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IMPROVING THE EFFICIENCY OF VESA-2 TO MAXIMIZE THE ENERGY UTILIZATION

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ABSTRACT

Kemplang is a crunchy traditional snack of the common people in Palembang, South Sumatra, Indonesia. Normally, it roasted on an open charcoal stove, where the smoke, the heat and the combustion gases spread out in all directions. Vertical Energy Saver (VESA) is name of equipment created to accommodate the heat to be used for roasting the kemplang and drying or preheating the kemplang before roasted. VESA-2 is a developed VESA operating to concentrates fly ash, particulate matters, heat and greenhouse gases to transport upward and throwing it to a safe place away from humans' breath. Tests are carried out to improve the energy efficiency by enlargement the volume of VESA-2 and the measurements are conducted at VESA-2 with no load. Test results show that the energy efficiency of original VESA-2 is 20.61%, the energy efficiency of VESA-2 with 30 centimeters height addition is 27.05% and the energy efficiency of VESA-2 with height addition and 28% of cross section area enlargement is 28.18%. The height addition and the cross-section area enlargement are significantly increasing the energy efficiency of VESA-2.

Keywords: Vertical Energy Saver (VESA), Kemplang, energy efficiency.

1. BACKGROUND

An appropriate technology has been developed in the form of a Vertical Energy Saver which is useful for baking kemplang which is a traditional food for the community. This tool is made with a roasting health background and is environmentally friendly for the community around the grill (Darmawi, 2020). This tool is currently undergoing development which all aim to improve construction and increase efficiency. So, the Vertical Energy Saver discussed on this occasion is referred to as the Second-Generation Vertical Energy Saver or 2nd Generation Vertical Energy Saver (VESA-2) which is a tool for roasting kemplang with excess heat, fly ash, particulates and minimal combustion exhaust gases to the toaster mother and the nature around it. The origin size of VESA-2 is (30 x 30 x 90) cm. This system works entirely on the principle of forced convection heat transfer, where air flows from the bottom of the VESA-2 upwards, and exits into the atmosphere through an exhaust fan (Darmawi *et al*., 2020).

The heat source comes from the charcoal furnace, where the air passing through the furnace is mostly used for burning wood charcoal or coal briquettes in the furnace. The heat generated is used to roast kemplangs, which are the traditional food of the people of South Sumatra. The rest heat from this furnace is used to dry or to preheat the kemplang before roasted. The dryness of kemplang greatly influence the quality of roasted products (Darmawi *et al*., 2021).

From the results of previous measurements and analysis (Darmawi *et al*., 2021), the problem with the current prototype is the VESA-2 exit temperature which is slightly high, which is around 76 - 81 ^{0}C. This shows that the heat content in the exhaust air is still high, so it is deemed necessary to carry out further development to make the exhaust air temperature being lowered and the thermal content in the VESA-2 is utilized more for drying and roasting process.

For this purpose, modifications were made to VESA-2 by increasing the volume of the VESA-2 room. Both of these tests is carried out under no-load conditions, where there is no roasting and no drying. So that in this way, it can be ascertained that the temperature of the exhaust air when it is loaded will be even lower due to the absorption of heat in the room for roasting and drying. So that the efficiency of the tool will increase more than at no load measurements. The presence of roasting and drying in the VESA-2 will have an impact on increasing the moisture content in the exhaust air. The addition of the room volume is intended to increase the air volume so that there is a decrease in enthalpy in the VESA-2 and at the same time lowering the exit temperature. The second way is to change the air intake method from the suction principle to the exhale principle. This second method will have implications for decreasing the velocity of the VESA-2 exit air. However, the results of the second method experiments are not reported.

