OPTIMUM DESIGN OF EVAPORATION DRYING PLANT FOR BAGASSE IN A SUGAR MILL

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ABSTRACT

A drying plant employing air heated by flue gases has been designed. Bagasses conveyed through a drier loses moisture by evaporation in the counter flowing hot air. The only additional equipments required are an airheater, two blowers, a drier and related ducting. The paper describes procedure for the design of airheater and drier and estimates the savings for a given percentage of moisture removal from bagasse and a specified temperature reduction of flue gases.

An optimization method for plant design has been described. The effect of drier dimensions, temperature of outgoing flue gases and velocity of air on economy has been studied. It has been found out that savings are maximum for a specific value of moisture reduction, air flow rate and width of the drier.

INTRODUCTION

The attainment of high efficiency in the bagasse fired boilers is impaired by condensation loss due to high moisture content in the bagasse. Under normal milling conditions the moisture content of bagasse after the last mill ranges from 48% to 52%. The condensation loss can be reduced by drying the bagasse before it
enters the furnace. Since the calorific value of the dried bagasse is high, a considerable quantity of bagasse can be saved and used as raw material for other industrial processes.

Sun drying is not a very practical proposition because of difficulties involved in the handling and sorting of large quantities of bagasse and excessive time taken from the process. The flue gases coming out of the air preheater have temperature of 593°K and can be usefully employed for drying the bagasse. One way of drying could be to pass these hot gases through the bagasse. This would raise the temperature of bagasse by convection process and also remove the moisture by evaporation. However, the reduction in moisture is not expected to be high by this method as the flue gases already have a high moisture content. Alternatively, the flue gases could be used in an air heater to heat air which could then be passed through the bagasse removing moisture by evaporation. In this study, the second proposal has been considered.

This paper describes a method for optimizing the design of such a plant with a view to achieve maximum economy in the overall operation. The parameters of study considered for a given flue gas temperature-drop are the sizes of the drier. The net savings obtained after deducting the annual operating costs of the plant from the income of the bagasse saved are maximized. The effect of other parameters like the temperature of the heated air, and the moisture reduction in bagasse on the economy of the plant has also been studied.

The drying plant air heater has counter flow arrangement and is assumed to be of similar construction as the existing air preheater. To meet the additional resistance introduced by the air heater in the flue gas path either a bigger capacity fan can be employed in place of the existing draft fan or an additional fan can be used at the air heater in-let, as shown in Fig. 1. A blower is also used for circulation.
of air through the airheater circuit. Additional piping is provided for taking the
flue gases from the preheater to the airheater and then to the chimney and for
taking hot air from the airheater to the drier letting it out to the atmosphere.

The drier is an enclosed chamber with provisions for air and bagasse inlet
and outlet. Wet bagasse is fed into the chamber and conveyed from one end to the
other by means of a conveyor. The hot air enters the chamber at the opposite
end and flows counter to bagasse. Conveyor speed is fixed depending upon the
percentage of moisture to be removed from the bagasse. Chutes are used for feeding
the wet bagasse on to the conveyor and for taking the dry bagasse to the boiler.

THE DESIGN PROCEDURE

Design of Airheater

The optimum design of an airheater is determined by the annual cost per
unit incremental area, the heat transfer coefficient, the annual money saving per
unit of heat recovered per hour and the inlet and outlet temperature of the fluid
streams. Assuming that the existing airpreheater is of optimum design, the follow-
ing relation is satisfied (Morse).

\[
\frac{CA}{Ya \cdot ct} \cdot \left( t'_{oa} - t_{ia} \right) \cdot \left( t'_{ia} - t_{oa} \right) = \ln \left( \frac{t'_{ia} - t_{ia}}{t_{oa} - t_{ia}} \right) \tag{1}
\]

The nomenclature of the symbols is placed in Appendix I. From a typical record
of temperatures, \( t'_{oa1}, t_{oa1} \) and \( t_{ia1} \) for the air preheater at the experimental
Sugar Mill of the National Sugar Institute, Kanpur, the value of cost parameter
given on the left hand side of equation (1) can be calculated. For a similar con-
struction this value would also be approximately true for the airheater. In the study
carried out, it has however, been allowed to vary in the vicinity of the value obtained
from the equation (1) to examine its effect on the overall design of the plant.

