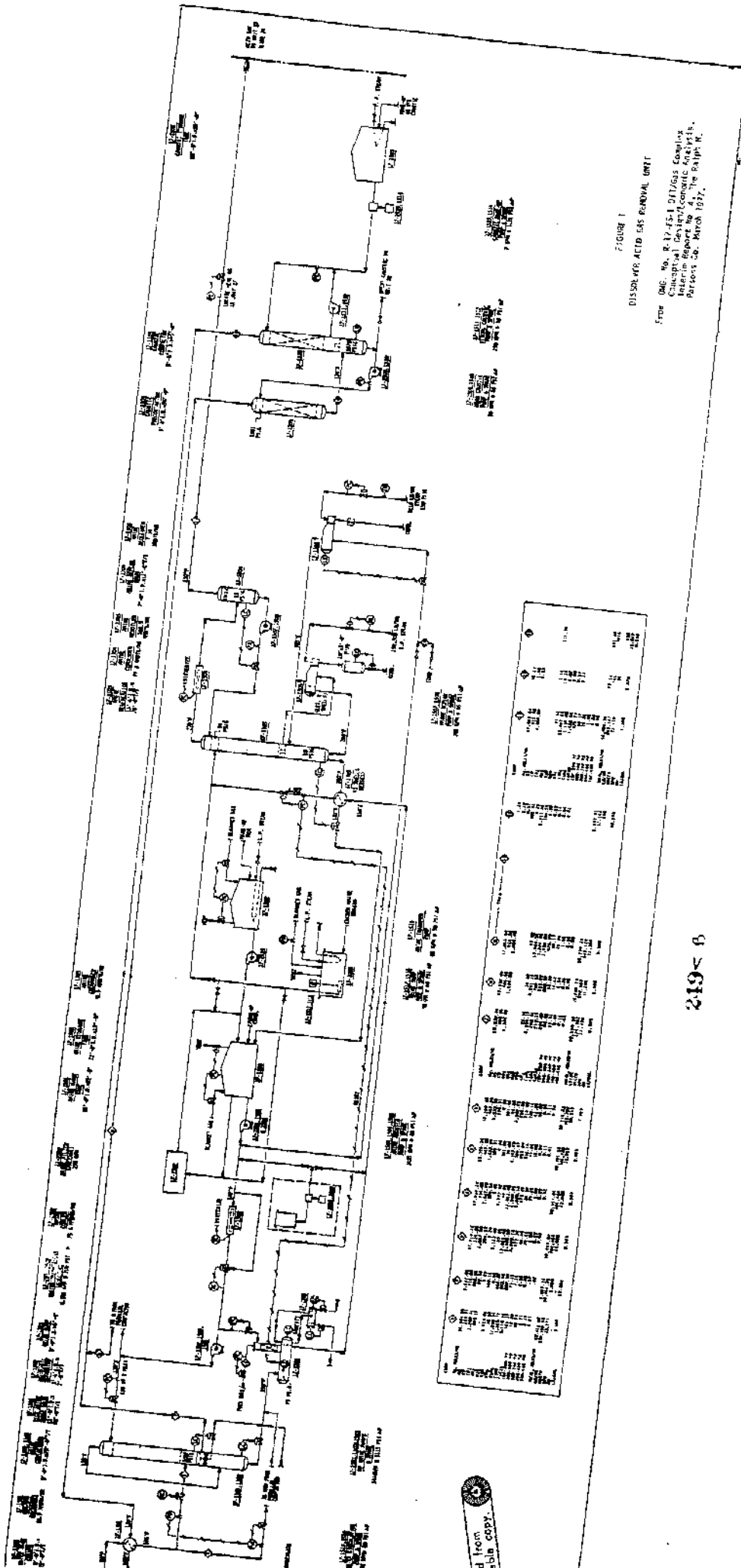