CHAPTER 5

CALCULATIONS

In the calculation process of total energy provided by heat source, it is assumed that heating rate is constant during the entire operation of the dryer.

5.1 Energy input from the saw dust burner used.

Table 14: Data to be used to calculate the energy input rate from the saw dust burner

Data	**Value**	**Reference**
m (kg)	4	Table 8
c ($jkg^{-1}\,^0C^{-1}$)	4200	
θ (jkg^{-1})	63	Table 7
λ (j/kg)	2,260	

Total energy input (E) = Energy required to vaporized 4 kg of water at 90 ^0C

$= m C_w \theta + \lambda m$

Where,

m = Saw dust consumption (m)

C_w = Heat capacity of water ($j\ kg^{-1}\,^0C^{-1}$)

θ = Temperature rise (^0C)

λ = Latent heat of evaporated water ($j\ kg^{-1}$)

Therefore, $E = (4\ kg \times 4200\ j\ kg^{-1}\,^0C^{-1} \times (90-27)\,^0C) + (2260\ j/kg \times 4\ kg)$

$= 1058400\ j + 9040\ j$

$= 1067440\ j$

Duration of saw dust burner used = 96 min

Therefore, energy releasing rate = 1067440 j / (96 min)

= **11119.17 j / min**

Therefore, total energy taken from the dryer in the drying period of 1250 min

= **13898963 j**

5.2 Total energy requirement to dry sheet rubber in SS dryer.

To calculate the energy requirement of the SS dryer, two methods were used. One method is used by applying mCθ equation for the entire system. To do these mean values of temperature variations for each and every time durations (APPENDIX 1) and average change of water content in the dried rubber sheets were used (E1).

In the second method of calculation mCθ equation was calculate for each and every time durations and finally the obtained values were summed up (Calculation Table 1) (E2).

- Total energy requirement (E1)= (Energy used for the drying of rubber sheets + Utilized energy for evaporation of moisture + Latent heat of evaporation of water (vaporization))

  $= m_R C_R \theta + m_W C_W \theta + \lambda m_W$

Where,

- m_R = Dry weight of rubber
- C_R = Specific heat capacity of rubber (1700 j kg^{-1} $^0C^{-1}$)
- θ = mean temperature of water
- m_W = mean weight of water
- C_W = specific heat capacity of water (4200 j kg^{-1} $^0C^{-1}$)
- λ = latent heat of water (2260 j /kg)

Table 15: Data to be used to calculate the Total energy requirement to dry sheet rubber in SS dryer.

Data	Value	Reference
m_R (kg)	47.35	Table 9
c_R ($jkg^{-1}\,{}^0C^{-1}$)	1700	-
θ (^0C)	(76.3-30.4)	APPENDIX 1
m_w	27.65	
λ (j/kg)	2260	

Therefore, E1 = 1955340 +5330367.0 + 41442.8

= **7327149.8j**

5.3 Drying efficiency Of SS dryer.

$$\text{Drying efficiency} = \frac{\text{Utilized energy for evaporation of moisture + Energy required for the drying of rubber sheets + Energy required for heat up sheets from ambient temperature to final temperature.}}{\text{Total energy Input/kg of Rubber}}$$

$$\text{Drying efficiency} = \frac{\text{Total energy utilized for drying of rubber x100}}{\text{Total energy Input rate}}$$

$$= \frac{E1 \times 100.}{E}$$

$$\text{Drying efficiency} = \frac{7327149.8j.}{13898963\ j} \times 100$$

$$= \underline{\mathbf{52.7\%}}$$

Calculations present in Calculation Table 1. give the total energy used (E2) by the system by means of time duration.

The total value of the energy from calculation table 1 = 7047414.5 j

$$\text{Drying efficiency} = \frac{E2 \times 100.}{E}$$

$$\text{Therefore the efficiency} = \frac{7047414.5\ j}{13898963\ j} \times 100$$

$$= \underline{\mathbf{50.7\ \%}}$$

5.4 Dry rubber wood consumption for drying of sheet rubber in the Conventional Smoke House.

Average weight of fire wood consumption = 52.57 kg

Moisture content of firewood used = 45.51 % (from Table 12)

Average dry weight of firewood = 52.57 kg X 54.49/100

= 28.6 kg.