Assuming no temperature drop in the pipings

\[ t'_{ia2} = t'_{oa1} \text{ and taking } t_{ia2} = t_{ia1} \quad \text{(Fig. 1)} \]

For the airheater

\[
C_c = \frac{(t'_{oa2} - t_{ia2}) \cdot (t'_{ia2} - t_{oa2})}{(t'_{ia2} - t_{ia2})} \tag{2}
\]

Equating the heat exchange from the flue gases to air (Huggot)

\[
m_a \cdot s(t_{oa2} - t_{ia2}) = \left[ 5.75 \left( 1 - 0.5 - \frac{x}{100} \right) \right] \cdot m + 1
\]
Where \( W_m = W \times 255 \) as one ton of cane crushed gives 255 Kg of bagasse. Combining equations (2) and (3) gives:

\[
W_m \left(1 - \frac{x}{100}\right) C_p \left(t'_{ia_2} - t''_{oa_2}\right) = \frac{(t'_{ia_2} + t_{ia_2} + C_2)}{2}
\]

and

\[-\frac{1}{2} \sqrt{(t'_{ia_2} + t_{ia_2} + C_2)^2 - 4(t_{ia_2} + C_2) (t'_{ia_2} - C_2 \cdot C_2)}\]

where

\[
C_1 = \left[(5.75) \left(1 - (0.5 - \frac{x}{100}) m + 1\right) \right] W_m \left(1 - \frac{x}{100}\right) \cdot C_p
\]

and

\[
C_2 = \frac{C_1 (t'_{ia_2} - t_{ia_2})}{m_a \cdot s}
\]

and

\[
Q_{\text{mean}} = \frac{Q_{\text{max}} - Q_{\text{min}}}{\log_{10} \frac{Q_{\text{max}}}{Q_{\text{min}}}}
\]

where

\[
Q_{\text{max}} = t'_{ia_1} - t'_{oa_1}
\]

and

\[
Q_{\text{min}} = t'_{oa_1} - t_{ia_1}
\]

the heat transfer coefficient for the air preheater of known area is obtained from the relation

\[
U_{a_1} = \frac{W_m}{\frac{A_{a_1} Q_{\text{mean}}}{\left(5.75 (1-x^1) \cdot m+1\right) \cdot C_0 \cdot (t'_{ia_1} - t'_{oa_1})}}
\]

For the heat transfer \( q_{a_2} \) in the air heater the expression is
Where $Q'$ mean is the mean temperature difference.

Hence,

$$A_{a2} = m_a S(t_{oa2} - t'_{ia2})$$

$$= U_{a2} Q'_{mean} A_{a2}$$

Design of Drier

As stated above the drying of bagasse takes place by evaporation of moisture into the hot air. For this process the mass transfer relation is (Eckert and Drake) as follows:

$$h_d \cdot W \cdot D = 0.16 \left[ \left( \frac{V}{D} \right)^{0.33} \frac{W \cdot \mu \cdot V}{P_o} \right]^{0.6}$$

where

$$D \text{ (m}^2/\text{hr)} \cdot 9.714 \cdot \frac{P_o}{T_o} \cdot 1.81$$

and

$$V = \frac{m_a \cdot R \cdot T_1}{P_1 \cdot W^2}$$

$m_a$ being the mass of air given by equation (15).

Assuming that the partial pressure of water vapor $P_{is}$ in atmospheric air equals to saturation pressure corresponding to temperature $t_{ia2}$, and the partial pressure of water vapor over the bagasse surface ($P_{iw}$) corresponding to its surface temperature, the amount of water evaporated per unit area per hour is given by:

$$m_c = \frac{h_d}{R_1 \cdot T_o} (P_{iw} - P_{is})$$
To calculate the length of the drier, the time required for removing a chosen moisture percentage must be known. It has been found experimentally (Roy and Singh) that when using air at 40°C it takes about 3 minutes to remove 30% moisture content. The rate of moisture removed is high in the beginning and reduces with decrease in moisture content of the bagasse. The process can be described approximately by the relation:

\[ 1 = 0.5\left(\frac{1}{(50-x)0.33} - \frac{1}{(50)0.33}\right) \]  