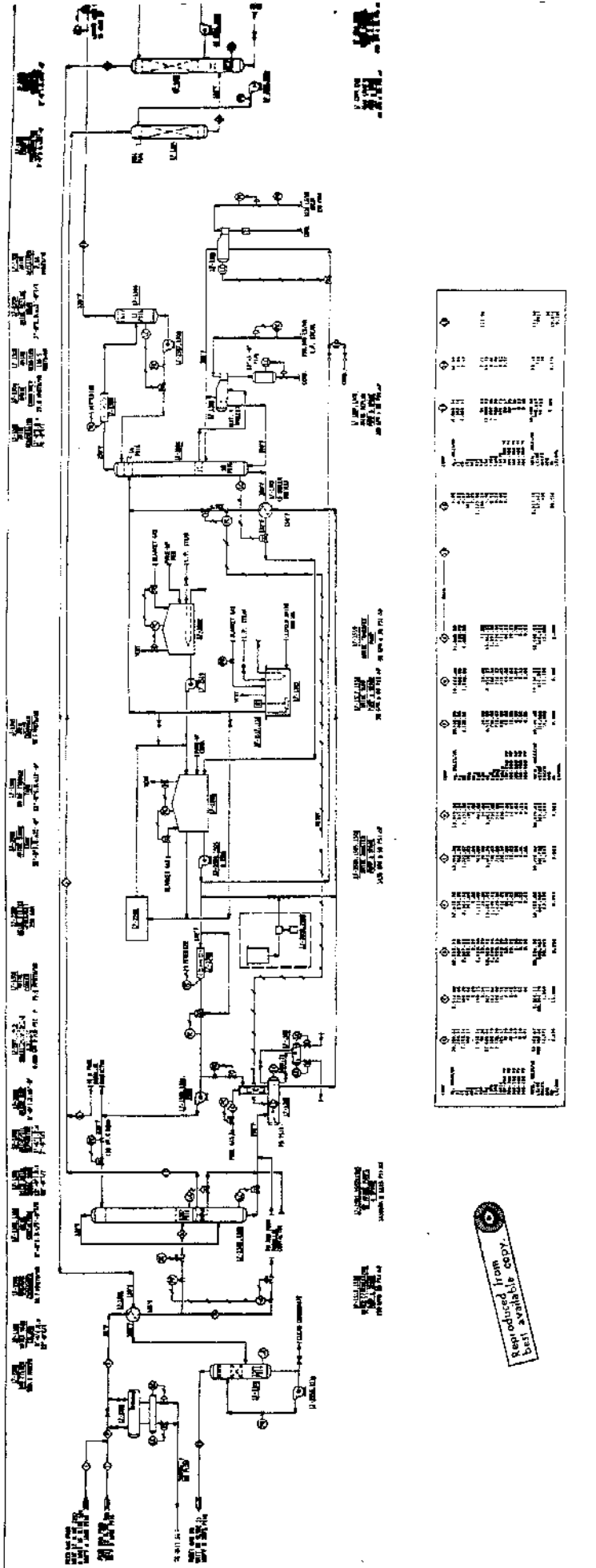
FIGURE 1