2. LITERATURE REVIEW

2a. Air Speed Flow Profile in Vesa-2

This paper will discuss the temperature distribution in VESA-2 where the heat transfer process takes place completely by forced convection (Wahyu Setiawan, 2021). The airflow pattern in VESA-2 does not follow the pattern as we know it in constant cross-sectional flow (Wijiati & Widodo, 2019), because there are obstacles at three points, namely: at the air inlet position, at the 1st shelf position and at the 2nd shelf position and finally going out into the atmosphere. Figure-1 shows the variation of flow velocity at each position on the VESA-2.

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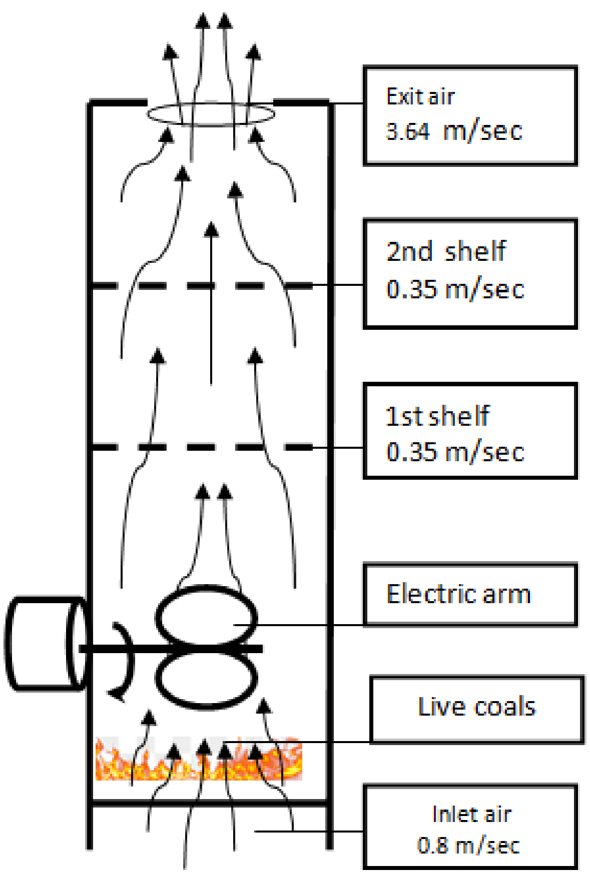
At the air intake position, the resistance occurs because the flow surface area is not as wide as the VESA-2 cross-section, where the air passage area is 56.71 cm2 and the inlet airflow velocity is 0.8 m/sec and the total intake airflow volume is equal to the incoming air from the bottom of the furnace 0.004536 m3/second plus air entering from the front door by 0.027 m3/second to 0.031536 m3/second (Darmawi *et al*., 2021). On the other hand, at the air exit position, the surface area of the exit door is the area of the door entering the exhaust fan, which is 0.008654625 m2, the velocity of the outgoing air flow is 3.6438 m/second and the volume of air exiting per unit time is: 0.031536 m3/second (Darmawi *et al*., 2021). There is a difference in the volume of intake air and outflow air of about 8% due to air entering the gaps and holes that have not been completely closed in the tool.



Gambar-1. Schematic image of air flow in VESA-2.

2b. Roasting Process

Roasting is a way of cooking process, using an indirect and diffused heat to cook kemplang a traditional snack of Palembang people of South Sumatra Indonesia. Roasting is a dry-heat cooking method where hot air is in the vicinity of kemplang and heating it evenly on all sides at a temperature of about 150 °C(Lecreuse, 2021). The heat is generated from an open flame placed at the bottom of Vesa-2, where the hot air is flowing from the furnace at the bottom of VESA-2 to the top by an induced draft fan. Kemplang is placed at the tip of electronic arm which turn slowly back and forth as an act of roasting. The electronic arm movement is completely simulating the manual roasting of kemplang as it traditionally done by the UMKM moms in Palembang.