(20)

Where \( t \) is the time in hours for reduction of \( x \% \) of moisture content from initial 50% level. The length of drier for removing \( X\% \) moisture is then given by

\[ = \frac{x \cdot W_m \cdot t}{100 \cdot W_c \cdot m} \]  

(21)

The cost estimates

The cost of air-heater, assumed proportional to heat transfer area, is given by

\[ C_{ap_2} = C_{ap_1} + C_1 (A_{a_2} - A_{a_1}) \]  

(22)

Taking fabrication cost equal to half of the material cost, the cost of the drier of length 1, is

\[ C_d = \frac{3}{2} w . d . c \left(\frac{25t_1}{24} + 4t\right) \]

The capacity of draft fan motor is approximately increased by 16% by the introduction of airheater in the flue gas circuit (Fig. 1). Since two fans have been used, total cost of draft fans may, therefore, be taken as:

\[ C_e = 2C_b \]

The total capital cost of the plant is:

\[ C = C_{ap_2} + \frac{3}{2} w . t . d . c . \left(\frac{25t_1}{24} + 4t\right) + C_e + C_m \]  

(24)

where \( C_m = \) Cost of conveyor motor.
If $E \ell$ is the life of the equipment and $R_c$, is the repair and other miscellaneous expenses expressed as percentage of total cost, the annual cost is

$$C_A = \left( \frac{1}{E \ell} + \frac{R_c}{100} \right) \cdot C$$ (25)

For $x\%$ of moisture removed from the bagasse the total weight of water vapor removed per year is

$$W_a = \frac{x}{100} \cdot W_m \cdot (24) \cdot n$$ (16)

Thus, the cost of bagasse saved is

$$C_v = \frac{W_a \cdot \ell}{(NCV)} \cdot C_g$$ (17)

and the annual profit is

$$P = C_v \cdot C_A$$

OPTIMIZATION OF PLANT DESIGN

For the purpose of optimization, the percentage of moisture removed, amount of air flow per hour through the air heater and drier-width are taken as design variables. The remaining variables are assumed to be pre-assigned parameters. The moisture content which can be removed ranges from 0.5 to 50%. The mass of the air flow has been kept varying between 10640 kg/hr to 3,81,820 kg/hr being the mass of air which could reduce the flue gas temperature from $593^\circ K$ to $448^\circ K$ and $373^\circ K$, respectively. The lower limit of the width of the drier has been kept as 0.9 m so that a conveyor for transporting bagasse is accommodated. The upper limit has been kept as 2.7 m for beyond this the length of the drier becomes too long. This causes both constructional difficulties and increases the drier cost towards unprofitable range.

Pre-assigned parameter $C_c$ has been allowed to vary, from 120 to 240, a range in the neighborhood of the value 185 for the air preheater. The value of other pre-assigned parameters are given in Appendix I.

The optimization problem is posed in the mathematical programming form as
Minimize \( P = - (C_A - C_V) \)

Subject to

\[
\begin{align*}
0.5 & \times 50 \\
10640 & \ m_a \ 381,820 \\
0.9 & \ W \ 2.7
\end{align*}
\]

The optimum solution of the problem for maximum profit is obtained after transforming it to unconstrained problem and using the univariate method of optimization, a first order sequential search technique. In this method the optimal position is searched in each design variable direction one by one in sequence. Pre-fixed steps are taken in the direction under search till the objective function shows a favourable change. When the optimal position is reached, the direction of search is changed to the next one. This continues until there is no improvement in any direction. The process is carried on with gradually reducing steps till termination criteria is satisfied. The search ends at this point giving the local optimal value.

The computer program consists of the: (i) Main Program (ii) Minimization sub-routine and (iii) objective function sub-program. The objective function sub-program calculates the value of penalty function \( P_1 \). Minimization sub-routine minimizes the value of objective function and transforms it to the main program. The flow charts for the minimization program is given in Appendix III.

**TABLE 1.** Annual cost, profit and values of \( \omega_1, \omega_2, \omega \) and \( t \) at different values of mass of air flow and drier width when reduction in moisture content = 42%, \( C_c = 180 \).

