Energy Usage and Saving in the Rubber Glove Industry

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Abstract

In this paper, the global energy consumption in the rubber glove industry using the bituminous coal and the liquefied petroleum gas (LPG) as principal fuel supply is presented. The process heat losses in the thermal components including heat transfer in the oven, leaching and washing tanks, glove mold, and conveyor system are comprehensively studied and discussed. It was revealed that higher cost was the result of energy loss in the case of poor thermal insulated components and maintenance. Significant heat loss caused by water evaporation and atmospheric combustion was found in hot water system. Suitable thermal insulation system and I-shape water tank is effectively helpful for reducing energy dissipation from these components.

Keywords*:* Rubber glove industry, Energy consumption, Energy saving

1. Introduction

The global demand of rubber glove grows steadily due to the increase in health and hygiene awareness. However, the smaller Thai manufactures are now facing stiff competition due to higher operational costs and volatile latex prices. Energy cost is considered as a key factor among other operational costs. The savings available from reducing energy used are a big incentive issue to the rubber industry. Energy cost could represent up to 10 percent of the direct costs in the rubber glove industry. Better control of energy usage is achieved by gaining a greater understanding of the processes though improved energy monitoring, management, and personal training. Better process monitoring can have positive effects such as better specification of the product, process energy saving and fewer wastes.

Recently, greatly increase of the energy price has global effect to Thai industrial sectors, especially for the small and medium enterprises (SME). Also, it is unavoidable for the rubber glove industry to encounter the similar crisis and challenge. Since huge amount of energy from fuel combustion is supplied to the thermal components including latex compounding, water washing, leaching, and drying process.

According to the British rubber manufacturers association [1], successive procedure in energy saving policy for rubber processing industry is to assess the current status of global energy supply, identify the source of thermal loss in the plant and implement practical energy saving methods. Experience gained from the feasibility study promoting the energy saving campaign conducted in two rubber plants is presented as the case study.

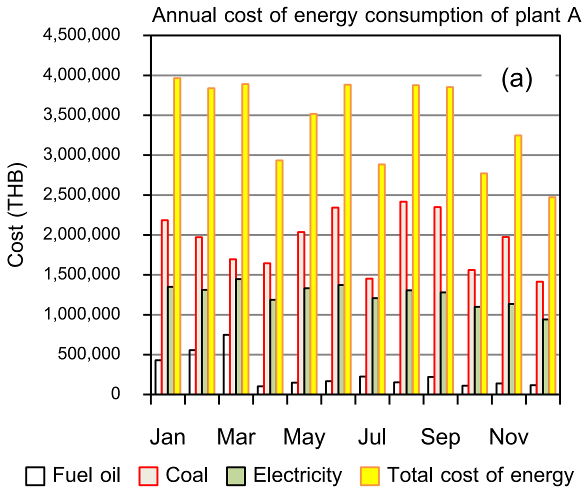
For the plant A, annual energy supply is shown in Fig. 1a. It is found from the study on energy conversion process and plant survey that thermal process in the plant A is operated by hot-oil boiler using bituminous coal as principal fuel. Total annual cost of energy for plant operation is approximately 40 million Baht. Contrary to the plant A, main fuel supply in the plant B is the LPG which is costly energy supply. Cost of the LPG purchasing and electricity bill is shown in Fig. 1b.

Basically, it is beneficial for the energy management program to determine the relationship between energy consumption and rate of productivity.

Commonly, energy usage is higher with the increase in productivity rate or number of produced rubber gloves. An index line on the graph in Fig. 2 is established and it provides the information on the process efficiency in terms of energy usage associating with the weight of products.

The points beneath this line are for relatively high performance of the plant operation which is less amount of energy supplied. The points locating above this line indicate uneconomic operation by consuming more or ineffective amount of energy in producing the same amount of products.

For the plant A, it is found that the line intersects the y axis at 9 million mega-joule for zero-product situation which is the minimum amount of energy required for the plant operation, e.g. lights, air conditioners, computers, office electric appliances, etc.



