ENERGY CONSERVATION IN COAL CONVERSION

Alternate De-Ethanizer Refrigeration System to Conserve Energy

A Case Study

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ABSTRACT

This study examines an alternate system to cool an ethane gas stream from the fractionator in Unit 18 of the Parsons Oil/Gas Complex. This alternate will save 2.6 x 10^5 Btu/hr of energy or .25 short TPD of coal which is a fraction of a percent of the 36,000 TPD of coal used in the Oil/Gas Complex. The installed cost of the alternate system is $151,000 with an operating and maintenance cost of $7550/yr. Assuming a 20-year life, 9% interest rate on borrowed capital, and an electricity cost of $.025/KW-hr, the Life Cycle Cost of the new system is-$179,000 over a 20-year period which shows that more money is spent installing new equipment than is realized from electricity savings. Using a Discounted Cash Flow Analysis, the Return on Investment is 0%.

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INTRODUCTION

The de-ethanizer condenser (Unit 18-1317) in the Parsons Oil/ Gas Complex cools an ethane gas stream from 53°F to 26°F. The cold side stream of this condenser is -40°F propane. The heated propane is piped to a storage tank, and a refrigeration unit maintains the tank at -40°F. Therefore, the heat added to the propane must be transferred from -40°F to ambient temperature (100°F) by the storage tank refrigeration unit.

The purpose of this study is to determine the energy savings resulting from a refrigeration unit to cool the ethane gas stream from 53°F to 26°F.

ENERGY SAVINGS FOR THE ALTERNATE REFRIGERATION SYSTEM

Assuming an effectiveness of .8(7) for the evaporator, the required evaporator temperature is 19°F for the alternate refrigeration system to cool the ethane stream from 53°F to the required 26°F. This results in a higher COP than the present system which must transfer heat from a -40°F reservoir. From Appendix A, the actual COP for the alternate system is 2.55 and for the required refrigeration effect of 1.3×10^6 Btu/hr (see Appendix B), 200 Hp is required(9). The present system has a calculated COP of 1.7 and for the same refrigeration effect requires 302 Hp. Therefore, the power requirement for the alternate refrigeration system is 102 Hp or 76 KW less than the present system.

ECONOMIC ANALYSIS

The savings in electricity for a 76 KW reduction in power for the alternate system is $15,050 per year or $301,000 over 20 years assuming an electricity cost of $.025/KW-hr(10). The installed cost of the alternate system is $151,000 and annual operating and maintenance costs are assumed to be 5% of the installed cost or $7,550. If the capital is borrowed at 9% the 20-year life cycle cost is -$179,000. The calculations and assumptions for computing the life cycle cost are given in Appendix C.

A discounted cash flow analysis was also performed. For the investment of $151,000, a rate of return of 0% is obtained. The basis for the DCF analysis are given in Appendix C.

CONCLUSIONS

For a capital investment of $151,000 and an annual operating and maintenance cost of $7,550, 601,920 KW-hrs, or $15,050 of electricity are saved annualy. This represents a 0% rate of return on investment, and a life cycle cost of -$179,000 over the 20 year life.

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APPENDIX A

COP Calculations

For the refrigeration effect required, 1.3×10^6 Btu/hr (from Appendix B) and the work input of 200 Hp (5.1×10^5 Btu/hr) given by reference 9, the actual COP is:

$$COP_1 = \frac{Q}{W}$$

$$= \frac{1.3 \times 10^6 \text{ Btu/hr}}{5.1 \times 10^5 \text{ Btu/hr}}$$

$$= 2.55$$

Since the only data known for the present refrigeration system is the heat load (1.3×10^6 Btu/hr), ambient temperature (100°F), and storage tank temperature (-40°F), the theoretical COP will be adjusted using a rule of thumb to arrive at a realistic value. The coefficient of performance can be written:

$$COP = \frac{T_L}{T_H - T_L}$$

To determine a realistic value of the COP, 20°F is subtracted from the low temperature reservoir or $T_L = -40° - 20° = -60°F = 400°R$. 20°F is added to the high temperature reservoir, $T_H = 100°F + 20°F = 580°R$, and to account for inefficiencies, the COP is multiplied by .75. This can be written:

$$COP_2 = .75 \left[\frac{400°R}{580°R - 400°R}\right] = 1.7.$$

APPENDIX B

Calculation of the Heat Load, Evaporator Temperature and Refrigeration Work

The mass flow of the gas stream to be cooled , the components, and the entering and exiting temperature and pressure are tabulated below. With this information the heat load or refrigeration effect can be calculated. From the first law of thermodynamics:

$$Q = \dot{m}_1 \ (\Delta h_1) + \dot{m}_2 \ (\Delta h_2) + \dot{m}_3 \ (\Delta h_3)$$

where:

Q = refrigerating effect (Btu/hr)

$\dot{m}$ = mass flow (lb/hr)

Δh = change in enthalpy (Btu/lb)

The following table shows the components of the gas stream, their percent composition, respective mass flows, h_1, h_2, Δh and Q from each component$^{(5)}$.

