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Importance of energy management in desiccated coconut industry

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ABSTRACT

Energy flow rates across commonly used desiccators and associated heat transfer equipment are quantified. It is seen that approximately 726 percent excess heat energy over the actual requirement is presently used for drying in desiccators. Approximately 49 percent of heat energy is exhausted to the atmosphere through the chimney and approximately 23 percent along with the desiccator exhaust gases. Approximately 40 percent of energy could be saved by introducing recirculation techniques of heat recovery. This saving represents about 83.2 million kwh of energy for 1981 alone, which is an equivalent of 4.5 percent of the total electrical energy generated in Sri Lanka in 1981.

INTRODUCTION

The commonly used process of manufacture of desiccated coconut is a batchwise process. Two types of drying equipment presently in operation in Sri Lanka, namely, desiccators which are loaded and unloaded manually and dryers with a semi automatic arrangement for loading and unloading. These are designed for indirect heating from flue gases obtained by either combustion of firewood or oil firing. The ambient air at approximately 30°C is sent through a heat exchanger. Combustion gases leaving the furnace enters the heat exchanger as the heating medium. Indirect heat transfer from combustion gases to the desiccator air increases the temperature of the desiccator air. Used combustion gases leave the heat exchanger via a chimney as a flue gas. The average drying temperature inside the desiccator is around 88°C (190°F). Under these conditions the drying process takes approximately 45 minutes. The normal inlet temperature of air is approximately 130°C (266°F) and the outlet temperature approximately 88°C (190°F).

In 1982 seventy five factories were engaged in the manufacture of desiccated coconut in Sri Lanka. The overall production capacity of these factories in 1982 was around 60,000 metric tonnes of desiccated coconut estimated on the basis of an 8-hours working day and 200 working days per year (Ministry of Coconut Industries, 1982).

The average consumption of firewood per tonne of desiccated coconut is approximatly 1.05 tonnes (3.5 yards) (Nattandiya Coconut Producers Co-op Society Ltd., 1983) representing in overall requirement of about 63,000 tonnes of firewood per year.

The following section presents an energy analysis of the production process.

ENERGY ANALYSIS

Excess Energy

The average moisture content of shredded kernel prior to desiccation is 43 percent on wet basis. The average moisture content to which the shredded kernel is dried within the desiccator is 3 percent on a wet basis. The average temperature within the desiccator is 88° C. The theoretical heat requirement for heating shredded kernel from an ambient temperature of 30°C to 88°C and for the removal of moisture from 43 percent to 3 percent is 2.227×10^6 kJ tonne of desiccated coconut. (See Appendix 1).

The process of drying of desiccated coconut usually required approximately 1.05 tonnes of firewood per tonne of desiccated coconut. The average moisture content of firewood in the western coastel belt of Sri Lanka between Chilaw and Colombo where the desiccated coconut mills are usually situated was found to be 13.77 percent on dry basis. The variation of calorific value of firewood with the moisture content is shown in Fig. 1. The nett calorific value of firewood at 13.77 percent moisture content is 17,235 kJ/kg (7420 Btu/lb). The actual heat generated in the process of drying one tonne of desiccated coconut is therefore 18.405×10^6 kJ.

The energy generated in excess of the requirement for drying one tonne of desiccated coconut is therefore 16.178×10^6 kJ. This represents an energy generation of 726.45 percent in excess of the theoretical requirement. (See Appendix 2)

APPROPRIATION ENERGIES

Energy Balance Across Desiccator

The average drying temperature within a desiccator is 88° C. If complete mixing is assumed within a desiccator, the exit air stream from the desiccator may be assumed to leave at a temperature of 88° C. The average flow rate of air through adesiccatoris estimated to be 7400 kg air per hour (See Appendix 3). The rate of moisture removal by this stream is 77.23 kg/hr. Estimated temperature of air inlet to the desiccator is 130.0° C (See Appendix 3). Taking the datum as the ambient conditions for energy measurements, the energy flow rates per tonne of desiccated coconut at the inlet and exit of the desiccator are 67.67×10^5 kJ respectively.

The accounted energy loss from the desiccator is 2.28 x 10^5 kJ per tonne of desiccated coconut.