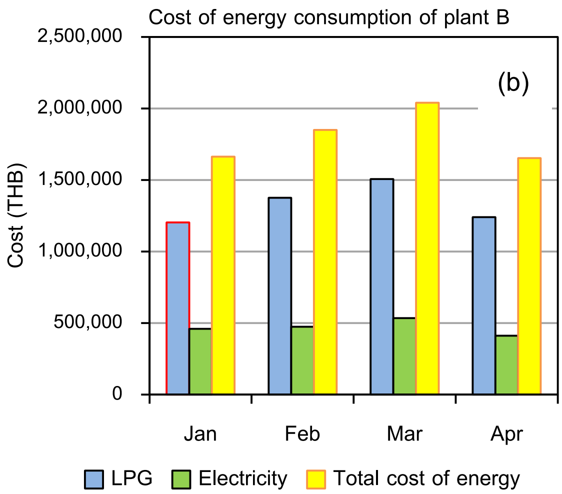


Fig. 1 Cost of energy consumption

(a) annual operation of the plant A *(b)* only four-month energy cost is reported for the plant B

Relationship between energy consumption and production of the plant A and B established and illustrated in Fig. 2 is helpful not only for the global energy monitoring but also for the first insight of the energy usage or loss in the case of the comparison among several rubber plants with different process equipments and energy sources.

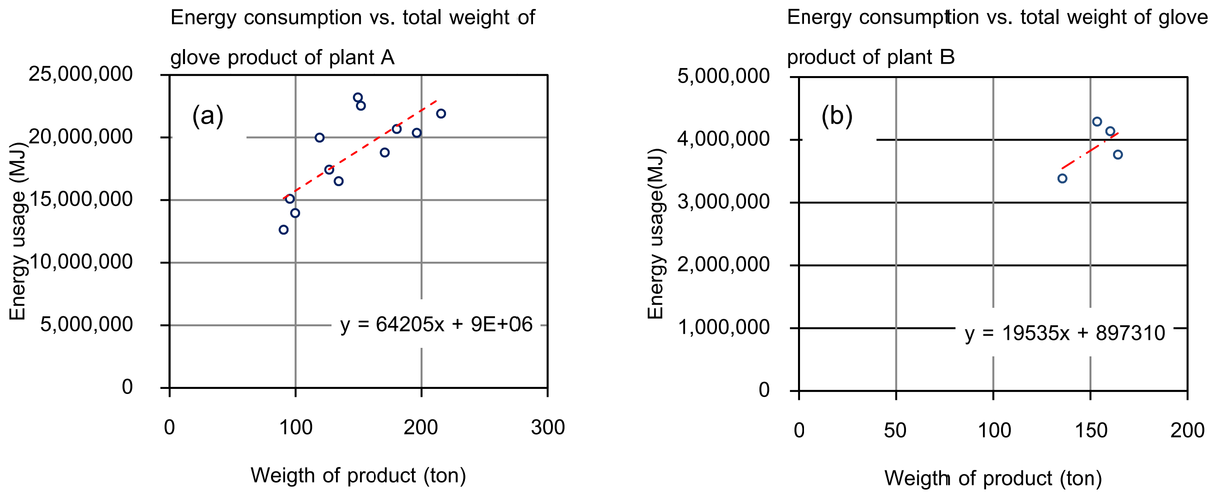


Fig. 2 Energy consumption as a function of produced rubber-glove weight *(a)* for the plant A *(b)* for the plant B