2c. Drying Process

Theoretically, the drying process requires heat energy to evaporate the water in the kemplang as preheating process before it roasted. According to the principle of equilibrium, the water vapor pressure in the commodity to be dried is the same as the water vapor pressure of the air around the object before drying. When drying begins, hot air that flows through the surface of the kemplang will increase the pressure of water vapor on the surface of kemplang. When hot air flows through the surface of the kemplang, mass transfer occurs from the surface of kemplang in the form of water vapor. In this way the drying process occurs followed by the entry of water pavor from the surface of the kemplang into the atmosphere air (Sary, 2017).

However, evaporation of surface water can only occur under one condition, namely that the air must not be saturated with vapor. Vapor-saturated air is air that contains so much vapor that it can no longer accept additional vapor. The drier the air, the easier it is for surface water of kemplang to evaporate. On the other hand, the more humid the air conditions, the more difficult it will be for water on the surface of commodity to evaporate (Muamar Syaidar, 2019). To find out the pressure and the temperature aspects in the drying process of food commodities, we need to understand the Hertz-Knudsen formula, or often called the Knudsen-Langmuir equation.

Irving Langmuir's basic assumption is that the number of water molecules lost due to evaporation is the same as the number of water vapor molecules in the air hitting the water surface when an equilibrium state occurs. In an equilibrium state, the rate of evaporation and the rate of condensation are the same (Heru Maruza, 2013). Formulatively written:

$$\frac{dM}{dt} = (p_v - p_p)\sqrt{\frac{m}{2\pi RT}}$$

where:

dM/s = mass flow rate (kg) over a given surface area (m-2) in one second (second, s-1), so the unit is kg/m2/s.

Pv = vapor pressure at a certain temperature, or boiling point pressure at temperature pecified, in units of pascals (pa).

Pp = vapor partial pressure of the substance in the gas mixture, for example the vapor pressure of water in airat a certain temperature, in units of pascals (pa).

m = molecular weight of water (0.01801528 kg/mol).

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R = ideal gas constant or Mendeleev's constant = 8.314 Joules /(mol Kelvin).

From the above formula it can be understood that if the vapor pressure (Pv) is greater than the partial pressure (Pp) of water vapor in the commodity, evaporation will occur. On the other hand, if the partial pressure of water vapor in the commodity (Pp) is greater than the vapor pressure (Pv), condensation will occur (Heru Maruza, 2013).

The weakness of the Irvin-Langmuir formula above is that the drying rate is only viewed from the aspect of pressure and temperature. Meanwhile, in the forced convection process, there are other factors that are no less important, namely: the speed of the drying air flow, the temperature of the drying air and the relative humidity of the drying air (Dina *et al.*, 2019) (Henderson & R.L. Perry, 2009).

3. METHOD OF EXPERIMENTS

Two tests of two method of experiments were carried out, basically called as the volume of the VESA-2 enlargement and changing the air flow method, from inhaled air in to exhaled air in. Diagrammatically, it can be sorted as shows in Figure-2.

To calculate the efficiency and effectiveness of equipment, tests and measurements are carried out at no load. This means that no roasting and drying takes place in the VESA-2. This is done to measure the performance of the VESA-2 at the worst performance, where all heat is considered unused.

$$q_{conv} = mc_p(T_{m,o} - T_{m,i})$$

where Tm denotes the average air temperature and the subscription i and o denote inlet and outlet air condition respectively. It is important to note that the above equation is a general expression of energy balance in VESA-2 (Sinaga, 2019). Cp is a constant of air heat capacity, 1.005 kJ/kg.K at room temperature (G.F.C. Rogers & Y.R. Mayhew, 1996).