Average weight of rubber dried = 78.85 kg (Average value from table 10)

Final moisture content of rubber sheets = 2.83 % (table 12)

Dry rubber content of dried rubber sheets = 78.85 kg X 97.17/100

= 76.62 kg

Therefore, rubber wood (dry) consumption for drying 1 kg rubber in the

Conventional dryer = 28.6 /76.62

= 0.373 kg

5.5 Dry rubber wood consumption for drying of sheet rubber in the SS dryer.

Average saw dust consumption = 40.0 kg

Moisture content of saw dust used = 35.23 % (from Table 12)

Average dry weight of saw dust = 40 X 64.77/100

= 26.0 kg.

Average weight of rubber dried = 47.35 kg (Table 9)

Final moisture content of rubber sheets (SS dryer) = 1.63 %

Dry rubber content of dried rubber sheet = 47.35 kg X 98.36/100

= 46.6 kg

Therefore, saw dust (dry) consumption for

drying rubber in the SS dryer = 26/46.6

= 0.558 kg of rubber dried

5.6 Comparison of firewood cost for drying of rubber.

Considering the average value of 1 kg of firewood is 7.50/= Sri Lankan Rupees

Cost of 1kg of firewood (Rs.) =7.50

Firewood cost per 1 kg of RSS drying in conventional smoke (Rs) = 0.373 X 7.5

= 2.79

In the case of saw dust burner, saw dust obtained from a saw mill is free of charge but considering the transport cost for saw dust as one rupee per kg, it can be calculated the cost of drying for SS dryer.

Saw dust cost per 1 kg of RSS drying in SS dryer = 0.558X 1.00

= 56 cents

However this value can be varied with the availability of saw dust in different part of the country. The value of a one kg of saw dust could be more in some places whereas it may be available free of charge in other places where saw mills are operated extensively. But the saw dust is the byproduct from saw mills and the use of it as an energy source is a good practice for energy conservation. Other sources of energy such as bio gases, paddy husk, pre heat treatment using sunlight would be greatly reduce the cost of production of RSS using the SS dryer.

Calculation Table 1: Calculation of $m_r c_r \theta$ (for Dry rubber content), $m_w c_w \theta$ (for water content), λmvp (Energy needed for evaporation of Water) and Total energy

Time duration	mrcrθ (for Dry rubber content)	mwcwθ(for water content)	λmvp (Energy needed for evoparation of Water)	Total energy
00:00:00-13:10:00	458003.3972	1173885.732	0	1631889.129
13:10:00-13:40:00	161465.6044	413844.4613	0	575310.0658
13:40:00-14:10:00	32603.63167	69783.497	21187.5	123574.6287
14:10:00-14:40:00	108678.7722	186674.1567	0	295352.9289
14:40:00-15:10:00	-77627.69444	-133338.6833	0	-210966.3778
15:10:00-15:20:00	65207.26333	112004.494	0	177211.7573
15:20:00-15:31:00	225120.3139	386682.1817	0	611802.4956
15:31:00-15:40:00	111783.88	144757.704	21187.5	277729.084
15:40:00-16:10:00	130414.5267	113758.988	0	244173.5147
16:10:00-16:40:00	91600.67944	79902.14633	0	171502.8258
16:40:00-17:10:00	215804.9906	157837.7897	7062.5	380705.2802
17:10:00-17:40:00	63654.70944	37587.72033	0	101242.4298
17:40:00-18:25:00	-465766.1667	-275032.1	0	-740798.2667
18:25:00-19:10:00	-52786.83222	-31170.30467	0	-83957.13689
19:10:00-19:55:00	-99363.44889	-58673.51467	0	-158036.9636
19:55:00-20:25:00	-551156.6306	-325454.6517	0	-876611.2822
20:25:00-20:40:00	821301.0072	484973.2697	0	1306274.277
20:40:00-21:45:00	332246.5322	196189.5647	0	528436.0969
21:45:00-22:45:00	931532.3333	550064.2	0	1481596.533
22:45:00-23:45:00	381928.2567	225526.322	0	607454.5787
23:45:00-0:45:00	-2344356.372	-723703.2367	14125	-3053934.609
0:45:00-1:45:00	-122651.7572	-3300.119667	0	-125951.8769
1:45:00-2:45:00	-155255.3889	-4177.366667	0	-159432.7556
2:45:00-3:45:00	-139729.85	-3759.63	0	-143489.48
3:45:00-4:45:00	-232883.0833	-6266.05	0	-239149.1333
4:45:00-6:00:00	2226362.277	59903.438	0	2286265.715
6:00:00-8:00:00	159913.0506	4302.687667	0	164215.7382
8:00:00-9:00:00	-136624.7422	-3676.082667	0	-140300.8249
9:00:00-10:00:00	-1065266.113	2222727.589	105937.5	1263398.976
total	1826060.348	5051854.202	169500	7047414.549