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>( m_a ) Kg/hr</th>
<th>M.</th>
<th>( \omega_1 )</th>
<th>( \omega_2 )</th>
<th>( \omega )</th>
<th>( V ) m/s</th>
<th>( m )</th>
<th>( C_A ) Rupees</th>
<th>Profit Rupees</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>99,100</td>
<td>0.9</td>
<td>145.5</td>
<td>64.8</td>
<td>30.3</td>
<td>1198.6</td>
<td>1198.6</td>
<td>45,862</td>
<td>1,78,000</td>
</tr>
<tr>
<td></td>
<td>1.8</td>
<td>145.5</td>
<td>64.8</td>
<td>7.6</td>
<td>1816.7</td>
<td>129,010</td>
<td>129,010</td>
<td>94,943</td>
<td>1,90,000</td>
</tr>
<tr>
<td></td>
<td>2.7</td>
<td>145.5</td>
<td>54.8</td>
<td>3.4</td>
<td>2317.1</td>
<td>2,42,300</td>
<td>2,42,300</td>
<td>18,361</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>190,000</td>
<td>0.9</td>
<td>137.1</td>
<td>43.3</td>
<td>56.1</td>
<td>828.4</td>
<td>828.4</td>
<td>33,484</td>
<td>1,90,470</td>
</tr>
<tr>
<td></td>
<td>1.8</td>
<td>137.1</td>
<td>43.4</td>
<td>14.0</td>
<td>1255.6</td>
<td>99,948</td>
<td>99,948</td>
<td>1,33,000</td>
<td></td>
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<tr>
<td></td>
<td>2.7</td>
<td>137.1</td>
<td>43.4</td>
<td>6.2</td>
<td>1601.4</td>
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<td>1,69,250</td>
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<tr>
<td>3</td>
<td>280,910</td>
<td>0.9</td>
<td>133.8</td>
<td>38.5</td>
<td>81.7</td>
<td>661.2</td>
<td>661.2</td>
<td>27,874</td>
<td>1,96,080</td>
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<td></td>
<td>1.8</td>
<td>133.8</td>
<td>38.5</td>
<td>20.4</td>
<td>1002.1</td>
<td>73,747</td>
<td>73,747</td>
<td>150,200</td>
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<tr>
<td></td>
<td>2.7</td>
<td>133.8</td>
<td>38.5</td>
<td>9.1</td>
<td>1278.2</td>
<td>1,36,260</td>
<td>1,36,260</td>
<td>87,883</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>371,820</td>
<td>0.9</td>
<td>132.1</td>
<td>35.9</td>
<td>196.5</td>
<td>561.8</td>
<td>561.8</td>
<td>24,526</td>
<td>1,99,420</td>
</tr>
<tr>
<td></td>
<td>1.8</td>
<td>132.1</td>
<td>35.9</td>
<td>26.8</td>
<td>851.5</td>
<td>63,498</td>
<td>63,498</td>
<td>1,60,450</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.7</td>
<td>132.1</td>
<td>35.9</td>
<td>11.9</td>
<td>1086.1</td>
<td>1,16,600</td>
<td>1,16,600</td>
<td>1,07,340</td>
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</table>
RESULTS AND DISCUSSIONS

A representative set of results obtained in the range of investigation are given in Tables 1 to 3.

TABLE 2. Optimal profit at different air heater cost-parameter and corresponding values of design variables; drier length = 0.9 m.

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Cc</th>
<th>X</th>
<th>( \text{m}_a )</th>
<th>W</th>
<th>Profit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>120</td>
<td>47.49</td>
<td>3,71,820</td>
<td>0.9</td>
<td>1,98,125</td>
</tr>
<tr>
<td>2.</td>
<td>180</td>
<td>47.39</td>
<td>3,71,820</td>
<td>0.9</td>
<td>1,98,946</td>
</tr>
<tr>
<td>3.</td>
<td>210</td>
<td>47.39</td>
<td>3,71,820</td>
<td>0.9</td>
<td>1,99,626</td>
</tr>
<tr>
<td>4.</td>
<td>240</td>
<td>47.39</td>
<td>2,71,820</td>
<td>0.9</td>
<td>2,00,196</td>
</tr>
</tbody>
</table>

TABLE 3. Optimal profit at different air-heater cost parameter and corresponding values of design variables; drier length = 1.06 m.