DISSOLVER ACID GAS REMOVAL UNIT

249-C

219< 6

MEA PROCESS DESCRIPTION

A schematic of the system designed by Parsons is given in Figure 1. The inlet gas composition temperature and pressure is given in Table 1. Table 1 shows that the acid gas concentration is 2.495% (1.85% H_2S + .645% CO_2).

The Ralph M. Parsons design, calls for an MEA wash, followed by a caustic wash (NaOH). The reactions involved in sweetening the acid gas with aqueous MEA (RNH_2)* are:

$$2RNH_2 + H_2S \rightleftharpoons (RNH_3)_2S$$

$$(RNH_3)_2S + H_2S \rightleftharpoons 2RNH_3HS$$

$$2RNH_2 + CO_2 + H_2O \rightleftharpoons (RNH_3)_2CO_3$$

$$(RNH_3)_2CO_3 + CO_2 + H_2O \rightleftharpoons 2RNH_3HCO_3$$

$$2RNH + CO_2 \rightleftharpoons RNHCOONH_3R$$
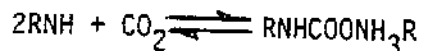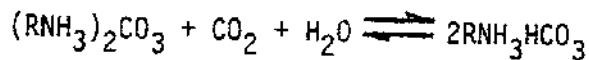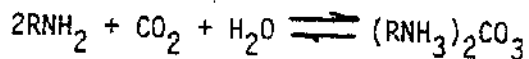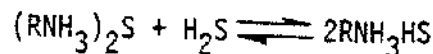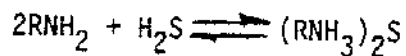
The reactions proceed to the right at lower temperatures (in the contactors) and to the left at higher temperatures (in the stripper). Thus, at 86°F (inlet gas temp.), the amines will absorb the acid gas and form the amine salts. At a temperature of about 300°F the salts disso-ciate, the acid gas is liberated, and the amine is available for reuse.[2]

The caustic wash insures that the CO_2 concentration is brought to less than 5 ppm. The equations governing these reactions are:

$$2NaOH + CO_2 \rightleftharpoons Na_2CO_3 + H_2O$$
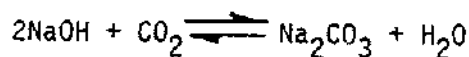
*where R = $HOCH_2CH_2$
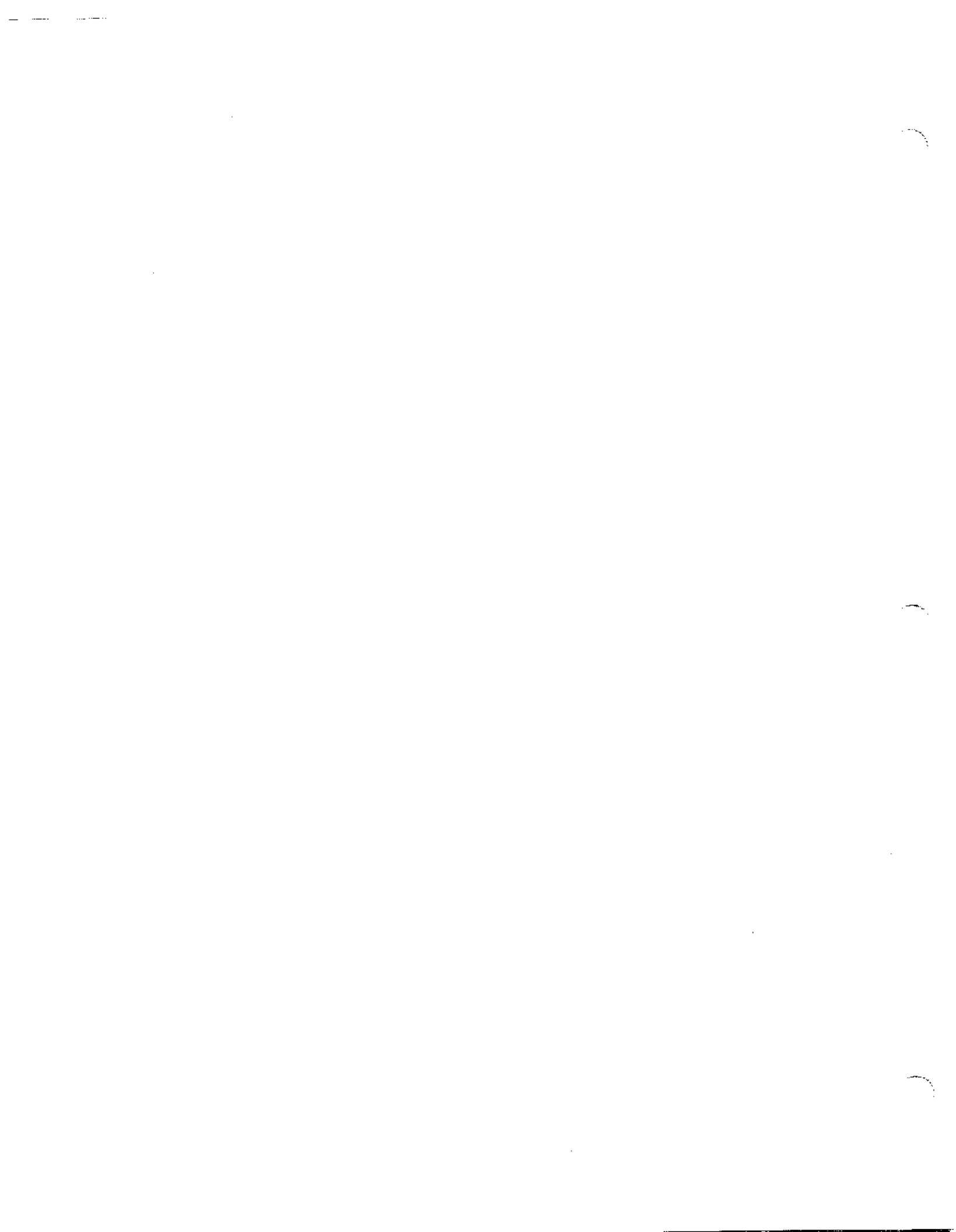
TABLE 1