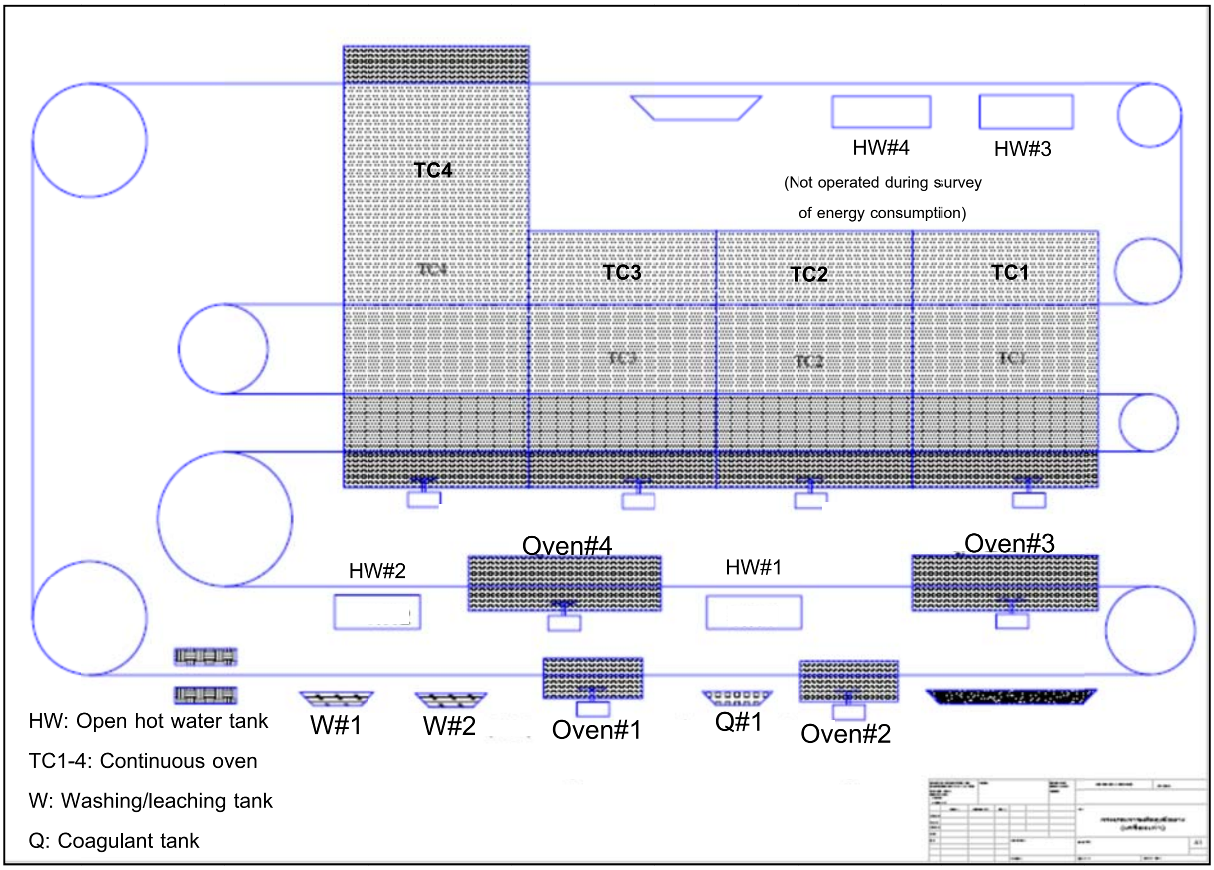


Fig. 3 Schematic representation of a production line including heating and washing units for the plant B

2. Heat Transfer Analysis for Heat Loss from Heating Components

A serie of glove molds is transported to heating/washing units by chain-drive conveyor system. Heating elements in production line are the oven for curing the glove, the open hot-water tank for washing and leaching process. Typical production line of the plant B is illustrated in Fig. 3 including open hot water tanks, ovens and continuous oven. Heat exchangers and piping system are mounted to these thermal units. Process heat losses can be underlined as follows:

2.1 Natural convection

Natural heat convection is the amount of heat transfer rate from hot surfaces of water tank and oven to the surrounding. Determination for amount of heat transfer rate can be given as follows [2]:

$$Q = hA(T_s - T_\infty) \tag{1}$$

Where

Q is the amount of heat (W)

h is the heat transfer coefficient (W/m^{2}K)

A is the area of wall (m^2)

T_s is the temperature of tank or oven wall (°c)

T_∞ is the ambient temperature (°c)

Heat transfer coefficient depends strongly on the flow characteristics and can be described as

$$h = \frac{Nu_L.k}{L} \tag{2}$$

Where

Nu_L is the Nusselt number

k is the thermal conductivity of the air (W/m.K)

L is the vertical distance or the height of the heating component (m)

2.2 Thermal radiation

The second mode of heat transfer from the hot surfaces of the water tank and oven is the radiation. Radiative heat loss can be calculated as

$$Q = \varepsilon.A.\sigma(T_s^4 - T_\infty^4) \tag{3}$$

Where

ε is the emissivity

σ is the Stefan-Boltzman constant

2.3 Evaporation from free water surface

The amount of energy loss due to water evaporation from the open hot-water tank is relatively dominant comparing with other two previous modes. The heat loss can be determined by

$$Q = m_v h_{fg} \tag{4}$$

Where

m_v is the mass flow rate (kg/s)

h_{fg} is the heat of evaporation of water (kj/kg) [3]