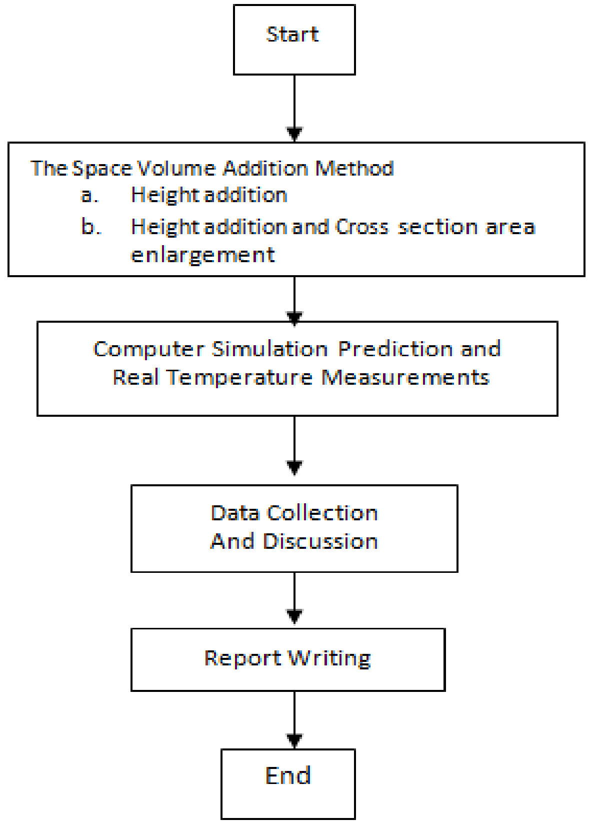

Figure-2. Flowchart of experiments.

4. COMPUTER TEMPERATURE DISTRIBUTION PREDICTIONS AND REAL TEMPERATURE MEASUREMENTS

4a. Computer Temperature Distribution Predictions

Prediction by computer simulation has been carried out using the flow simulation program as a technical reference. Assuming the fluid is compressible. Solid particles such as particulate matters are not considered specifically. The flows are laminar and steady. Temperature distributions in VESA-2 are as follows:

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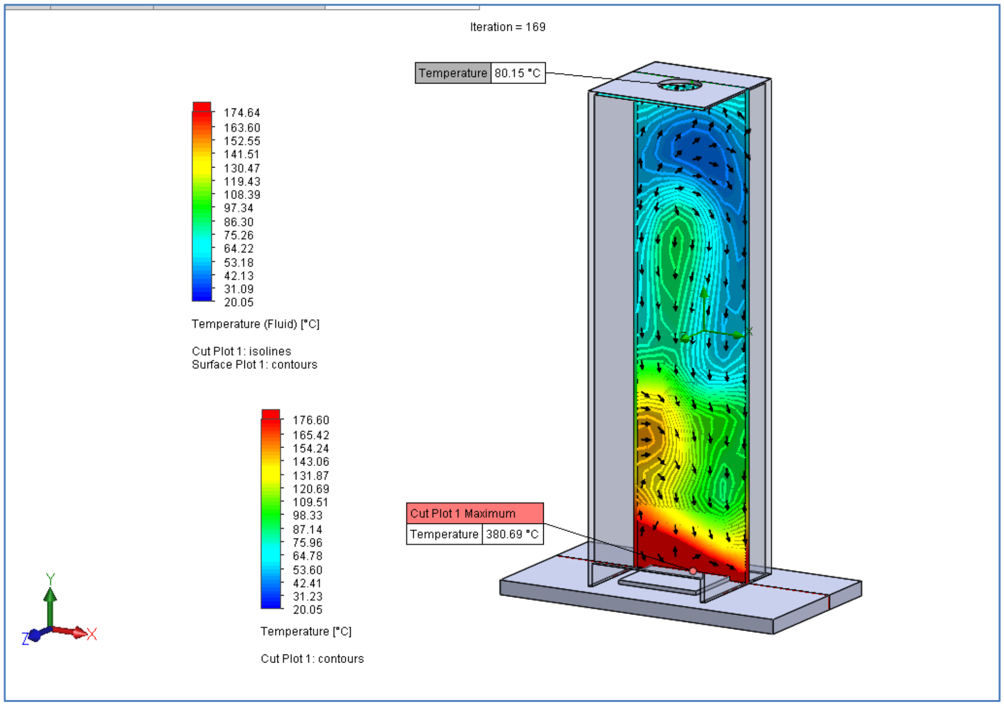