Energy Balance Across the Furnace

Ambient air of zero energy flow rate (datum at ambient conditions) enters the combustion chamber in which 184.05 x 10^5 kJ of heat per tonne of desiccated coconut is generated by combustion of firewood (Appendix 2). If 10 percent of this is assumed to be lost to the atmosphere due to radiation and other effects, this amounts to 18.405 x 10^5 kJ per tonne of desiccated coconut. Heat balance across the furnace gives a flow rate of 165.645 x 10^5 kJ of energy per tonne of desiccated coconut being carried away by combustion gases from the furnace to the heat exchanger.

The energy balance across the furnace is shown in Fig. 2.

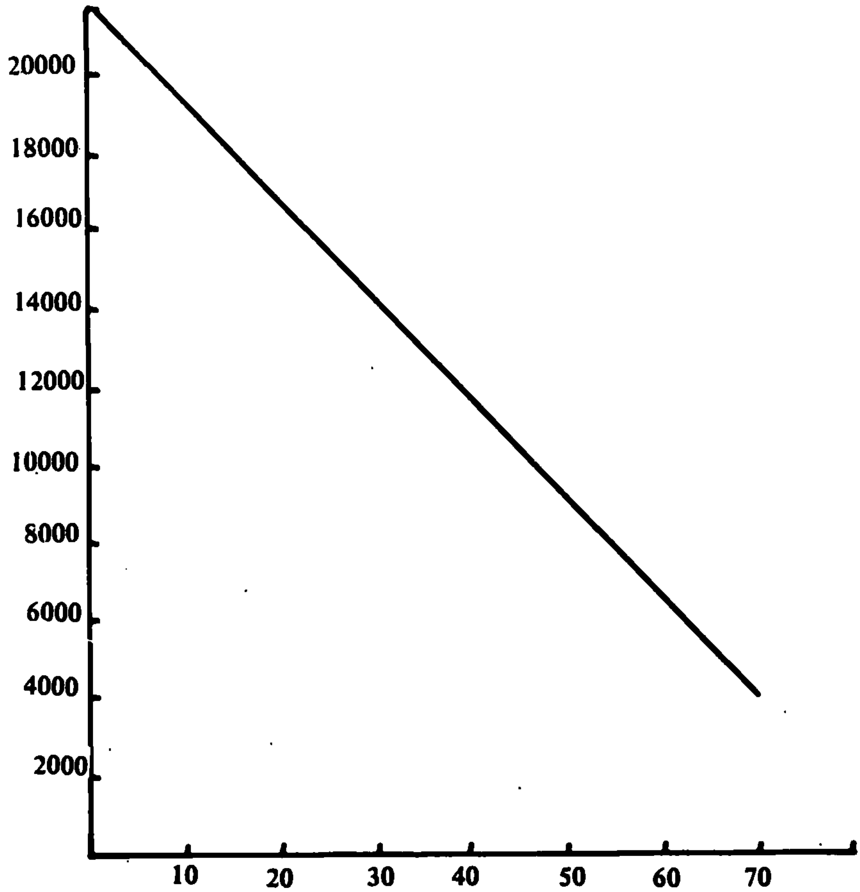

Fig 1. Net calorific value of wood as a function of moisture content (dry basis)

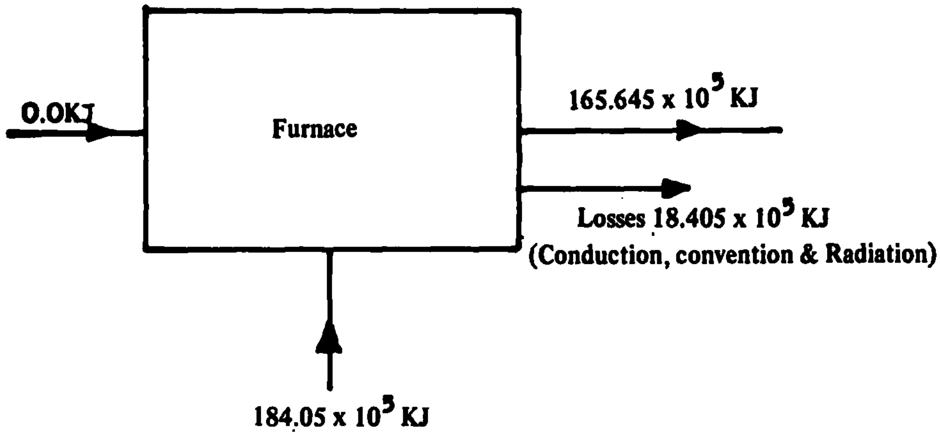

Fig 2. Energy balance across furnace (basis : 1 tonne desiccated coconut & 30°C as datum)

Energy BalanceAcross the Heat Exchanger

The air flow into the desiccator enters the heat exchanger at embient conditions, representing a zero energy flow rate. The air stream is heated to a temperature of 130.0° C of energy flow rate 67.67 x 10^5 kJ per tonne of desiccated coconut.

