CHAPTER THREE
MONITORING OF RUBBER SMOKING PROCESS

SUMMARY

Monitoring of rubber smoking process was carried out. The smoking room in this study had a capacity of 45 tons of rubber sheets and required heat of 20120 MJ during 116 h of operation. Only 31% of the input heat was useful. The rest was lost through conduction (57%) and ventilation (11.8%). However, energy saving measure was not recommended since financial benefit was very low compared to the overall financial scale. Water inherent in the exhaust gas was found to be 4.2 tons of which 2 tons, 1 ton and 1.2 tons could be derived from inlet air, firewood and the rubber, respectively. It is believed that dehumidification of the inlet air will significantly increase the productivity by reducing the processing time.

3.1 INTRODUCTION

Survey of rubber smoking factories resulted in the existance of two types of the smoking rooms namely ; single layer and double layer rooms. Survey data revealed that the performance of the single layer rooms is far better than the double layer rooms [6]. However, there is no solid evidence leading to a conclusion that the single layer rooms are being operated at optimum condition. Furthermore, there was a sign that a better-than-present performance can be achieved [11]. However, every characteristics of the smoking process have to be well perceived before improvement can be achieved. Monitoring of the actual smoking process is therefore vital.

3.2 MATERIALS AND METHODS

The monitoring of the rubber smoking process was conducted in an actual smoking practice at Southland Rubber Co. Ltd., Bangklum, Hat Yai, Southern Thailand. The factory consists of two rows of ten smoking rooms each. Therefore, there are four rooms that one of the side walls open to atmosphere. It is anticipated that such rooms are operating at lower energy efficiency. Hence, one of these rooms was chosen for monitoring.

Under normal operation condition, parameters measured were temperatures at various locations as depicted in Figure 3.1 (type k thermocouple and Omega HH81 digital thermometer, Omega Engineering, USA), moisture contents of inlet and exhaust air (wet bulb and dry bulb method), inlet air flow rate (calibrated vane type anemometer, Airflow Development Ltd., UK), firewood consumption and combustion products (samples were taken by a vacuum pump and analysed by a Fyrite II combustion analyser, Bacharach, USA). Data were acquired for every 30 minutes. Three experiments were carried out during 3-24 May 1991.

3.3 ENERGY ASPECT OF SMOKING PROCESS

Energy flowing into the system was determined from heating value of the firewood. Energy flowing out of the system was calculated from heat conducted through the walls and exhaust gas. The balance of energy was the sensible heat of the rubber and the room structure and latent heat of the water evaporated from the rubber. Calculations were based on 42.2% moisture content [12] and 4.1% ash content [13] of the firewood. The heating value of the firewood (rubber wood) was taken as 13,600 kJ/kg [14]. Thermal properties of materials involved were obtained from some well known sources [15,16]. Equations used in the calculation were given in Appendix A.

The basic data are described in Table 3.1 while the analyzed results are presented in Table 3.2.

Average specific firewood consumption was 54 kg/ton of rubber. The smoking process lasted about 116 hours (4.8 days). Table 3.2 revealed that only 31% of input energy was used in the rubber drying process while 57% was the loss through the four walls and 11.8% via ventilaton. Typical room temperature is illustrated in Figure 3.2 while heat lost through the room structure was characterized in Figure 3.3. Negative heat flow occurred in some period was the result of heat