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Cc</th>
<th>X</th>
<th>( \text{m}_a )</th>
<th>W</th>
<th>Profit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>120</td>
<td>46.89</td>
<td>3,71,820</td>
<td>1.06</td>
<td>1,92,583</td>
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<tr>
<td>2.</td>
<td>150</td>
<td>46.89</td>
<td>3,71,820</td>
<td>1.06</td>
<td>1,93,396</td>
</tr>
<tr>
<td>3.</td>
<td>180</td>
<td>46.89</td>
<td>3,71,820</td>
<td>1.06</td>
<td>1,94,066</td>
</tr>
<tr>
<td>4.</td>
<td>210</td>
<td>46.89</td>
<td>3,71,820</td>
<td>1.06</td>
<td>1,94,626</td>
</tr>
<tr>
<td>5.</td>
<td>240</td>
<td>46.89</td>
<td>3,71,820</td>
<td>1.06</td>
<td>1,95,099</td>
</tr>
</tbody>
</table>

The relation between Annual Profit and variation of length of drier with the percentage of moisture reduction is shown in Fig. 2.

The annual profit increases with increase in the reduction of moisture content linearly till 40%. Thereafter it increases rapidly and attains a maximum of about 47%. The length of drier increases non-linearly with the increase of the reduction of bagasse moisture content. The increase is more significant in the range of 35% onwards tending to infinity at 50% moisture reduction.

The relation between annual profit, outlet temperature of the flue gases, velocity of air and length of drier with the mass flow of air are shown in Figs. 3 & 4.

Annual profit increases non-linearly with the increase in mass flow attaining a maximum of about 371,820 kg/hr after which it has a tendency to fall down slightly. Outlet temperature of flue gases drops down non-linearly with its concavity.
upwards from around 388°K to 372°K when the mass flow of air increases from 99,100 kg/hr to 371,820 kg/hr. The length of drier decreases non-linearly from around 270 m to around 160 m when the mass flow of air increases from 99,100 kg/hr to 371,820 kg/hr. Thereafter, with further increase in mass flow of air, the length of the drier remains almost unchanged. The velocity of air increases linearly with increase in mass flow of air.
The variation of profit, length of drier and velocity of air with the width of drier is given in Fig. 5.

Annual profit increases almost linearly whereas velocity of air decreases non-linearly and the length of drier increases with the increase of width of drier non-linearly.

The annual cost at optimal point decreases non-linearly with the increase in cost parameter $C_c$ and the optimal profit increases but with very small increments in comparison to annual profit. During the range of study of the values of $C_c$, the optimal profit could be assumed to vary linearly with the increase in the value of $C_c$.

CONCLUSIONS

A bagasse drying plant using the heat of the flue gases has been designed. The nature of variation of important outputs like the temperature of outgoing flue gases, the velocity of air, the length of drier and the annual profit, with that variation of percentage of moisture removed, the mass of air flow, the width of drier and the air heater cost parameter have been studied.

Considering its cost and other operational implications, the operation of the drying plant has been optimized with the help of digital computer to give the maximum profit. It has been found out that when 47.4% of moisture is removed and 371,826 kg/hr of air is supplied and the drier width is 0.9 m, maximum profit is attained.

The optimum profit increases with the increase in the value of air heater cost parameter, but, the effect being small gives the designer the liberty to use any type of construction.

APPENDIX – I

NOMENCLATURE

$A_{a1}$ Heat Transfer area in the air preheater; sq m
$A_{a2}$ Heat Transfer area in the drying plant airheater; sq m
$A_d$ Area of drier; sq m
$C$ Cost of steel; Rupees/kg
$C_a$ Annual operating cost including depreciation; Rupees
$C_v$ Annual Saving achieved; Rupees
FIGURE 3. Effect of mass flow of air on outlet temp of flue gases and profit.
Figure 4. Effect of mass flow of air on length of duct and velocity of air.