Figure 3. Temperature distribution at VESA-2 where the temperature at live charcoal is of 380.9 °C and exit temperature is 80.15 °C

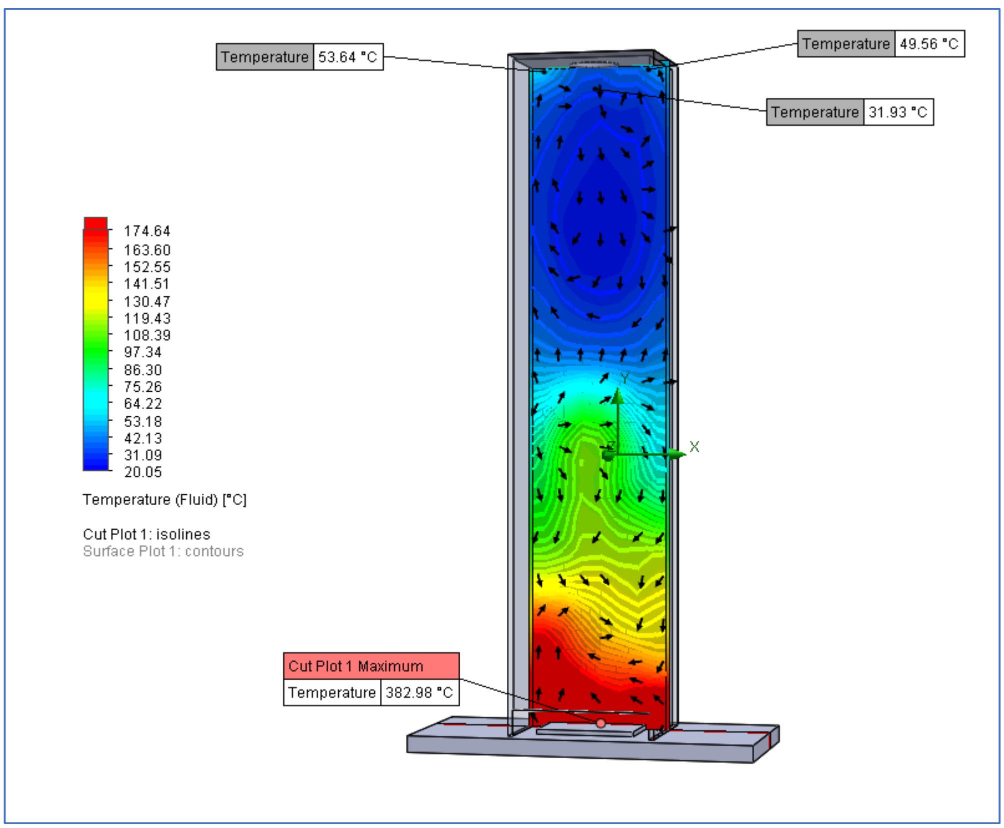

Figure-4. Vesa-2 with height addition, where the live charcoal temperature is 382.98 °C and exit temperature is 53.84 °C