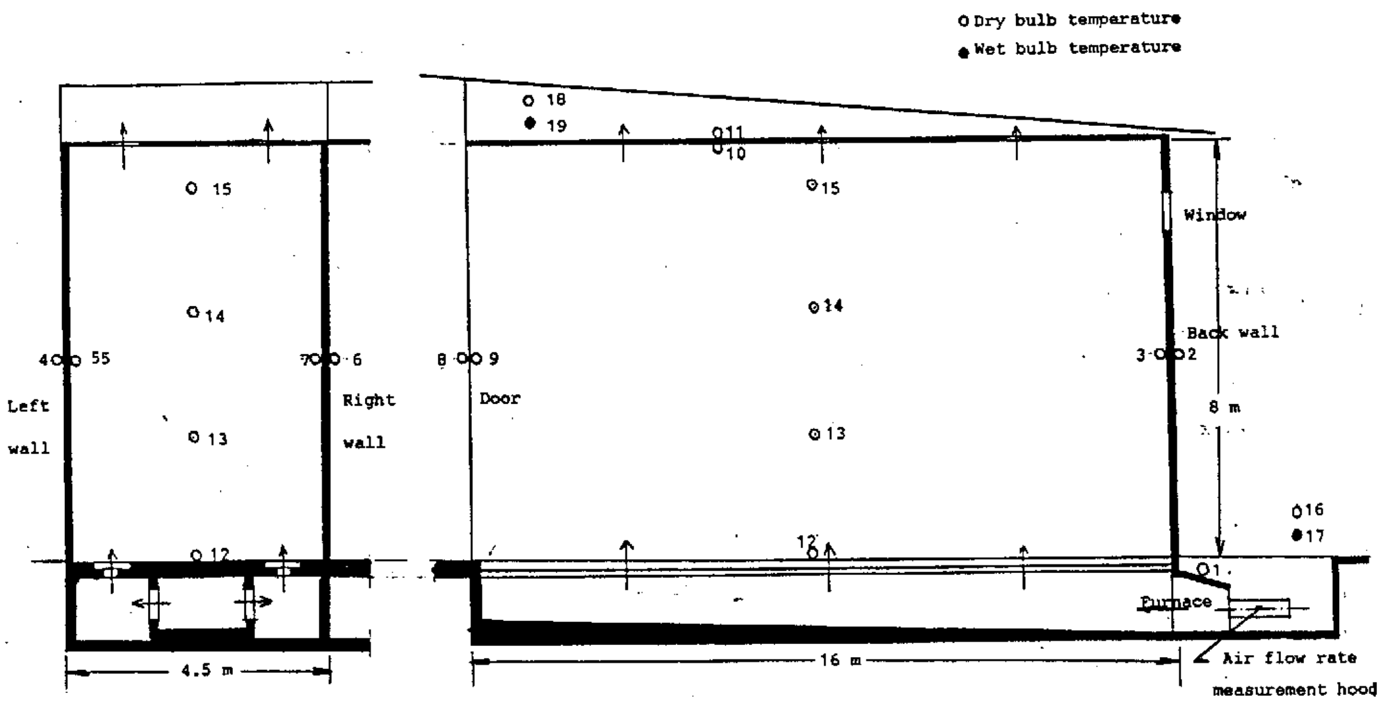

Figure 3.1 Description of the smoking room and parameters to be measured

Table 3.1 Basic Data of Experiments

Description	**Test 1**	**Test 2**	**Test 3**
D/M/Y	8-13/5/91	13-18/5/91	18-24/5/91
Smoked rubber (kg)	45,526.0	43,850.0	47,322.0
Water removed (kg)	1,312.0	1,255.6	1,091.2
Firewood (kg)	2,698.0	2,460.0	2,225.0
Smoking time (hr)	166.5	110.0	122.5

Table 3.2 Energy Analysis for the Smoking Process

Figures in brackets are %

Energy (MJ)	Test			Average
	1	2	3	
Input energy[*]	22245.5(100)	19510.0(100)	18604.5(100)	20120.0(100)
Useful energy				
-Latent heat	3082.3(13.8)	2949.3(15.1)	2560.2(13.8)	2863.9(14.2)
-Rubber sen. heat	3367.5(15.1)	3404.9(17.5)	3430.6(18.4)	3401.0(16.9)
Stored energy				
-Left wall	206.1(0.92)	141.7(0.70)	172.7(0.93)	173.5(0.86)
-Right wall	232.9(1.05)	247.2(1.3)	122.3(0.65)	200.8(1.0)
-Back wall	47.5(0.20)	21.5(0.11)	40.5(0.22)	36.5(0.18)
-Door	6.4(0.03)	2.3(0.01)	3.2(0.02)	4.0(0.02)
-Ceiling	16.5(0.07)	11.5(0.06)	11.1(0.06)	13.0(0.06)
-Floor	818.5(3.7)	851.2(4.4)	881.8(4.7)	850.5(4.2)
Energy losses				
-left wall[@]	4478.5(20.1)	7747.4(39.7)	6318.7(34.0)	6181.5(30.7)
-right wall	607.0(2.7)	852.2(4.4)	576.9(3.1)	678.7(3.4)
-back wall[@]	2638.0(11.8)	2940.5(15.1)	3385.9(18.2)	2988.1(14.8)
-door[@]	1424.0(6.4)	1546.6(7.9)	1653.9(8.9)	1541.5(7.7)
-Exhaust	2059.4(9.2)	2447.5(12.5)	2600.9(14.0)	2369.3(11.8)
Uncountable	3260.9(14.0)	-3653.8(-18.0	-3154.2(-16.9	-1182.4(-5.9)