INLET STREAM COMPOSITION FROM DISSOLVER

	Moles/hr	Mole %
H_2	37,918.72	62.6
N_2	934.28	1.54
CO	2,667.93	4.4
CO_2	391.02	.645
NH_3	5.29	.009
H_2S	1,123.60	1.85
H_2O	49.20	.08
CH_4	13,883.42	22.91
C_2H_6	1,599.33	2.64
C_3H_8	1,428.18	2.36
C_4H_{10}	472.29	.78
IBP-200°F	86.40	.14
200-300°F	29.25	.05
300-350°F	1.88	.003
350-400°F	0.22	-
400-450°F	0.03	-

TOTAL	60,591.4	
lb/hr	605,464	
MSCFH	23,025	

Inlet Pressure - 1095 psig

Inlet Temp. - 86°F

$$Na_2CO_3 + H_2S \rightleftharpoons HaHS + NaHCO_3$$
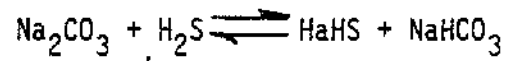
The caustic is not regenerated. The NaOH make-up is approximately 6TPD.

Steam is used to reboil the rich amine solution from the Ralph M. Parsons flowsheets which specify an MEA concentration of 18% (weight) and a flowrate of ∿2850 gpm, the amine reboiler uses 190,300 1bm/hr (166.5 MMBtu/hr) of low pressure steam.

ALTERNATIVE ACID GAS REMOVAL SYSTEMS

There are other acid gas removal processes available that are more energy efficient than the amine process. Unfortunately, the partial pressure of the acid gas is too small for these processes to work efficiently[3].

DEA (diethanolamine) offers a substantial energy savings, as well as a savings in chemical costs. The mechanism by which it sweetens the gas is essentially the same as MEA, and an analagous set of reaction equations can be written[2]. The energy savings results from the lower heats of reaction of H_2S and CO_2 with DEA[2]. Thus, less steam is needed to reboil the rich amine solution. The calculated steam savings per year is 1.267×10^8 lb (see Appendix A). The savings in chemical costs result from a lower vapor pressure than that of MEA. The DEA make-up requirements are 50% lower than that of a similar MEA system[3]. The resulting savings in chemical costs are $88,180.00/yr (see Appendix B).

Another advantage of DEA is its ability to react reversibly with COS, unlike MEA, which reacts irreversibly. Thus, both amines will remove COS from the gas stream, but MEA will be deactivated, while DEA will not. COS does exist as a trace compound in the dissolver.