If 10 percent of energy is assumed to be lost to the atmosphere, this represents 6.767 x 10^5 kJ per tonne of desiccated coconut. The combustion gases entering the heat exchanger is of an energy content 165.645 x 10^5 kJ per tonne of desiccated coconut. A heat balance across the heat exchanger reveals that 91.208 x 10^5 kJ per tonne of desiccated coconut is lost to the atmosphere through the chimney.

Discussion

Fig 3 is a heat balance chart for the process of desiccated coconut manufacture showing the energy flow rates entering and leaving the furnace, heat exchanger and the desiccator. It can be seen that 49 percent of energy generated by firewood combustion escape through the chimney to the atmosphere. 23.42 percent of energy generated by combustion is seen to escape through the exhaust from the desiccator. This indicates 63.72 percent of the useful energy in the form of hot air entering the desiccator is lost via exhaust from the desiccator. It has been shown (Fernando, W.J.N. and Thangavel T., 1983) that about 40 percent of the energy lost could be saved by introducing recirculation techniques to the manufacturing process of desiccated coconut. This represents saving of 83.2 million kwh of energy for a production of 40,685 tonnes of desiccated coconut which was the output in 1981. This also represents an energy equivalent of approximately 4.5 percent of power generated by the Ceylon Electricity Board in that year. In terms of firewood the saving represents approximately 17,087 tonnes of firewood.