[*] Include heat gain from the adjacent room at the beginning

[@] Walls that open to surroundings

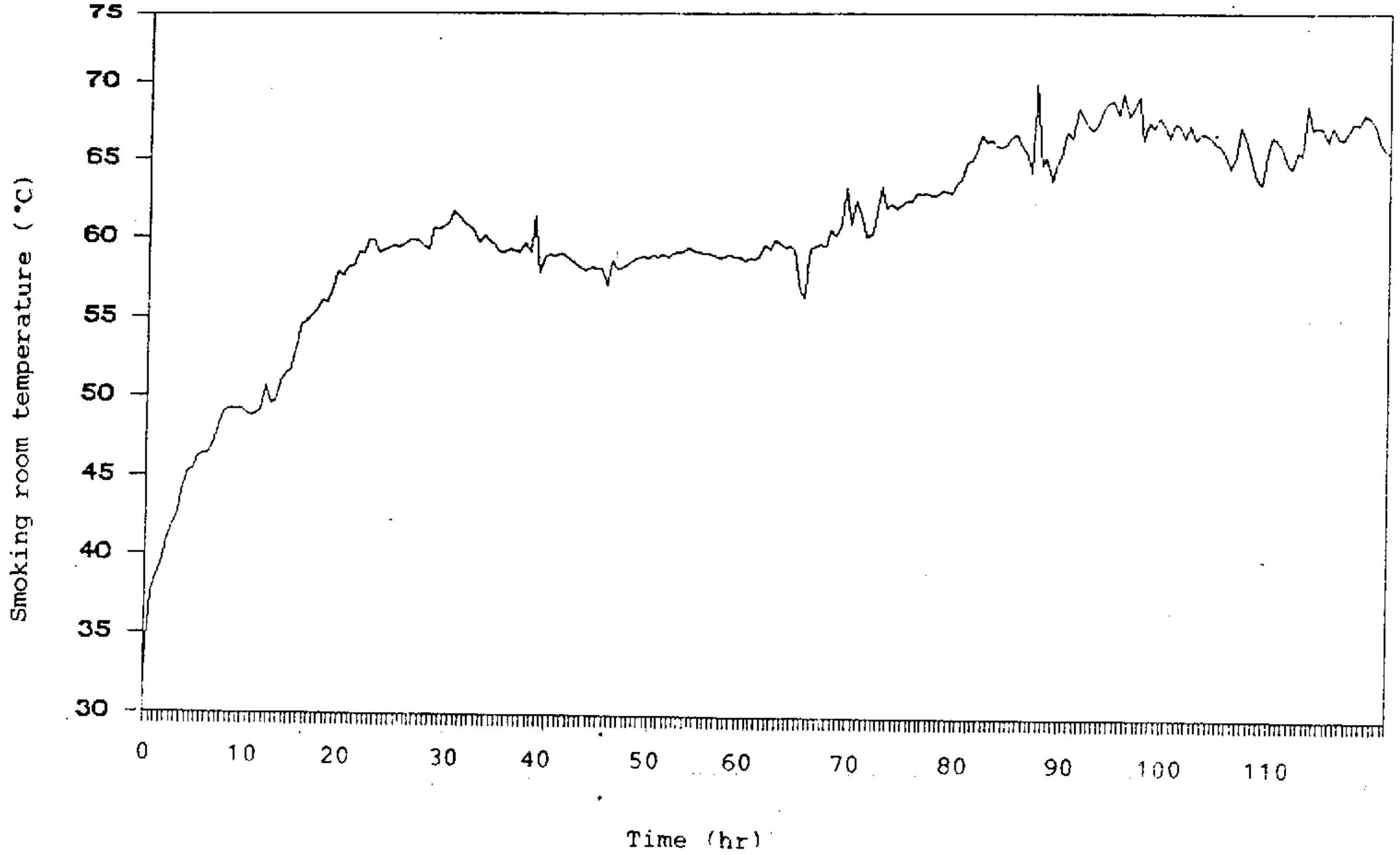

Figure 3.2 Typical smoking room temperature

(average of 3 levels in the room)

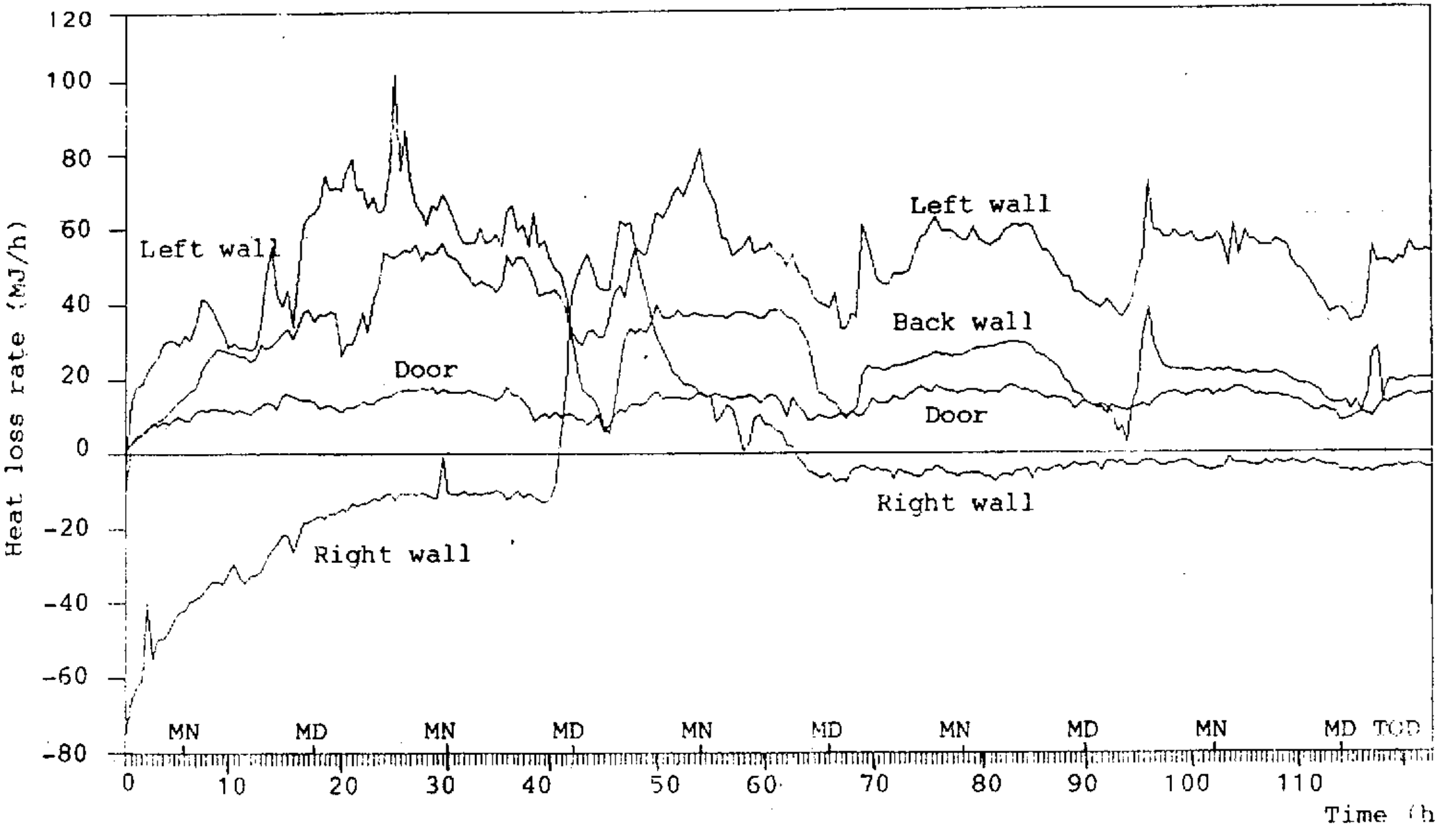

Figure 3.3 Typical heat loss rate through walls

TOD = Time of Day

MD = Mid Day

MN = Mid Night

gained through the right wall from the adjacent room. The overall heat transferred through the right wall is negative (input heat). It must be noted that the positive heat loss of the right wall in Table 3.2 was derived from the positive portion of Figure 3.3 only. Energy lost through the door was relatively steady while the losses through the left and back walls varied with time of the day. The two losses had similar pattern which indicated the influence of surroundings as will be discussed later. However, the total loss through room structure was considerably constant with time as was verified by a linear relationship between accumulative loss and time, Figure 3.4. Similar characteristic was also found for the exhaust loss as shown in Figures 3.5 and 3.6. The low frequency fluctuation in Figure 3.5 was mainly due to variation of the reference temperature (day-night ambient temperature). The ceiling was enclosed by the roof which the space-in-between was filled with hot exhaust gas. Both surfaces of the ceiling apparently had the same temperature. Hence conduction loss of the ceiling was negligible. It was not able to measure heat lost through the floor and roof. These losses were incorporated in the uncountable loss category. The amount of heat due to thermal inertia of the room structure was only 6%. Economic analysis (Appendix B), showed that it was feasible to insulate the left and back walls. These two walls open to surroundings and have the areas of 16x8 m^2 and 4.5x8 m^2, respectively. Although higher percentage of heat loss occurred on the left wall, the loss intensity of the left wall (48.3 MJ/m^2) is lower compared to that of the back wall (83.0 MJ/m^2). Furthermore, only the loss through the back wall is common in every rooms. Consequently, it is likely that thermal insulation, if needed, is suitable for the back wall and/or front door.