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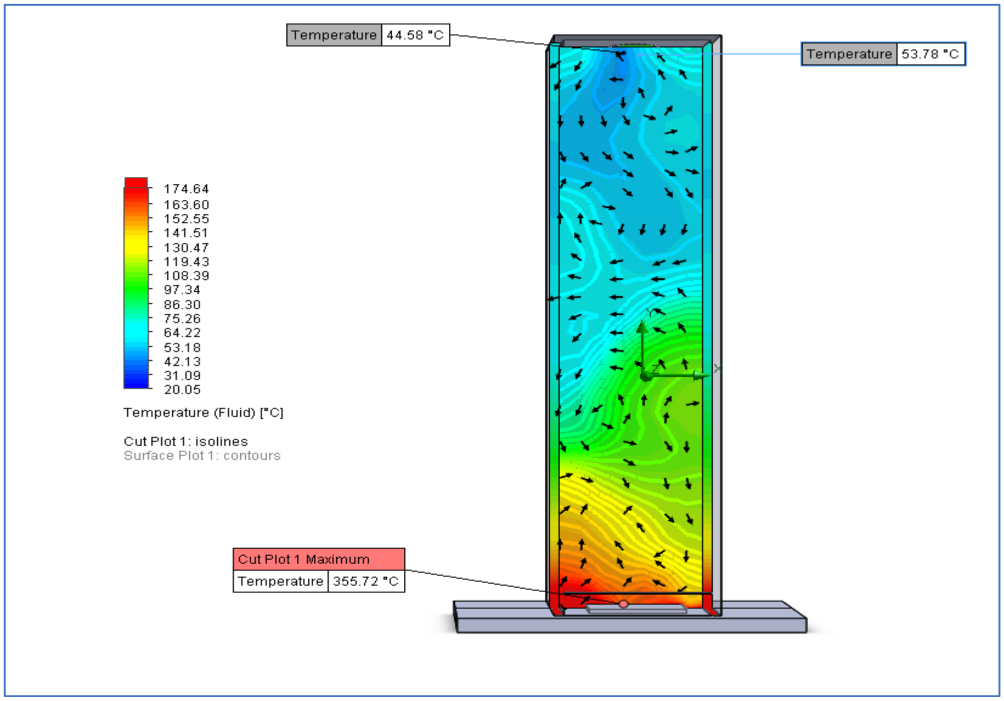

Figure-5. Vesa-2 with height addition and 28% cross section area enlargement, where the live charcoal temperature is 355.72°C and exit temperature is 44.58°C.

4b. Average Actual Temperature Distribution Measurements in VESA-2

Real measurements are already carried out at VESA-2. In this paper we present three modification of VESA-2. The three of them are Vesa-2 with no size modification is called Original Vesa-2, Vesa 2 with 30 cm height addition, and Vesa-2 with 30 cm height addition and 28% cross section area enlargement. The average actual temperature measurements of related VESA-2 as presented in Table-1.

Table-1. Average actual temperature in VESA-2.

	Original Vesa-2	Vesa-2 With Height Addition (°C)	Vesa-2 With Height and Cross Section Area Enlargement (°C)
Point 1	104.57	104,6	102.3
Point 2	86,14	82,4	81.5
Point 3	82,85	74.3	70,1
Point 4	79,91	51.3	44,6

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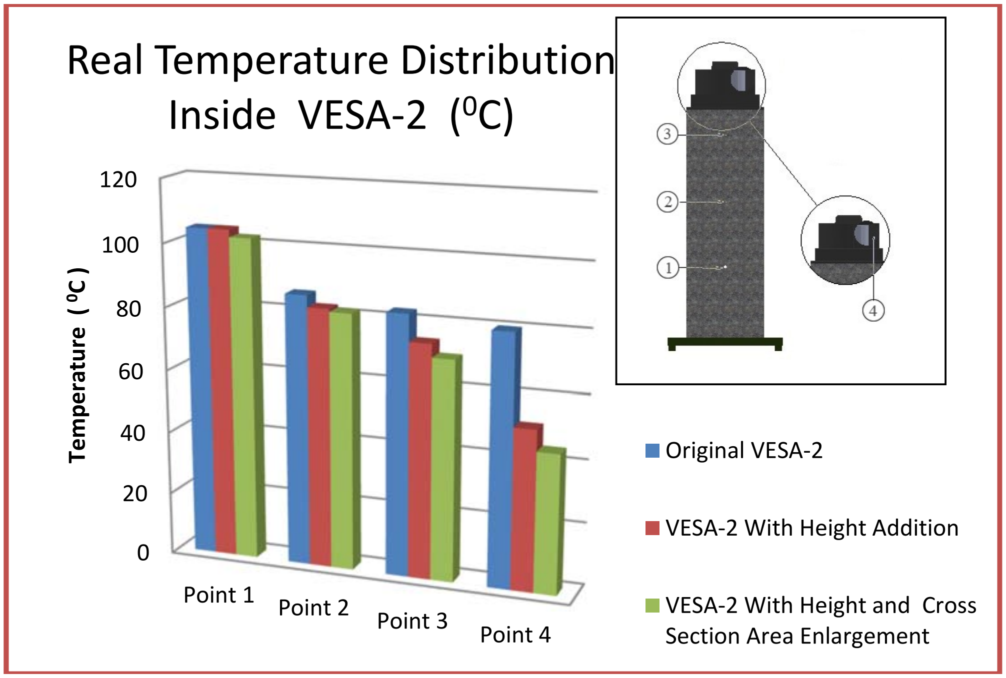