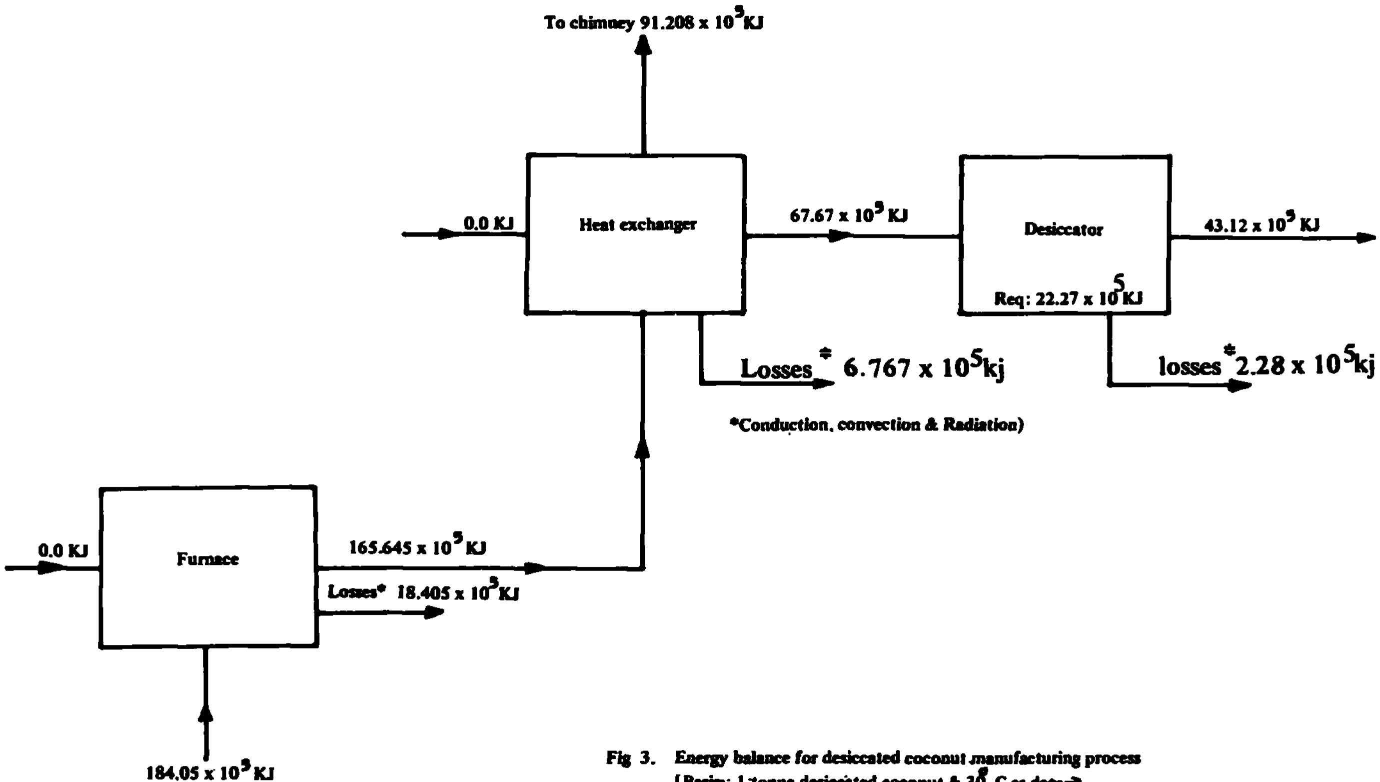

Fig 3. Energy balance for desiccated coconut manufacturing process
[Basis: 1 tonne desiccated coconut & 30° C as datum]

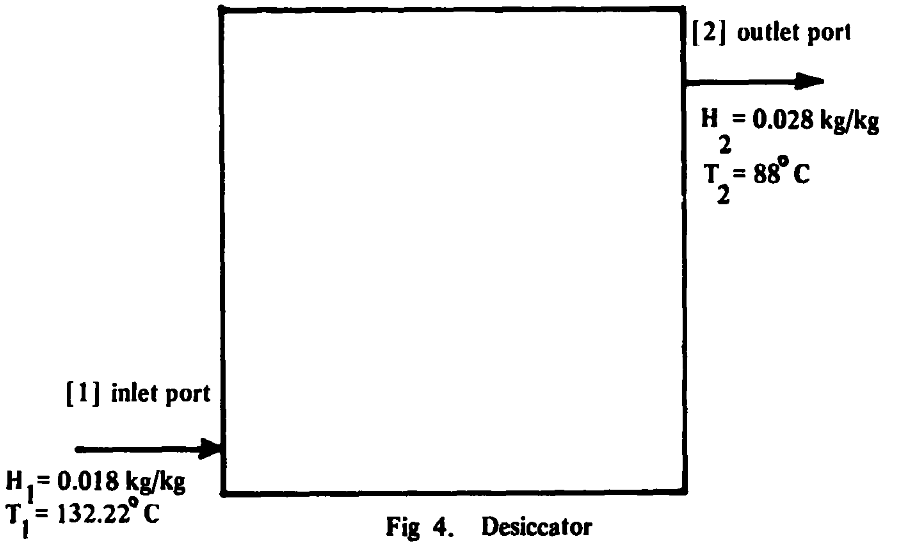

Fig 4. Desiccator

The whole desiccator process generates approximately 726 percent of energy in excess of the actual requirement for drying. Annually this amounts to a wastage of 269.63 million kwh of energy for a production rate of 60,000 tonnes of desiccated coconut which is the full capacity of the industry. This amounts to an equivalent of 14.40 percent of power generated by the Ceylon Electricity Board in 1981. It is evident, from this analysis, that the management of energy in the desiccated coconut industry of Sri Lanka is not satisfactory. If the large amount of heat which is now, is properly utilized the profits from this industry would rise appreciably and the contribution to the national energy saving efforts would be substantial.

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Appendix 1

Energy Requirement : (Basis 1 tonne of desiccated coconut)

Moisture content of shredded coconut before drying	=	43% wet basis
Moisture content of desiccated coconut	=	3% wet basis
The amount of moisture removed per tonne of desiccated coconut	=	701.8 kg

The shredded coconut is to be heated from an ambient temperature of 30°C to 88°C prior to drying

Energy required for heating shredded coconut from 30°C to 88°C = Energy required for heating desiccated coconut from 30°C to 88°C + Energy required for heating balance moisture from 30°C to 88°C

Specific heat of desiccated coconut	=	1.87 KCal / kg °C (by experiment)
Heat required for heating of desiccated coconut from 30°C to 88°C	=	1000 x 1.87 x 58
	=	108,460 kCal
Heat required for heating 701.8 kg of moisture	=	701.8 x 1.0 x 58
	=	40,704.4 kCal
Heat required to evaporate moisture at 88°C	=	701.8 x 545.96
	=	383154.7 kCal
Total Heat requirement	=	(383154.7 + 40704.4 + 108460) x 4.185
	=	2.227×10^6 kJ