3.4 MOISTURE ASPECT OF SMOKING PROCESS

Apart from smoking, drying is another important process. From Table 3.1, it is obvious that the raw material was considerably dry. Water removed from the rubber accounted for only 2.7%. It must be noted that in this analysis the amount of water removed from the

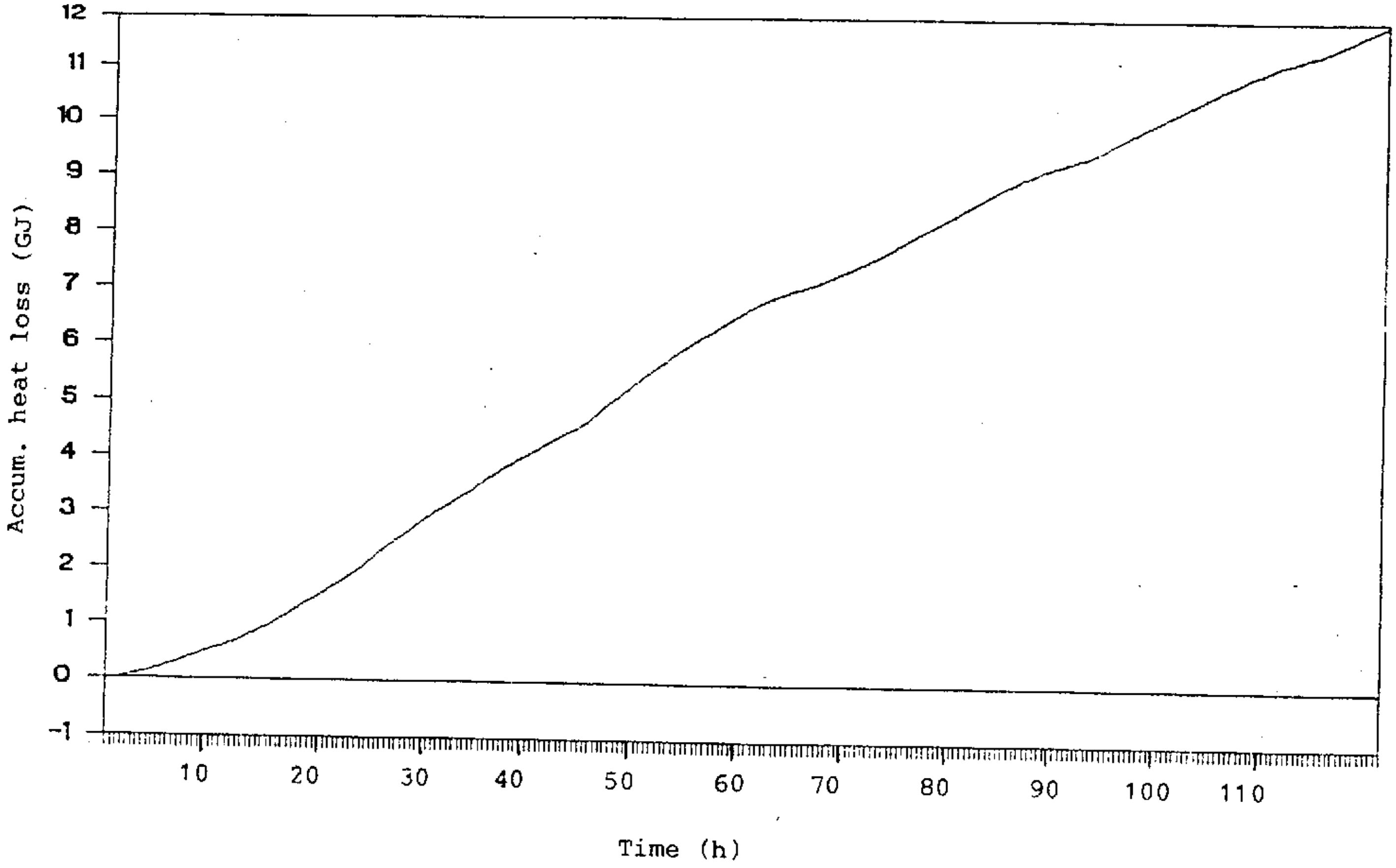

Figure 3.4 Typical accumulative heat loss through walls

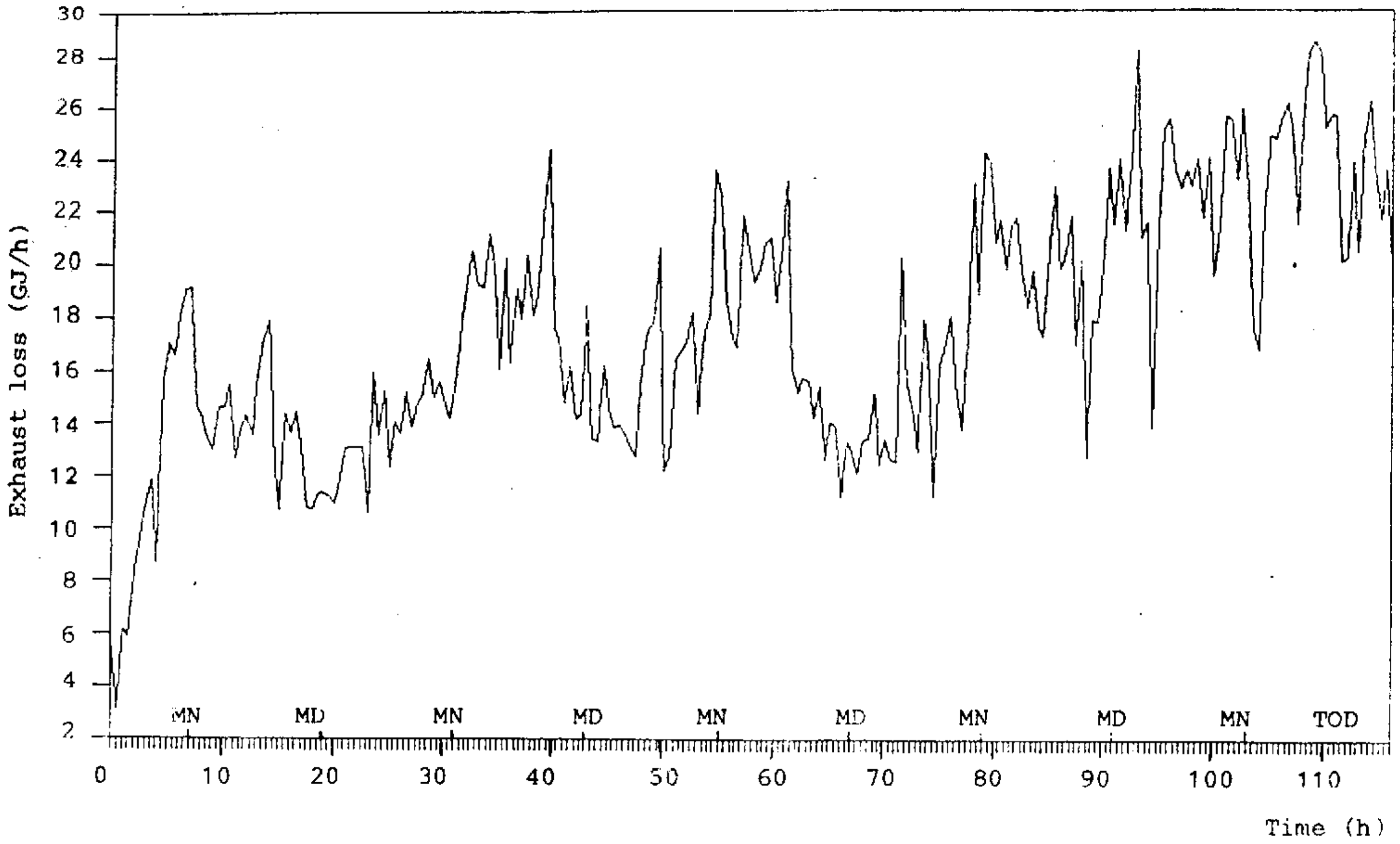