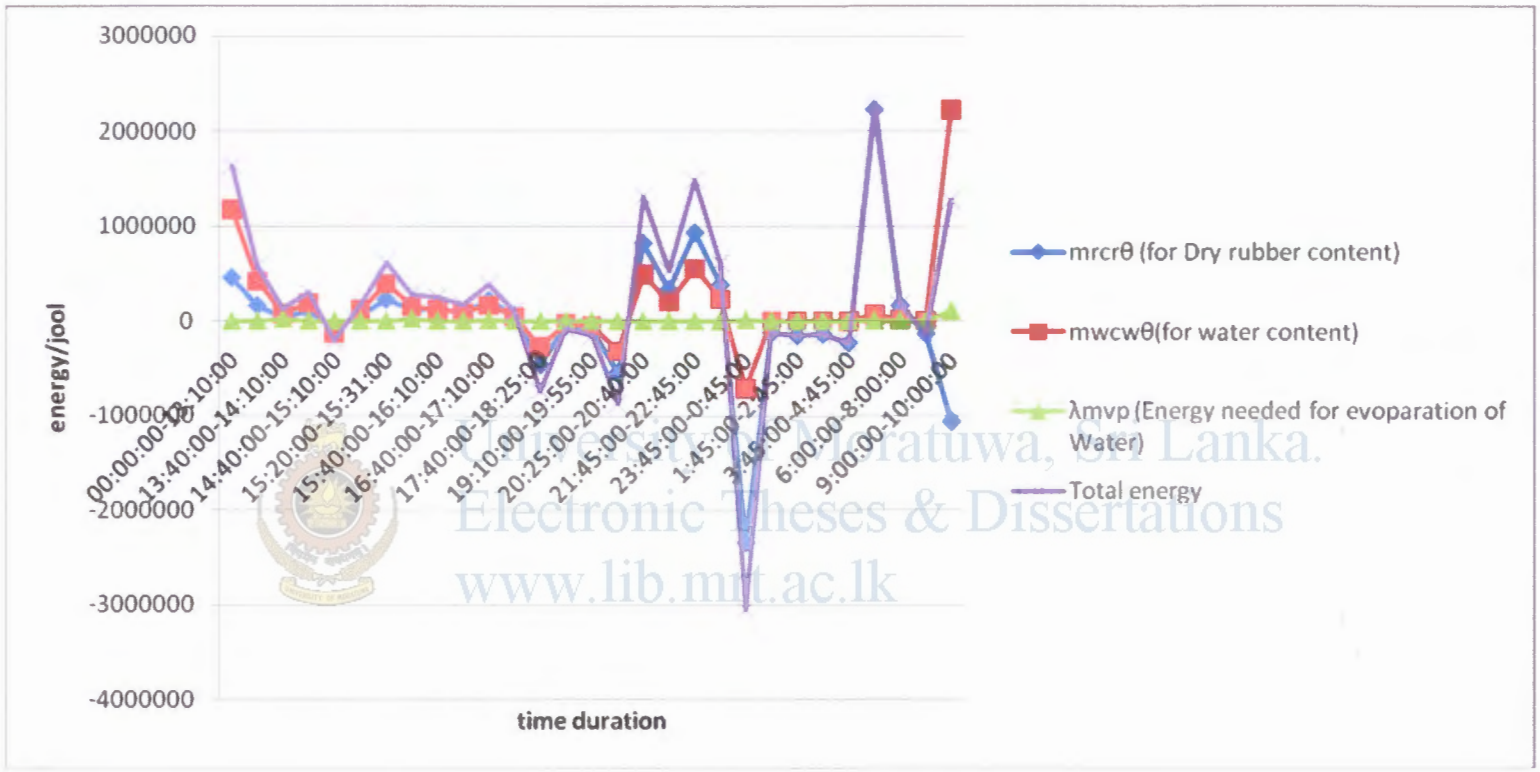
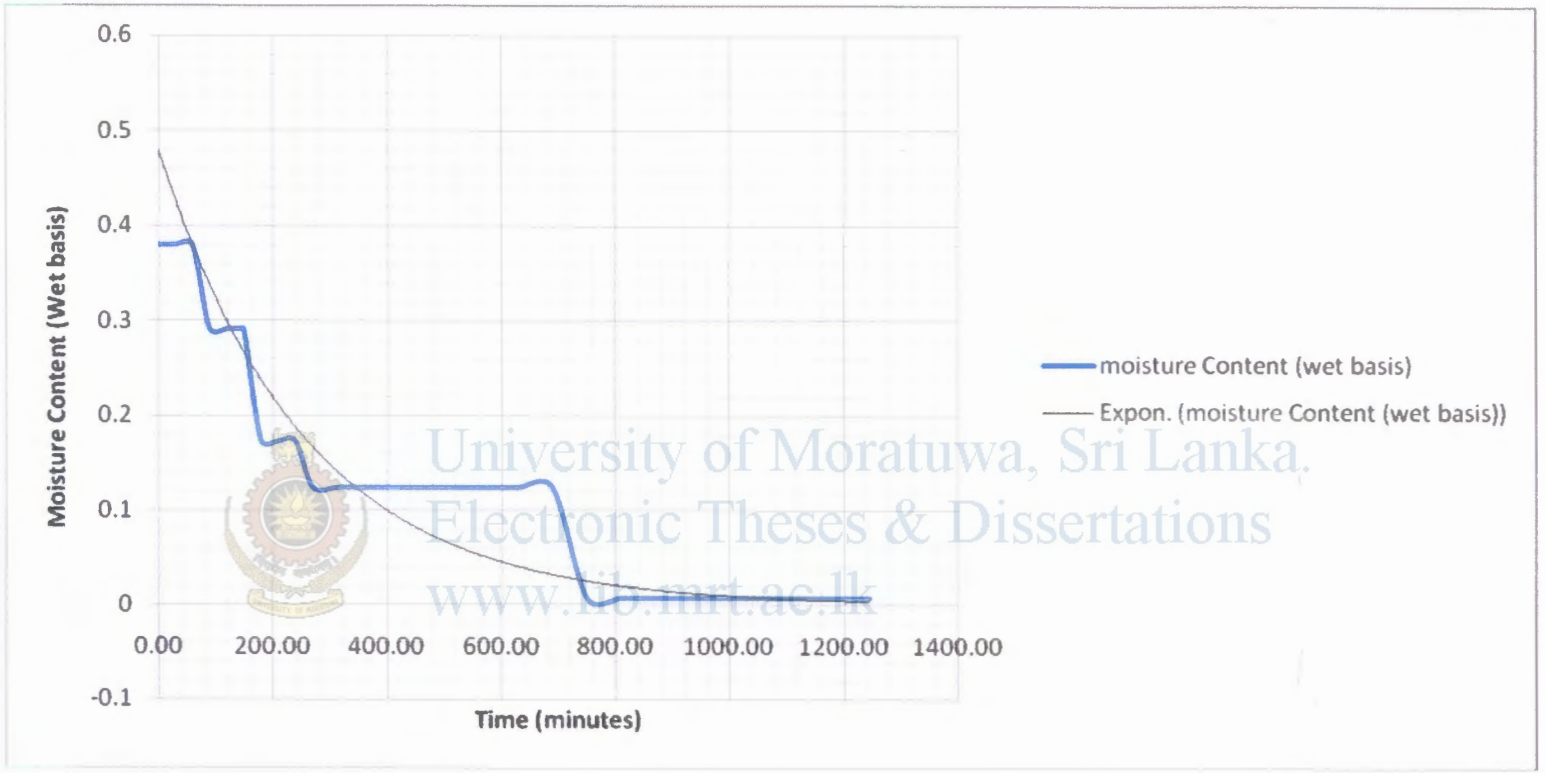


Fig 18: Energy consumption and total energy vs time

Calculation Table2: Total Moisture Content of RSS in the Dryer

Time	Moisture Content (wet basis)
0.00	0.378978444
30.00	0.378978444
60.00	0.378978444
90.00	0.290261079
120.00	0.290261079
130.00	0.290261079
141.00	0.290261079
150.00	0.290261079
180.00	0.171971259
210.00	0.171971259
240.00	0.171971259
270.00	0.123263686
315.00	0.123263686
360.00	0.123263686
405.00	0.123263686
435.00	0.123263686
450.00	0.123263686
510.00	0.123263686
570.00	0.123263686
630.00	0.123263686
690.00	0.123263686
750.00	0.006365511
810.00	0.006365511
870.00	0.006365511
930.00	0.006365511
1005.00	0.006365511
1125.00	0.006365511
1185.00	0.006365511
1245.00	0.006365511

Fig 19: Drying Curve (Changing of Moisture Content with Time)



The drying curve (Fig 19) obtained from the research work is very similar to literature data (19), so this dryer is follows the typical drying behavior of a standard dryer. But it is obtained from exponential curve because the weighing scale used to measure weight is not much sensitive.