According to the above equation, it is delicate to determine the mass flow rate due to evaporation. Bower *et al.* [4] conducted an elaborate study on mass transfer process for evaporation of free surface water system. They proposed the relationship for the rate of mass transfer under atmospheric pressure.

$$Sh = BSc^{1/3}Ra^n \tag{5}$$

Where

Sh is the Sherwood number

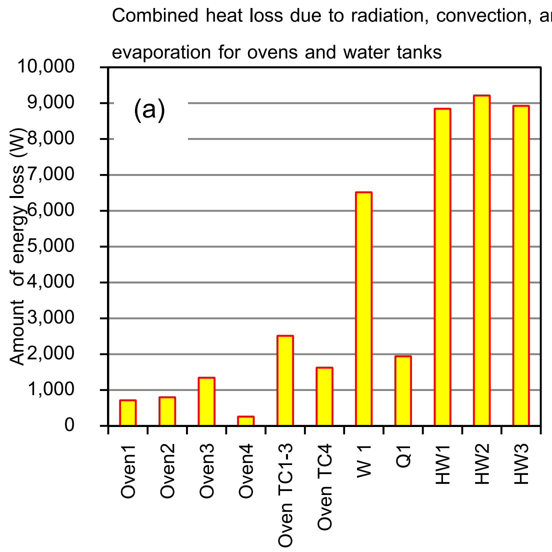
B is the Sh-Ra power law prefactor

Sc is the Schmidt number

Ra is the Raleigh number

3. Results and Discussion

Result of heat loss calculation is concluded in Fig. 4 illustrating the current status for the amount of thermal losses in production line of the plant A. Total annual cost is also presented in order to identify the most suitable energy saving method for crucial thermal units which are the sources of heat loss. According to Fig. 4a, it is found that all open hot-water tanks for glove washing/leaching process, e.g. HW1, HW2, HW3, W1, are the major sources of heat loss.



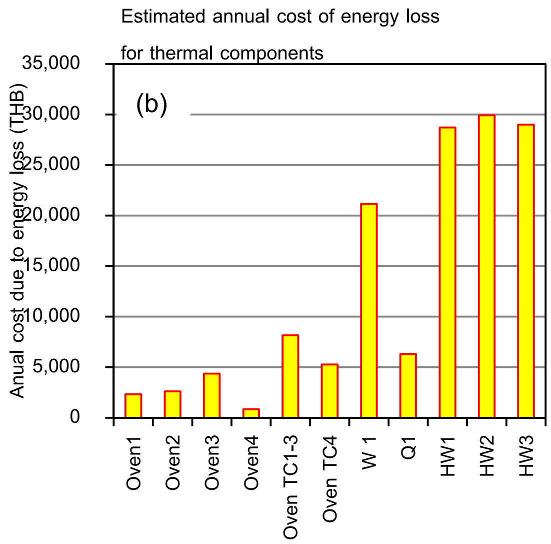
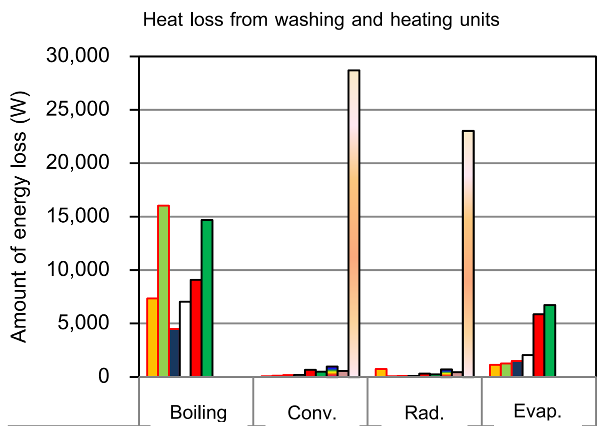


Fig. 4 Energy losses of a production line in plant A *(a)* amount of energy loss *(b)* estimated annual cost of energy losses for individual heating component

Energy loss from water tank is the combination of convection/radiation from the walls and the bottom surface. The evaporation from the upper surface of the tank including mass transfer process depends strongly on the area of free surface and temperature of the water.

Annual cost for total losses from the water tanks is approximately one hundred thousand Baht as shown in Fig. 4b.