Figure 3.5 Typical exhaust loss calculated with reference to surroundings

TOD = Time of Day

MD = Mid Day

MN = Mid Night

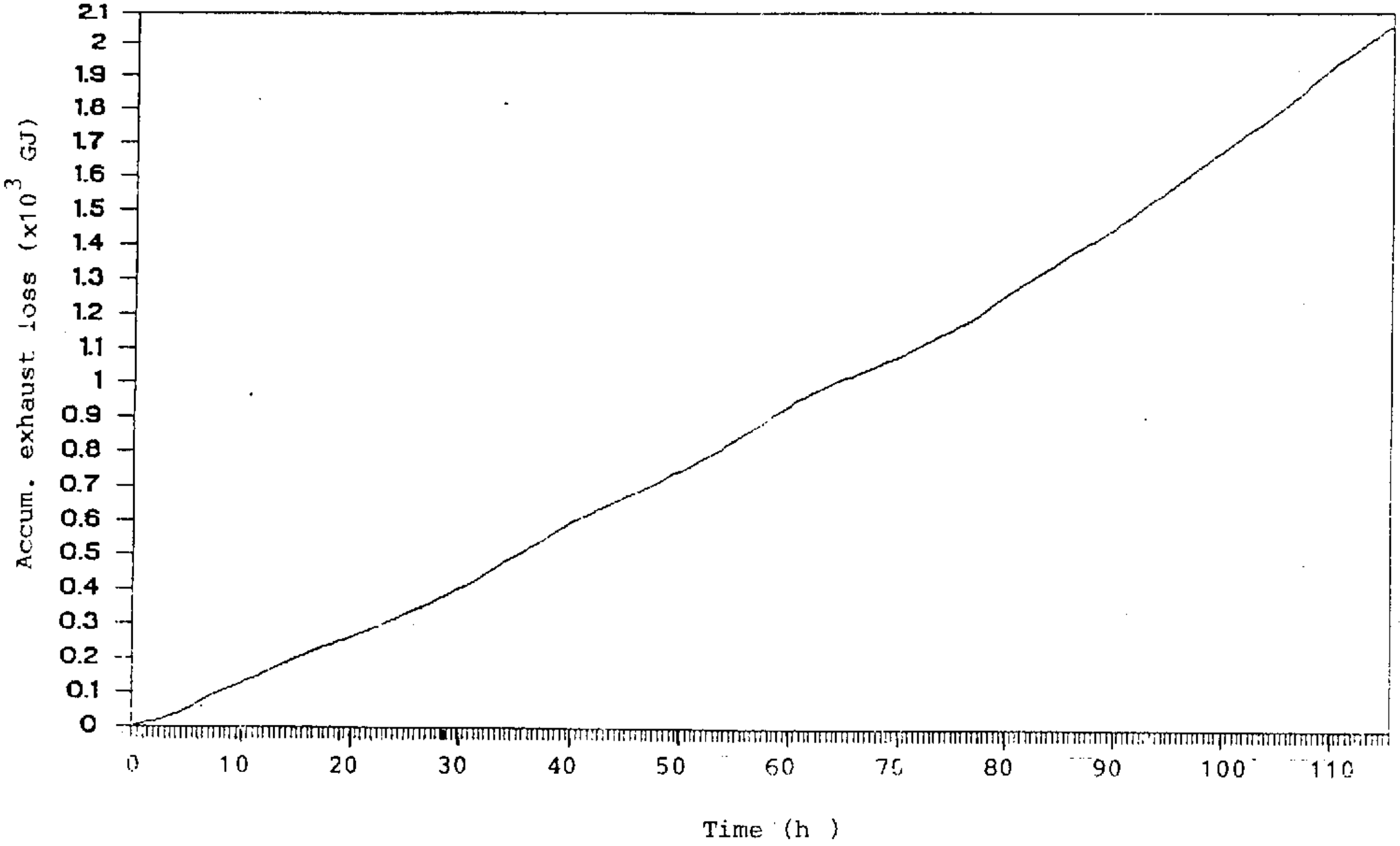

Figure 3.6 Typical accumulative heat loss via the exhaust

rubber was obtained indirectly, i.e., by subtracting the amount of exhausted water by water input (inlet air and firewood moisture). However, measurement of weight loss of over 100 rubber sheets (about 150 kg) agreed well with this indirect calculation [17].