Figure-6. Real temperature of VESA-2 at varying size modification.

5. THERMAL ENERGY EFFICIENCY OF MODIFIED VESA-2

Thermal energy efficiency of VESA-2 at no load operation. This is the worst efficiency VESA-2 would make. The thermal efficiency of VESA-2 is defined as the energy out of VESA-2 per second divided by the energy produced by the live charcoal at the bottom of VESA-2 per second.

Table-2. Thermal energy efficiency of VESA-2 The following calculation is based on the quantity of air intake and exit VESA-2 as measured previously. Cp = 1,005 (Kj/Kg.K). Air density is 1.2 kg/m^3(John Twidell & Tony Weir, 2006).

	$\dot{m}_{out}$ (Kg/sec)	$\dot{m}_{in}$ (Kg/sec)	Q_{in} (Kj/sec)	Q_{out} (Kj/sec)	η_{th} (%)
Original VESA-2	0,0378432	0.03214	14.37418	11.41058	20.61
VESA-2 with Height Addition	0.0378432	0.03214	14.37532	10.48554	27.05
VESA-2 with Height Addition and Cross Section Area Enlargement	0,0378432	0.03214	14.28776	10.26030	28.18

6. DISCUSSIONS

Comparation between the computer temperature prediction and the real temperature measurements are tend to similar or a tiny different. It is because the dynamic flow of air inside VESA-2 and the dynamic fluctuation of energy supply to VESA-2 regarding the quantity and the quality of charcoal burnt at the furnace. Charcoal is a hydroscopic matter, the higher the moisture contents in the charcoal, the lower the thermal energy produced in furnace. The charcoal water contents cannot be accurately detected or measured, so it is considered the same.

From the data analyzing and the results presented above, we can see the improvements of VESA-2 energy efficiency. The energy efficiency tends to increase by the addition VESA-2 body volume. This body volume is enlarged by VESA-2 size modification. The measurements show clearly that the height addition of VESA-2 and the cross-section area enlargement significantly lowering the air exit temperature of VESA-2. This phenomenon indicating that the height addition or the cross-section area enlargement is encourage the better energy accomodation inside VESA-2. It means the more energy will be utilized. The lowest energy efficiency is found at original VESA-2 where no size modification was made. It is mainly because there is a window at the bottom of the equipment where the air could enter. This window is used to roast the kemplang manually. A part of air is partially not absorbing the heat from the furnace because rapidly in haled by the top fan. This is the one of the causes of low efficiency. Modified VESA-2 has better efficiency because the size of the window already reduced; even at the next experiments VESA-2 has no more window. The manual roasting act is already replaced by an electronic arm. It is hoped that a better thermal efficiency will get.

7. CONCLUSIONS

From the data found and the analysis we can conclude the followings:

a) The volume enlargement will increase the heat utilization of VESA-2

b) The height addition significantly increases the thermal energy efficiency. Meanwhile, the cross-section area enlargement of VESA-2 support slightly.

c) The combination between height addition and cross section area enlargements is considered as a wise decision to downgrade the heat loss and increase the thermal efficiency of VESA-2.

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