CHEMICAL COMPONENTS	PERCENT COMPOSITION	MASS FLOW ($\dot{m}$) lb/hr	ENTHALPY (h_1) Btu/lb	ENTHALPY (h_2) Btu/lb	Δh $h_1 - h_2$	$Q = \dot{m}(\Delta h)$ Btu/hr
Methane (CH_4)	5.6%	5,849	- 1544.3	- 1558.9	14.6	85,395
Ethane (C_2H_6)	66 %	68,934	- 844.9	- 856.8	11.9	820,315
Propane (C_3H_8)	28.4%	29,245	53.7	40.4	13.3	388,959
TOTAL HEAT REJECTED						1,294,669

Enthalpies are based on the following temperatures and pressures:(4)

$$T_1 = 53°F \; ; \; P_1 = 216 \text{ psia}$$

$$T_2 = 26°F \; ; \; P_2 = 211 \text{ psia}$$

The refrigeration effect required is:

$$Q = 1.3 \times 10^6 \text{ Btu/hr.}$$

Evaporator Temperature Calculation

Assuming the effectiveness of the evaporatorto be $\varepsilon = .8$, we have:

$$\varepsilon = \frac{T_1 - T_2}{T_1 - T_L}$$

$$.8 = \frac{53°F - 26°F}{53°F - T_L}$$

or $T_L = 19°F$.

Refrigeration Work Required

Using the values of COP determined in Appendix A the work load of the present refrigeration unit can be determined by using the definition of COP.

$$W = \frac{1.3 \times 10^6 \text{ Btu/hr}}{1.7} = 7.7 \times 10^5 \text{ Btu/hr}$$

$$= 302 \text{ Hp.}$$

For the alternate system the work input is given as 5.1×10^5 Btu/hr(9). The energy saved by installing the alternate system is:

$$7.7 \times 10^5 \text{ Btu/hr} - 5.1 \times 10^5 \text{ Btu/hr} = 2.6 \times 10^5 \text{ Btu/hr (76 KW)}$$

Assuming the coal used in the Oil/Gas Complex has a heating value of 12,125 Btu/lb(1), this presents a saving in coal consumption of:

$$\frac{2.6 \times 10^5 \text{ Btu/hr}}{12{,}125 \text{ Btu/hr}} \text{ (24 hr/day)} = 515 \text{ lb/day} \simeq 1/4 \text{ short ton/day (TPD).}$$

This is only a fraction of a percent of the 36,000 TPD(1) used in the entire complex.

APPENDIX C

Economic Calculations

Life Cycle Cost

The electricity cost savings over 20 years, with 330 full stream days/yr(1), and assuming electricity costs \$.025/KW-hr is:(10)

$$(20\text{ yr})(2.6 \times 10^5\text{ Btu/hr})(2.928 \times 10^{-4}\text{ KW-hr/Btu}) \times$$
$$(330\text{ day/yr})(24\text{ hr/day})(\$.025/\text{KW-hr}) = \$301{,}467$$

Savings = \$301,000.

The cost of equipment, installation, operation, and maintenance for the alternate refrigeration system is based on the following assumptions:

1) Interest rate on borrowed money is 9%.
2) 20-year life with no salvage value(1).
3) Installation is 40% of equipment cost(3).
4) Operational and maintenance is 5% of installed cost.

The following lists give design specifications and equipment costs of the de-ethanizer condenser to be removed and the new refrigeration system to be installed.

De-ethanizer Condenser

Item number: 18-1317(1)

Heat Load: 1.3×10^6 Btu/hr

Surface Area: 1,230 ft^2 (1)

Installation Cost: \$24,000(1)

Alternate Refrigeration System

Heat Load: 1.3×10^6 Btu/hr (110 tons)

Power requirement: 200 Hp(9)

COP: 2.55

Evaporator Temp.: 19°F

Ambient Temp.: 100°F

Equipment Cost: \$125,000(9)

The total installed cost of equipment with credit taken for the existing condenser is:

\$125,000(1.4) - \$24,000 = \$151,000

If this money is borrowed at 9% interest, the uniform annual payments for the loan using the Capital Recovery Factor (CRF) are:(8)

\$151,000(.1095) = \$16,535/yr

Annual operation and maintenance cost is:

\$151,000(.05) = \$7550/yr.

The total cost of installation, maintenance and operation is:

\$16,535 + \$7550 = \$24,085/yr

Therefore, the total cost over 20 years is:

\$480,000.

The Life Cycle Cost (LCC) is the total saving - the total costs, or in this case:

$$\$301,000 - \$480,000 = -\$179,000.$$

Discounted Cash Flow Analysis

With a cost of electricity of \$.025/KW-hr, capital cost of \$151,000, net cash flow of \$7,523, and the assumptions below, the rate of return on investment can be calculated.

Assumptions:

1) 20 year project life
2) 16 year SYD depreciation (sum-of-year-digits)
3) 0% tax rate since the revenues result in a decrease in electricity use
4) No investment tax credit
5) 100% equity

The discounted cash flow formula is given as:

$$C_o = \sum_{n=1}^{N} \frac{C_n}{(1+r)^n}$$

where:

C_o is the capital cost

C_n is the annual net cash flow

N is the project life

r is the rate of return

For this problem we have:

C_o = \$151,000

C_n = Annual revenues from savings in electricity - annual operation and maintenance costs

$= \$15,073 - \$7,550$

$= \$7,523$

$N = 20$

Solving for the rate of return, r by interpolating, we get:

$r = -.04\%$ or $r = 0\%$