Mass of water involving in the process was calculated from moisture ratio of the inlet and exhaust air, mass flow rate of air into the room, moisture content of the firewood and the firewood consumption. Results are tabulated in Table 3.3.

There were 4.28 tons of water released through ventilation of which 2.02 tons, 1.04 tons and 1.22 tons were water from inlet air, firewood and rubber, respectively. That is, only 28.5% of total water involved in the process were contributed from the rubber while 24.3% and 47.2% were from firewood and inlet air, respectively.

Figure 3.7 showed that the humidity ratios of the inlet air and the exhaust have a similar trend of low-frequency fluctuation. The rise and fall of the humidity ratios were affected by time of the day (day or night). The fluctuation of the exhaust humidity, while the exhaust temperature was relatively constant, implied that during the lower humidity period the exhaust should have absorbed more water if it had been allowed to do so. This means that the circulating time of the hot gas in the room can be extended so that it can effectively dry the rubber. Another word, inlet air flow rate was unnecessarily high. As time elapsed, larger difference between inlet and exhaust humidity ratios was apparent. This can be explained by the increasing drying capability of hot gas due to higher temperature (lower relative humidity), as has been shown in Figure 3.2. Typical accumulative mass of water is shown in Figure 3.8. During the first 16 hours, the drying rate of the rubber was very low as the room temperature was building up to 55°C. Although Figures 3.2 and 3.8 represented only results of one test, similar trend was observed in the other two as well but the corresponding time, at which the effective drying occurred, were 15.5 h (48°C) and 15.0 h (52.5°C).

Table 3.3 Water in the Process

Water (kg)	Test.			Average	Contribution (% of exhaust)
	1	2	3		
Exhaust[+]	4460.9	4180.6	4200.5	4280.7	100
Inlet air[+]	1995.0	1897.7	2174.0	2022.2	47.2
Fuelwood[*]	1154.0	1027.3	935.3	1038.9	24.3
Rubber[@]	1311.9	1255.6	1091.2	1219.5	28.5

[+] Calculated from wet bulb and dry bulb temperatures

[*] Calculated from moisture content 42.2% wet basis [12]