With minor modification, the DEA system would utilize the same parallel contactor system as the proposed MEA system. A 30% DEA solution has a slightly higher pickup rate than 18% MEA (see Figure 2) thereby cutting pumping costs slightly. Operating with the caustic wash, the 30% DEA system will bring CO_2 levels to less than 5 ppm, and H_2S levels to less than .25 grain/ccf[3].
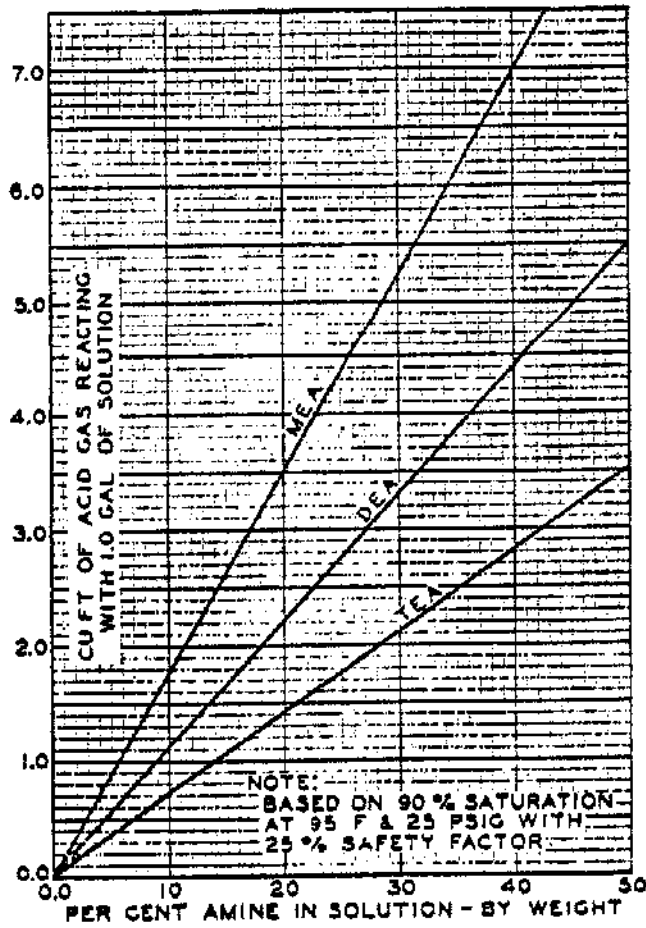
FIGURE 2

ACID GAS PICK-UP VS AMINE SOLUTION CONCENTRATION

from reference 2.

ECONOMIC COMPARISON OF DEA AND MEA

In comparing the economics of the two systems, the following assumptions will be made:

1. Process plants are considered equivalent.

2. Labor, maintenance, and startup costs are equivalent.

3. Caustic consumption is equivalent.

Therefore, the basis of comparison will rest solely on energy and amine consumption.

The annual steam savings of the DEA system is $316,760.00/yr (see Appendix A).

The annual amine make-up cost of each system is:

MEA - $180,180.00/yr

DEA - $ 92,000.00/yr   (See Appendix B)

The annual DEA make-up cost is $88,180.00/yr less than the MEA make-up cost.

The cost of the initial charge of chemicals for each system is:

MEA - $117,000.00

DEA - $200,000.00   (See Appendix B)

The DEA charge is $83,000.00 more than the MEA charge.

Therefore, in the first year the savings realized by the DEA system are: $88,180 + $316,760 - $83,000 = $321,940. In subsequent years the annual saving are: $88,180 + $316,760 = $404,940. Over the twenty year life of the plant $8,015,800 is saved, in 1977 dollars.

CONCLUSIONS AND RECOMMENDATIONS

Since the DEA system meets the required plant specifications (<5 ppm CO_2, $<.25$ grain/ccf H_2S) and saves a significant amount of energy as well as chemicals, it should be used. There exists an additional area for energy savings in the DEA system. A step-down turbine installed between the contactor and the surge tank could supply up to 50% of the shaft power required to drive the high pressure amine pumps. This is 1200 Hp or $177,000 savings per year for electricity at .025 $/KWhr[6].