Appendix 2

Excess Energy

The average moisture content of firewood on the western coast of Sri Lanka where the desiccated coconut mills are usually situated	= 13.77% dry basis
The variation of calorific value of firewood vs moisture content obtained experimentally is shown in Fig. 1.	
The nett calorific value of firewood at 13.77% moisture content	= 17,235 kJ/kg (7420 Btu/lb)
Firewood requirement per tonne of desiccated coconut	= 21 cwt Approximately 1.05 tonnes
The heat generated to dry one tonne of desiccated coconut	= 7420 x 21 x 112 x 1.0546 = 18.405×10^6 kJ
The excess energy generated to dry one tonne of desiccated coconut	= $(18.405 - 2.227) \times 10^6$ kJ = 16.178×10^6 kJ
The excess energy generated as percentage of requirement.	= $\frac{16.178}{2.227} \times 100\%$ = 726.45%

Appendix 3

Heat Analysis across Desiccator

The quantity of wet shredded coconut which could be spread on one tray = 50 lbs

The quantity of desiccated coconut produced per = $50 \times \frac{57}{100} \times \frac{100}{97}$

= 29.38 lbs

A double desiccator contains six trays

Total desiccated coconut per batch = 29.38 x 6 x 0.454

= 80.03 kg.

To manufacture one tonne of desiccated coconut

the number of batches required = $\frac{1000}{80.03}$

= 12.45 Batches

The operating time of desiccator for the production one tonne of desiccated coconut = 12.45 x 45

= 562.5 mts

= 9.375 hr

The head developed by the fan = 500 ft

Motor Horsepower = 7.5

Fan efficiency = 0.55

Air flow rate through the desiccator

(Perry, 1963) = $\frac{(7.5 \times 0.55 \times 550 \times 3600 \times 0.453)}{500}$

= 7400 kg/hr

Measurements taken at the factory confirms the above value of air flow rate

Moisture removal per hour = 724 kg/ tonne of desiccated coconut

$$= \frac{724}{9.375}$$

= 77.23 kg/hr

The average conditions of atmosphere represents an air humidity of 0.18 kg/kg dry air Fig. 4 represents the inlet and outlet ports of air to and from a desiccator respectively.

Let H_1 and H_2 be the humidities of air at entry and exit to desiccator, respectively.

H_1 = 0.018 kg/kg

Evaporation rate in the desiccator = 77.23 kg/hr

Air flow rate through the desiccator = 7400 kg/hr

$$\therefore H_2 = 0.018 + \frac{77.23}{7400}$$

= 0.028 kg/kg dry air

The specific enthalpy of air at port (2) = 77.7 Btu/lb dry air

Assuming 10% of the heat is lost to the atmosphere

Air heat supply to the desiccator = $2.227 \times 10^6 \times 1.1$ kJ/tonne

$$= \frac{1.1 \times 2.227 \times 10^6}{7400 \times 9.375}$$

= 35.31 kJ/kg

= 15.20 Btu/lb dry air

Enthalpy at port (1) = 77.7 + 15.20

= 92.9 Btu/lb

Humidity at port (1) = 0.018 kg/kg

By reference to standard psychrometric charts inlet temperature = 130 °C (266 F)

Assuming ambient conditions at 30 °C

represent the datum for energy, Energy flow rate at port (2) per tonne of desiccated coconut = Flow rate of air x h_2

-Flow rate of air x h_x

= 7400 x (77.7-51.0) x 9.375 Btu/Tonne

= 43.12×10^5 kJ/tonne

(where h_x is the enthalpy of air and associated water vapour at 30 °C)

Energy flow rate at port (1) per tonne of desiccated coconut = $\frac{7400}{0.453}$ x (92.9-51.0) x 9.375 Btu/tonne

= 67.67 kJ/tonne

Theoretical heat loss from the desiccator per tonne of desiccated coconut = Enthalpy of entering stream - Enthalpy of gas stream leaving - (Heat required for initial heating up of 1 tonne desiccated coconut and associated moisture + latent heat of evaporation of moisture associated with 1 tonne of desiccated coconut) = $(67.67\text{-}43.12\text{-}22.27) \times 10^5$ kJ/tonne

= 2.28×10^5 kJ/tonne

Energy loss to the atmosphere via exhaust air of desiccator as a % of requirement = $\frac{43.12}{22.27} \times 100\,\%$

= 193.62 %