[@] Calculated from mass balance

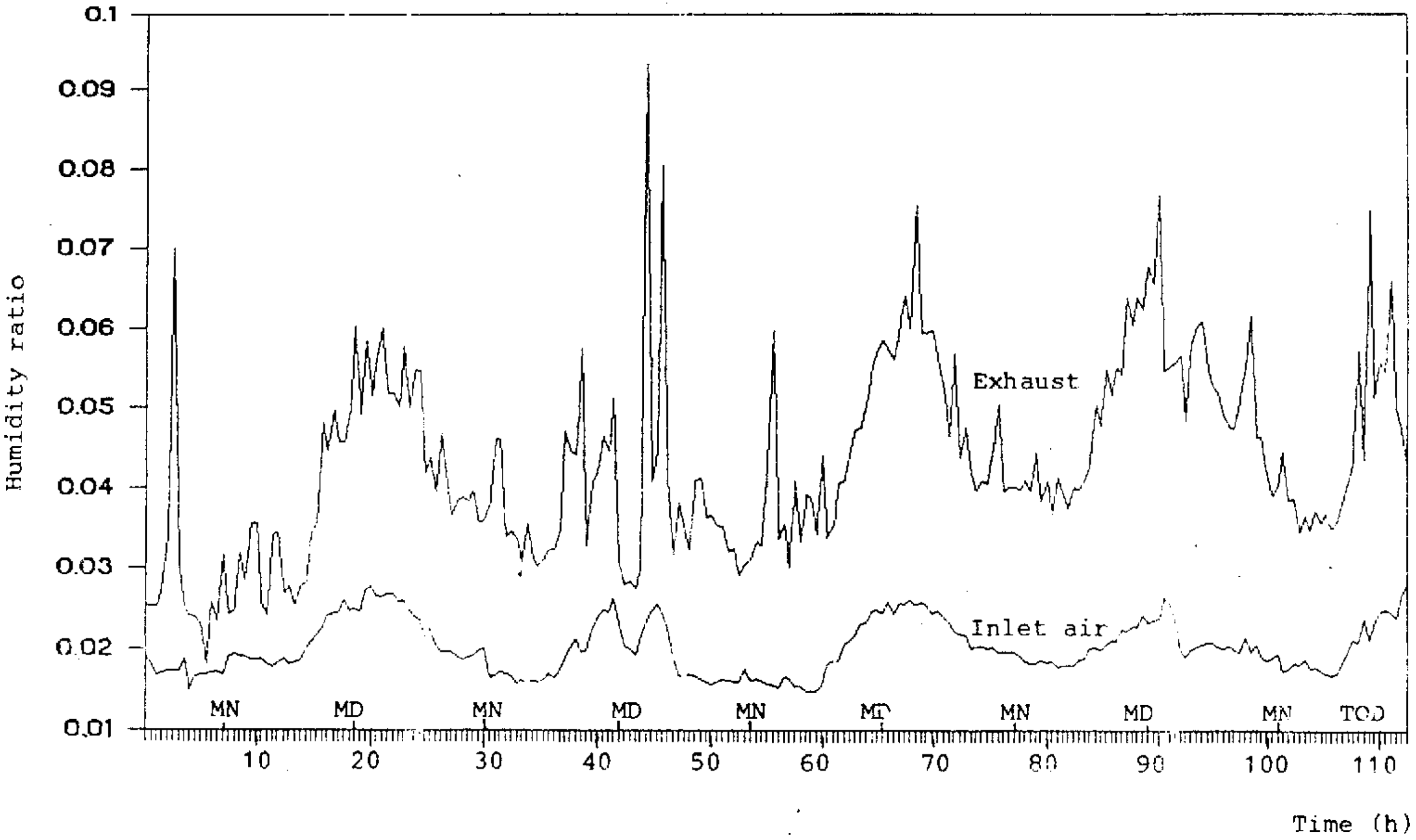

Figure 3.7 Typical exhaust and inlet humidity ratios

TOD = Time of Day

MD = Mid Day

MN = Mid Night

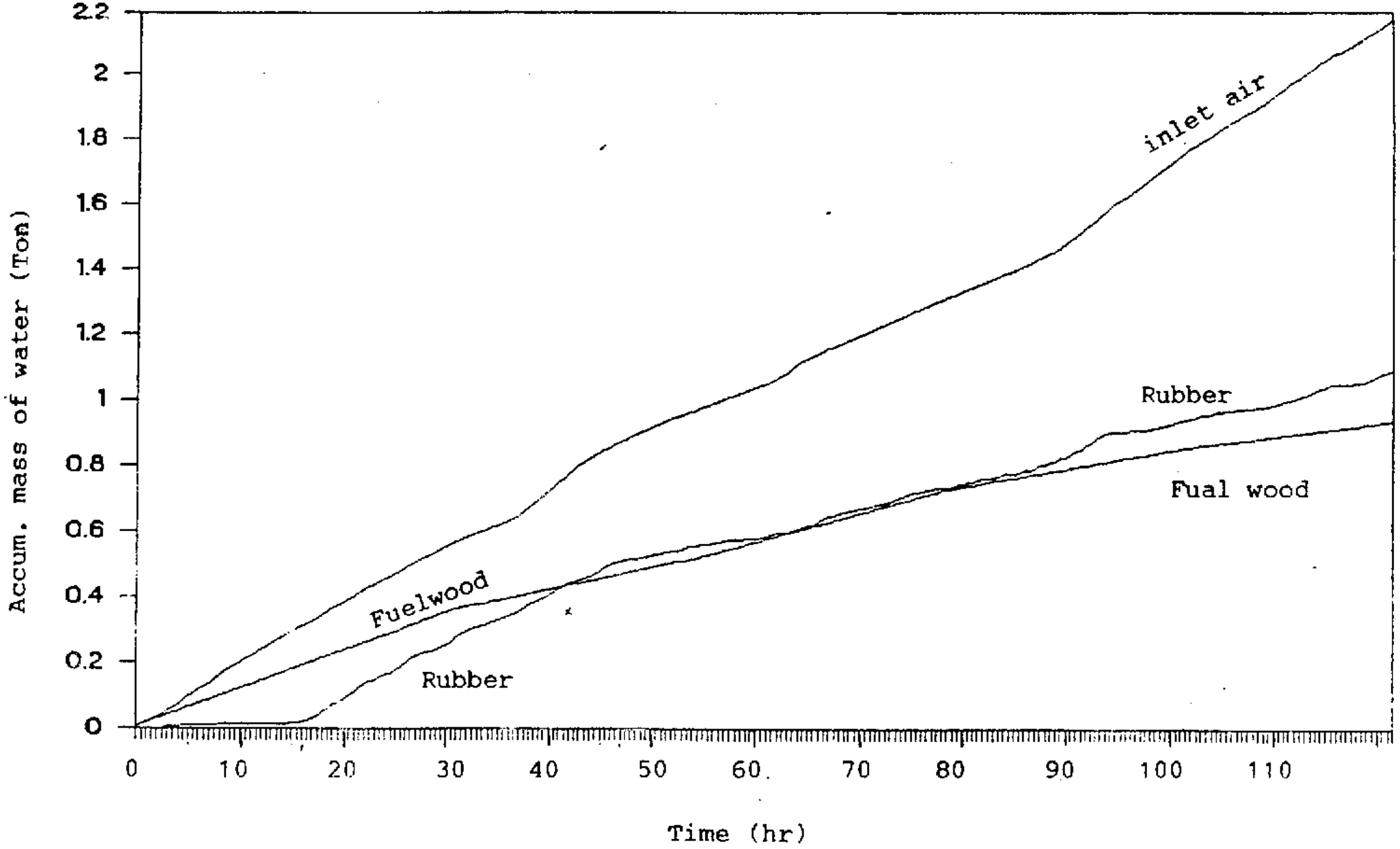

Figure 3.8 Typical accumulative mass of water emitted by firewood, extracted from rubber and admitted with inlet air

3.5 GENERAL DISCUSSION

If energy conservation is the major concern in energy management, it is likely that the application of thermal insulation on the front door and back wall is necessary. Thick and bulky insulation like glass fibre was found not suitable because there is only few centimeters clearance when the rubber is loaded into the room. The forklift truck may easily damage the insulator. Thin insulator which is commercially available appears in the form of liquid coating, e.g., ceramic fiber. However, its application to the inner surface is not possible because the atmosphere inside the room is very corrosive (even the construction bricks do not last long). Economic analysis revealed that both kinds of insulation are feasible but application must be on the outside surface, Appendix B.

Rubber smoking industry is not sensitive to the firewood price. In general, less than 10 m^3 of firewood is required for each batch of the smoking (see Chapter 2). Such amount of firewood costs the factory only 1000 Bahts (U$ 38) which is insignificant compared to about 700,000 Bahts (U$ 27,000) worth of raw material. Heat lost through the back wall and the front door, which is common in every rooms, was equivalent to about 2.25 m^3 or 225 Bahts (U$ 8.6) of firewood. This makes energy saving measures that reduce firewood consumption not attractive enough for the factory's owners if there is other better alternative.

