



COST OF EFFECTIVENESS OF THE NUMBER OF EFFECTS OF A MULTIPLE-EFFECT EVAPORATOR IN SUGAR CANE FACTORIES

Engineering

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ABSTRACT

Evaporators are integral part of a number of process industries like Pulp and Paper, Sugar, Caustic Soda, Pharmaceuticals, Desalination, Dairy and Food Processing etc. Optimization is the use of specific methods to determine the most cost-effective and efficient solution to a problem or design for a process. It is one of the major quantitative tools in industrial decision making. The aim of this study is to explain how the total cost of evaporators can be reduced by using multi-effect evaporators and achieve an economically optimal number of effects. Multi-effect evaporators system for the concentration of sugar cane was studied it was found that four-effect evaporator system is the most optimum and most economical.

KEYWORDS

Multiple Effect Evaporators, Optimum Number of Effects, Steam economy

INTRODUCTION

Multiple-effect evaporator is one of the three components of the juice evaporation process in raw sugar manufacturing. The other two components are juice heater and crystallizer. The juice heater is used to raise the temperature of incoming juice to the boiling point before the juice is sent to the evaporator. The crystallizer is used to evaporate the remaining water content of concentrated juice leaving the evaporator. The output of the crystallizer is raw sugar. The evaporation process requires a supply of low-pressure steam from a turbine. Pinch analysis has identified the multiple-effect evaporator as the most intensive thermal energy consumer in raw sugar manufacturing process (Cortes et al., 2010). Therefore, previous suggestions to improve the process performance have mostly focused on the multiple-effect evaporator. Urbaniec et al. (2000) used Process Integration methodology to demonstrate that retrofitting sugar evaporation process led to energy saving. Heluane et al. (2007) investigated the problem of optimizing sugar evaporation process through operation scheduling of the evaporator. Ensinas et al. (2007) used a thermo-economic procedure to optimize the design of multiple-effect evaporator. Higa et al. (2009) showed that increasing the number of evaporator effects and using vapor bleeding for juice heating led to reduced steam consumption. Sharan and Bandyopadhyay (2015) proposed an analytical method for integrating the multiple-effect evaporator with background process to minimize steam consumption. Energy efficiency can also be increased by optimizing the distribution of heating surface area among the effects of the evaporator. The chief factor influencing the economy of an evaporator system is the number of effects.

MATERIALS AND METHODS

This chapter contains brief information about the methods for determining optimum conditions graphically and analytically.

Graphical optimization

Is a simple method for solving optimization problems involving one or two variables? For problems involving only one optimization variable, the minimum (or maximum) can be read simply from a graph of the objective function. For problems with two optimization variables, it is possible to obtain a solution by drawing contours of constraint functions and the objective function. The procedure is discussed in detail in the first section. After developing the procedure in detail with hand calculations, a Mathematical function called Graphical Solution is presented that automates the process of generating the complete contour plots. The second section presents solutions of several optimization problems using this function.

General procedure for determining optimum conditions

The first step in the development of an optimum design is to determine what factor is to be optimized. Typical factors would be total cost per unit of production or per unit of time, profit, amount of final product per unit of time, and percent conversion. Once the basis is determined, it is

necessary to develop relationships showing how the different variables involved affect the chosen factor. Finally, these relationships are combined graphically or analytically to give the desired optimum conditions

Optimum design and design strategy

An optimum design is based on the best favorable conditions. This optimum condition can ultimately be reduced to a consideration of costs or profits. Thus, an optimum economic design could be based on conditions giving the least cost per unit of time or the maximum profit per unit of production. When one design variable is changed, it is often found that some costs increase and others decrease. Under these conditions, the total cost may go through a minimum at one value of the particular design variable, and this value would be considered as an optimum. Although cost considerations and economic balances are the basis of most optimum designs, there are times when factors other than cost can determine the most favorable conditions. For example, in the operation of a catalytic reactor, an optimum operation temperature may exist for each reactor size because of equilibrium and reaction rate limitations. This particular temperature could be based on the maximum percentage conversion or on the maximum amount of final product per unit of time..

Analytical Procedure

The optimum value of x is found at the point where (dc/dt) is equal to zero. Similarly, the same results would be obtained if y were used as the abscissa instead of x . If this were done, the optimum value of y (i.e., y') would be found at the point where (dc/dt) is equal to zero. This immediately indicates an analytical procedure for determining optimum values. All other costs are considered independent of insulation thickness. The two cost relationships are:

$$\text{Fixed charges} = ax + b \dots\dots\dots(1)$$

$$\text{Cost of heat loss} = \frac{c}{x} + d \dots\dots\dots(2)$$

$$\text{Total Variable cost, CT} = ax + b + \frac{c}{x} + d \dots\dots\dots(3)$$

Where:

C , a , b and d are constants.

Graphical Procedure

The graphical method for determining the optimum is found at the minimum point on the curve obtained by plotting total variable cost; the slope of the total-variable-cost curve is zero at the point of optimum.

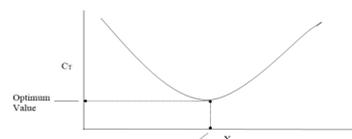


Fig 1: Minim Cost

Where:

C_T = Total cost
 X = cost

Case study

In this case study 450 ton/day of 5% solid using six evaporators to raise the concentration to 40% solid. The cost was calculated and shows the following.

Table 1: Cost for a Case study

Cost	18000 \$
The service life	10 years
The service life	6000 \$
The service life	20 % yearly
Steam costs	0.60\$ per 1000 Kg
Administration, labor and miscellaneous costs (no matter how many evaporator effects are used)	40\$ per day
Operating days per year	300days

Where:

X is the number of evaporator effects, 0.9x equals the number of Kg of water evaporated per Kg of steam. If the minimum acceptable return on any investment is 15 % taken, then what to be optimum number of effects.

Result and discussion:

Procedure

Basis: 1 day

X = total number of evaporator effects

Fixed charges – depreciation = 20% of initial investment

$$\text{Depreciation per day (St.line)} = X \frac{18,000 - 6,000}{10 \times 300} = \$4.0 \text{ x per day} \dots\dots\dots (1)$$

$$\text{Fixed charges – depreciation} = X \frac{18,000 \times 0.20}{300} = \$12 \text{ X per day} \dots\dots\dots (2)$$

Table 1: Cost analysis

No of effects X	Steam cost per day	Fixed charges depreciation per day	Depreciation per day	Labor – cct per day	Total cost per day
1	\$262.5	\$12	\$4	\$40	\$318.5
2	131.3	24	8	40	203.3
3	87.5	36	12	40	175.5
4	65.6	48	16	40	169.6
5	52.5	60	20	40	172.5
6	43.8	72	24	40	179.8

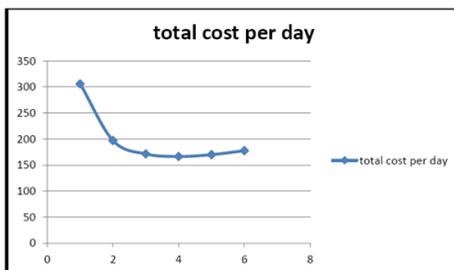


Fig 3: Optimum no. of evaporator at 5% sugar cane initial feed.

DISCUSSION

The total daily costs continue to increase as the number of effects is increased. A four-effect evaporator system was used to concentrate sugar cane to from 5% to 40 % by weight cane is the best and economical. This shown is table 2

Recommendations

The fourth effect evaporators system should be used because it proved to be the most optimum and economical.

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