	Boiling	Conv.	Rad.	Evap.
HW3	7,348	63	755	1,144
HW 4	16,033	126	66	1,256
HWL 2	4,499	176	98	1,500
HWL3	7,038	196	106	2,053
HWL4	9,098	669	307	5,865
HWL5	14,697	493	234	6,727
Oven 1	0	983	703	0
Oven 2	0	574	447	0
Oven 4-6	0	28,702	23,022	0

Fig. 5 Comparison of energy loss from washing/leaching tanks and oven walls of a production line in the plant B

For the plant B, thermal energy produced by the LPG combustion is for heating the water in the washing and leaching tanks and also for curing the gloves in ovens. Most of heat losses in this plant are the consequence of atmospheric combustion of LPG to produce thermal energy without insulating panel. A portion of energy product from the LPG combustion is for heating the make-up water that supplies for the water tank indicated as boiling in Fig. 5. It is well understood for the effective operating thermal plant that industrial boiler and heat exchanger helps improving the efficiency of energy conversion and reducing the thermal losses from the distribution system.

Considering heat transfer process from water tank, it is found that heat loss due to evaporation is more pronounced than the radiation and convection. For the plant B, the water tank is well insulated and therefore less heat loss through the wall.

Other modes of thermal loss including the radiation and convection are significant only for the oven as shown in Fig. 5. Because higher operating temperature and larger area of the oven than that of water tank. Great amount of heat loss from oven is found in continuous or grand oven, namely oven4-6, with the largest total wall area than other thermal elements in this line.

3.1 Outstanding energy saving measurement

Energy saving measurement is proposed to the entrepreneur and the implementation is voluntarily done after the presentation of the investment cost and payback period.

1) Installation of new insulation system is done for hot-water tank walls in the plant A. Since most of energy losses in the production line is from the hot-water tanks as illustrated in Fig. 4. Calculation of investment cost and payback period conducted for the plant A is summarized in Table. 1.

2) Insulation measurement is for the oven walls in the plant B. Because high amount of heat loss is detected at the oven wall. Investment cost and payback are detailed in Table. 2.

Table. 1 Implemented energy saving measurement for plant A

Measurement feature	
Thermal component: HW1-3 and W1	**Value**
Annual saving (THB)	35,872
Investment cost (THB)	17,000
Payback period (years)	0.52

Note: Blanket insulator is Thermaflex® cross linked sheet with thickness of 30 mm

Table. 2 Implemented energy saving measurement for plant B

Measurement feature	
Thermal component: Non-insulated Oven3	**Value**
Annual saving (THB)	223,447
Investment cost (THB)	100,000
Payback period (years)	0.49

Note: Blanket insulator used is the rockwool with thickness of 2 inches. Oven3 was shut down during the survey and monitoring of energy loss for plant B

Payback period can be determined from

$$P\frac{i(1+i)^n}{(1+i)^n-1}=A \tag{6}$$

Where

A is the annual saving (THB)

P is the investment cost (THB)

i is the interest rate, e.g. at 12.5% annual

n is the payback period (years)

4. Conclusions

Typical measurements can be proposed regarding the result of this feasibility study on energy saving potential as follows:

1) Energy saving in the rubber processing is an important issue in terms of cost saving for the plant and reducing environment impact. It was found that energy loss in the production line was mainly found in the heating and washing/leaching components such as oven and hot-water tank. For the oven, the amount of energy loss through walls is relatively important regarding higher operating temperature of the oven and appropriate thermal insulator must be inserted into the oven panel to reduce heat loss. Rockwool blanket is suitable material used as thermal shield for intermediate temperature component, e.g. oven or furnace.

It was disclosed that high amount of energy loss from hot water tank was due to evaporation. To reduce such a heat loss, it is feasible with the optimal upper surface of the tank by design its free surface in the I-shape configuration regarding the dimensions of the glove mold and conveyor system at the inlet and outlet of water tank. This tank configuration is successfully used in rubber glove industry in order to minimize the evaporative heat loss. Common rectangular shape tank becomes great source of heat loss through evaporation. Using polyethylene floating balls covering some portions of free surface and thus reducing the evaporative heat loss is not recommended. Since the ball could produce some particular defects on the glove surface.

2) It is necessary to redesign thermal units in the case of the operation of the ineffective heat exchangers, boilers and piping system. Atmospheric combustion as a direct heat source for heating the water tank or curing the glove inside the oven should be avoided if possible. Since this method produces significant amount of heat loss from the production line.

5. Acknowledgement

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6. References

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