At present a batch of smoking process takes from 5 to 9 days depending on the season (dry or wet). As a matter of fact, it indicates the effect of moisture content of the inlet air. As illustrated by Figure 3.9, water removed from the rubber is generally in the range of one ton while water from the inlet air can be estimated at 2-6 tons (depending on season). Furthermore, water inherent in the air uses huge amount of heat (from combustion) to raise its temperature to the room temperature. This hot vapor does not only possess no beneficial property for the drying process but also causes more firewood to be burnt to maintain the required room temperature. In contrast, if dry air is used in conjunction with dry

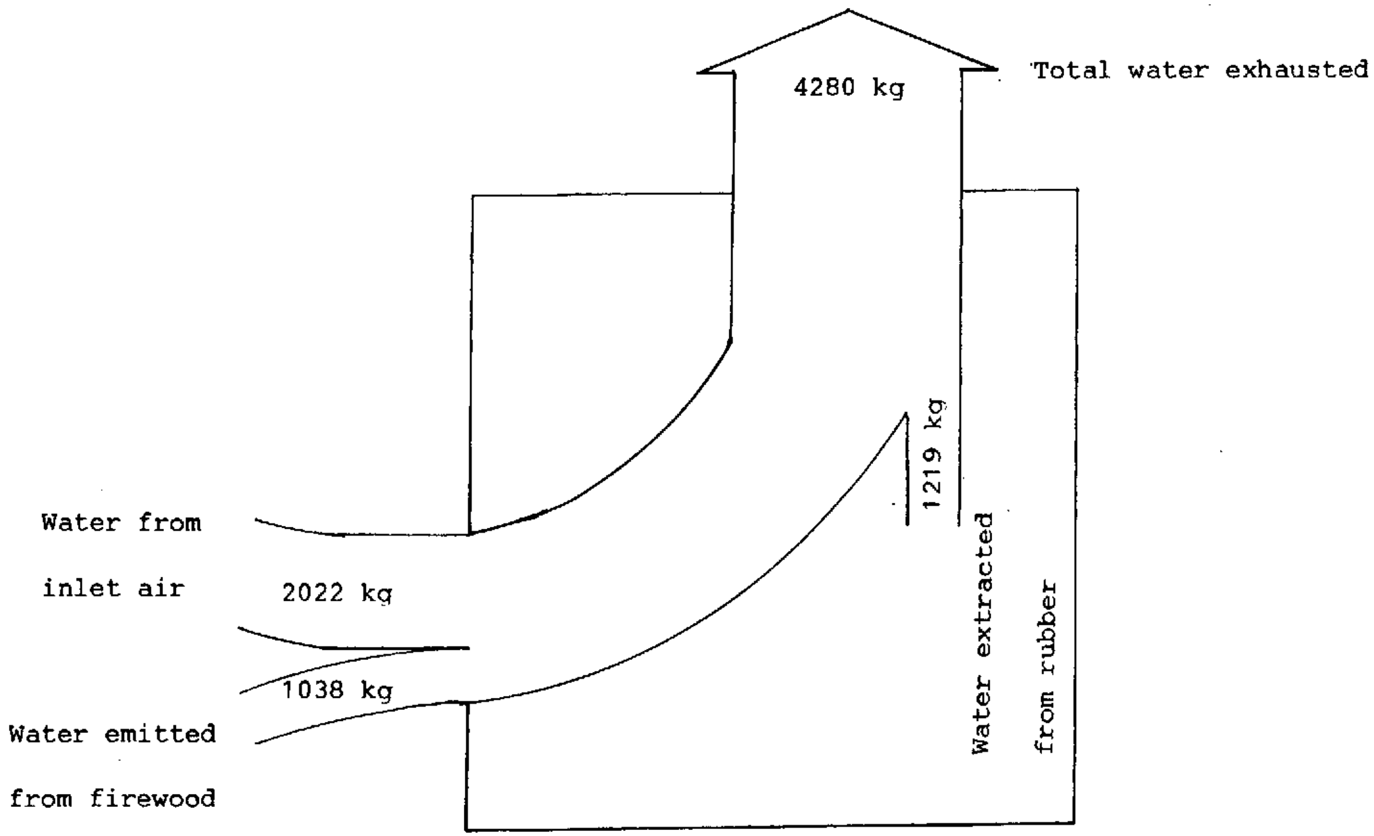

Figure 3.9 Flow of water in the rubber smoking process

firewood, the specific wood consumption will be less because there is no extra heat required to vaporize and heat the water. The real advantage appears in the shorter processing time (because of much lower relative humidity in the hot air). Shorter processing time means less wood consumption and higher production rate.

Low relative humidity in the smoking room is desirable because it can accelerate the drying time. Relative humidity in the room can be reduced by raising the room temperature or dehumidifying the inlet air and using dry firewood. However, the room temperature is limited by the temperature-tolerance property of the rubber. The current practice has already arrived the maximum allowable temperature of 70°C.

Although the low relative humidity can be achieved by both dehumidification of the inlet air and the use of dry firewood, only the former is practical. Not only higher mass of water is contributed from the inlet air but also wet (green) firewood is essential as it generates larger amount of smoke than the dry firewood does. It is then likely that, if it is economically viable, inlet air dehumidification could possibly be a promising technique for the rubber smoking industry as it can significantly increase the productivity by reducing the drying time.

3.6 CONCLUSION

From engineering point of view, there are two parameters to be managed in the rubber smoking process. The two parameters are energy and moisture. Energy is usually viewed as the burden of the factory and is needed to be resolved as it directly affects the production cost. Although only 1/3 of the input energy was used for the smoking purpose and 2/3 were the losses via conduction and ventilation, it was found that energy saving measures are unlikely to be accepted as the benefit is not attractive enough (compared to benefit from inlet air dehumidification) for the factory's owners to invest. Reduction of relative humidity in the smoking rooms is desirable as it can significantly increase the productivity and save firewood by shortening the processing time. As half of the water in the precess comes from the inlet air, the technique that economically dehumidifies the inlet air deserves serious consideration.