Mass Flow of Air (kg/hr)
0  37.1  800

Velocity of Air (m/s)
0  40  60

Length of Duct (meters)
0  100  200

Cost of motor used for driving the conveyor, $C_m$
Incremental cost per unit area, $C_l$, $\text{Rs/} \text{m}^2$
Cost of pipeline, $C_p$, $\text{Rs/} \text{kg}$
Non-dimensional cost parameter for air preheater, $C_c$

Factory Engineering
2024
Specific heat of hot gases

Diffusion coefficient

Characteristic Dimension

Density of steel; Kg/cu m³

Life of equipment; years

Net profit; Rupees

Convective heat transfer co-efficient

Mass transfer parameter; meter/second

Conductivity

Latent heat of vaporization of water

Length of drier; m

Index of proportion of air flow

Rate of mass flow of air; kg/hr

Mass transfer rate; kg/Sq m/hr

Net Calorific Value

Number of days the plant is kept under operation in one year.

Weight of flue gases produced per unit weight of bagasse; kg/kg of bagasse

Partial pressure of water vapor at media temperature; kg/sq m

Saturation pressure of water vapor at bagasse temperature; kg/sq m

Air pressure; Kg/sq m

Heat Transfer in the air preheater

Heat Transfer in the air heater

Gas constant of air

Gas constant of moist air
\( R_e \) Percentage of the cost due to recurring expenses

\( R_e \) Reynolds number

\( S \) Specific heat of air

\( x \) Percentage reduction in moisture content

\( W \) Width of drier; m

\( t \) Plate thickness of conveyor; m

\( t_i \) Plate thickness of Chamber; m

\( t'_{ia} \) Flue gas temperature at the inlet of air preheater; \( ^{0}K \)

\( t'_{oa} \) Flue gas temperature at the outlet of air preheater; \( ^{0}K \)

\( t'_{oa_2} \) Flue gas temperature at the outlet of air heater; \( ^{0}K \)

APPENDIX II

PRE-ASSIGNED PARAMETERS

Maximum weight of bagasse available/hr \( W_m = 7400 \) kgs/hr

Latent heat of vaporization \( L = 600 \) CHU

Cost of bagasse \( C_g = \) Rs.60/- per tonne

Life of equipment \( E_1 = 20 \) years

Maintenance and other Miscellaneous cost as percentage of initial cost \( R_c = 5\% \)

Thickness of conveyor plate \( t = 1.6 \) mm

Thickness of chamber cover plate \( t_i = 3.2 \) mm

Cost of steel \( c = \) Rs.3.30 per Kg

Density of steel \( d = 0.008 \times 10^{-6} \) kg/mm\(^2\)

Cost of motor \( c_m = \) Rs. 15,000/-

Cost of two blowers \( c_B = \) Rs. 14,000/-

Gas constant of moisture \( R_1 = 47 \) mkg/kg\(^0\)C

Absolute air temperature \( T_A = 300^{0}K \)
Specific heat of air \( S = 0.24 \)

Diffusion coefficient \( D = 4.24 \times 10^{-4} \)

Partial pressure of water vapor in the air \( P_{ls} = 0.008 \text{ kg/cm}^2 \)

Partial pressure of water vapor at bagasse surface \( P_{lw} = 0.017 \text{ kg/cm}^2 \)

Gas constant of air \( R = 29.3 \text{ mkg/kg°C} \)

Inlet flue gas temperature \( t'_{ia_2} = 250°C \)

APPENDIX — III

FLOW CHART
DISEÑO OPTIMO DE UNA PLANTA PARA SECAR BAGAZO POR EVAPORACION PARA INGENIO

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RESUMEN

Ha sido diseñada una planta de secado empleando los gases de combustión para calentar el aire. El bagazo es transportado a través de un secadero que a su vez, pierde humedad por el calienta de contra corriente. Los únicos equipos requeridos son un calentador de aire, dos ventiladores, un secadero y los relativos ductos. El trabajo tecnico describe el procedimiento de, como diseñar el calentador de aire y el secador, calcula la economía para un porcentaje dado de disminución de humedad en la bagazo y especifica la reducción de temperatura en los gases de combustión.

Se describe la optimización en el método del diseño de la planta. Se estudia el efecto del tamaño del secador, la temperatura de los gases de combustión saliendo del secador y la economía de la velocidad del aire. Se ha encontrado que las máximas economías son para un valor específico de reducción de humedad, la rata de flujo de aire y el ancho del secador, que son estudiadas en este caso.