REFERENCES

1. Oil/Gas Complex, Conceptual Design/Economic Analysis. Interim Report No. 4, The Ralph M. Parsons Co., March 1977.

2. Gas Engineers Handbook. C. George Segeler, Ed.-in-Chief, The Industrial Press, New York, NY 1965.

3. Personal Communication, J.D. Crow, Graf Engineering Co., Dallas, TX.

4. Personal Communication with Bill Pierce, Dow Chemical, Inc., Midland Mich.

5. Personal Communication with John Valentine, Allied Chemical, Morristown, NJ.

6. Section XII, Basis for Fuel and Utility Costs, Energy Conservation in Coal Conversion Progress Report, June, 1978.

APPENDIX A

ENERGY SAVINGS OF DEA SYSTEM

The following assumptions will be made:

1. Specific heats of 18% MEA solution and 30% DEA solution are equivalent.

2. Flow rates of MEA and DEA are equivalent.

3. Saturated steam @ 50 psia is condensed to saturated liquid @ 50 psia in the reboiler of both the MEA and DEA systems.

4. The cost of low pressure steam is $2.50/mlb[6].

The heats of formation of CO_2 and H_2S for the two amine systems are:

$$MEA - H_2S: \quad 820 \text{ BTU/lbm}$$
$$CO_2: \quad 825 \text{ BTU/lbm}$$
$$DEA - H_2S: \quad 511 \text{ BTU/lbm}$$
$$CO_2: \quad 653 \text{ BTU/lbm}$$

The mass flow rates of H_2S and CO_2 are:

$$H_2S: \quad 38277 \text{ lbm/hr}$$
$$CO_2: \quad 17208 \text{ lbm/hr}$$

The energy savings per year of a DEA system can be calculated as follows:

$$H_2S: (820-511) \text{ BTU/lbm-}H_2S \cdot 38277 \text{ lbm-}H_2S/hr \cdot 7920 \text{ hr/yr*}$$
$$= 9.37 \times 10^{10} \text{ BTU/yr}$$

$$CO_2: (825-653) \text{ BTU/lbm-}CO_2 \cdot 17208 \text{ lbm-}CO_2/hr \cdot 7920 \text{ hr/yr}$$
$$= 2.34 \times 10^{10} \text{ BTU/yr}$$

Total savings per year: 11.71×10^{10} BTU/yr.

*Basis - 330 Day year

From the first law of thermodynamics:

$$\dot{Q} = \dot{M} (h_1 - h_2)$$

@ 50 psia, $h_g - h_f$ = 924.2 BTU/lbm.

$$\dot{Q} = 11.71 \times 10^{10} \text{ BTU/yr.}$$

Therefore, the amount of steam saved is:

$$\dot{M} = \dot{Q}/(h_1 - h_2) = 11.71 \times 10^{10}/924.2 = 1.267 \times 10^8 \text{ lbm/yr}$$

which is a dollar savings of:

1.267 x 10^8 lbm/yr · 1 mlb/1000 lbm · 2.50 $/mlb

= 316,670 $/yr

APPENDIX B

CHEMICAL COSTS FOR DEA AND MEA SYSTEMS

Assumptions:

1. Caustic consumption is the same for both the MEA and DEA systems.

2. DEA make-up is one-half MEA make-up.

Initial Charge:

MEA, 18% solution: 300,000 lbm @ .39 $/lbm[3]

$117,000.00

DEA, 30% solution: 500,000 lbm @ .40 $/lbm[3]

$200,000.00

Therefore the additional initial lost for the DEA system is:

$200,000 - $117,000 = $83,000

Annual Make-Up:

MEA solution: 462,000 lbm/yr @ .39 $/lbm

$180,180.00/yr

DEA solution: 230,000 lbm/yr @ .40 $/lbm

$92,000.00/yr

The DEA system saves:

$180,180 - $92,000 = $88,180 per year