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Utilization of Geothermal Brine Heat to Produce Essential Oil of Commodities Plants Through Steaming Process

Achmad Ardialim, Ahmad Indra Sakti Harahap, Viqar Adly Gani, Gumelar Ahmad, M. Albarrosyah Putra, Faiq Kautsar

PGE Area Lahendong, Jl. Raya Tomohon 420 Lansot, Tomohon, Sulawesi Utara, Indonesia, 95431

achmad.ardialim@pertamina.com; ahmad.harahap@pertamina.com; viqar.gani@pertamina.com; gumelar.ahmad@pertamina.com; m.albarrosyah@pertamina.com; faiq.kautsar@pertamina.com

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ABSTRACT

Pertamina Geothermal Energy operates in several regions in Indonesia, one of which is in North Sulawesi, Indonesia. These areas are surrounded by tropical plantations managed by local farmers for their living. Mainly the plant commodities crops are cultivated for months then the crops are dried before being distributed to the nearest market. Some of the primary commodities in North Sulawesi are Cloves and Ornamental Plants. Currently, the commodity of clove itself is sold as it is without experiencing any process to obtain derivative products. Similar condition to ornamental plants, plants that are harvested and only sold locally and sometimes have withered before selling to customers. PGE takes responsibility to improve this issue by adding value to crops through community empowerment programs. This program utilizes brine geothermal energy to extract commodities, particularly cloves and ornamental plants by using a reactor to produce essential oils. Cloves or ornamental plants that are heated in the reactor will produce steam which is further condensed to get essential oils. Extraction is carried out using a steaming method that operates at 95 degrees Celsius and 1 atm. The results obtained 10 ml with the average heating time for 90 minutes. This process could add value to commodities through derivative products to be traded in larger markets without incurring additional costs. In addition, this activity also increases the direct use of excess heat from geothermal energy.

1. INTRODUCTION

The Indonesian Government is committed to developing the utilization of New and Renewable Energy through National Energy Policy, as mandated in Government Regulation No. 79 of 2014. Geothermal energy is targeted to contribute 7,242 MW of the total national energy distribution for New and Renewable Energy sources, securing 23% of the entire portion by 2025. Nevertheless, as of today, Indonesia's geothermal development has reached a mere 2,004.5 MW. By optimally utilizing geothermal energy, energy independence and security are expected for our Nation, due to its contribution towards reducing Indonesia's dependency on the very limited fossil energy and maintaining environmental sustainability. The Company stands at the front line to develop Indonesia's geothermal energy and fully commits to supporting the Government's effort in realizing energy independence through the expansion of installed capacity of Indonesian Geothermal Power Plants ("PLTP") on a periodical basis, targeting an addition of 1,017 MW of installed capacity by 2025.

As a Subsidiary of PT Pertamina (Persero) which is mandated by the Government as the motor for the development of geothermal energy in Indonesia, PT Pertamina Geothermal Energy (hereinafter referred to as the "Company") is fully committed to realizing energy independence by continuing the expansion of installed capacity of Geothermal Power Plants ("PLTP") in Indonesia. The Indonesian Government is committed to developing the utilization of New and Renewable Energy through National Energy Policy, as mandated in Government Regulation No. 79 of 2014. Geothermal energy is targeted to contribute 7,242 MW of the total national energy distribution for New and Renewable Energy sources, securing 23% of the entire portion by 2025. Nevertheless, as of today, Indonesia's geothermal development has reached a mere 2,004.5 MW. By optimally utilizing geothermal energy, energy independence and security are expected for our Nation, due to its contribution towards reducing Indonesia's dependency on the very limited fossil energy and maintaining environmental sustainability. The Company stands at the front line to develop Indonesia's geothermal energy and fully commits to supporting the Government's effort in realizing energy independence through the expansion of installed capacity of Indonesian Geothermal Power Plants ("PLTP") on a periodical basis, targeting an addition of 1,017 MW of installed capacity by 2025.

As of the end of 2018, the Company had managed five (5) geothermal areas. PT Pertamina Geothermal Energy currently has a total of 617 MW installed capacity, with the following details:

- Kamojang Units I-V, West Java at 235 MW
- Lahendong Units I-VI, North Sulawesi at 120 MW
- Sibayak Units I & II and Monoblock, North Sumatra at 12 MW
- Ulubelu Units I-IV, Lampung at 220 MW
- Karaha Unit I, West Java at 30 MW

In addition to the 5 areas above, the Company has completed the construction work of the 55 MW Lumut Balai unit I PLTP with a target of commercial operation in 2019. The project is located in the Lumut Balai and Margabayur WKP, South Sumatra Province. Accordingly, the Company's total installed capacity at the end of 2018 is 672 MW.

2. GEOTHERMAL UTILISATION SCHEME

Geothermal energy cultivation is based on the lifting of hot water and/or steam contained in underground reservoir. In general, the utilization of geothermal energy is divided into two:

2.1. Indirect Utilization

Indirect geothermal utilization is performed by converting thermal energy of geothermal fluid into kinetic energy which is further converted into electricity. Geothermal fluid expelled to earth surface may come as whole steam or two phase steam which contains steam and water. This depends on the geothermal system of each of the fields, whether they are steam-dominated or water-dominated. The utilization of geothermal energy into electricity on field using water-dominated system is commonly performed through single flashing. High-pressurized 2-phase fluid flowing through production is delivered to the separator to separate steam and brine. Steam with certain mass resulted from separator is channeled to generator through pipeline, to turn the turbine, activate the generator, and generate electricity. Further, the electricity generated is distributed to consumers. Meanwhile, brine resulted from the separation in the separator is re-injected into the earth through re-injection well located outside the reservoir boundary. This aims to avoid reservoir cooling down which eventually results in the decline in production. Steam expelled from the turbine will change phase into condensate, and later cooled down inside the condenser with vacuum-kept pressure. From the condenser, the condensate is pumped into the cooling tower and collected in the cooling tower basin. From the basin, condensate is re-injected into the earth through re-injection well. Currently, geothermal energy is mainly used for indirect utilization, i.e. electricity.

2. Direct Utilization

With this method, geothermal energy is directly utilized without undergoing energy conversion. The utilization includes the functions such as room heater, room cooler, hot water pool, fish breeding, plantation, palm sugar heater, and coffee, copra, chili, and wood drying. Direct utilization of geothermal energy is highly beneficial for tourism, industries, agriculture, hospitals, and office buildings. Direct utilization can also be carried out to brine resulted from the 2-phase fluid separation at the separator, using cascading system.

3. DIRECT USE UTILIZATION IN LAHENDONG GEOTHERMAL FIELD

Location of Pertamina Geothermal Energy Lahendong area is surrounded by various plantation and agricultural areas such as maize, coconut, chili, and clove, as well as the processing industry. One of the household scale industries is the palm sugar industry with a total number of 6,285 farmers. In producing traditional palm sugar, each farmer needs 14 m3 of firewood per day so that the amount of fuelwood needed in the area is around 7 tons of firewood per day. This clearly threatens the existence of forests in the area.

Knowing this, in 2001 PGE took the initiative to make a drying machine capable of utilizing the remaining steam from PLTP production. The location of the drying building covering 3 x 5 meters [Figure 2] is located in area cluster 13. The drying machine consists of pipes to drain brine, the blower as a heat exchanger and tray for the drying place. Based on the results of research from universities, experiments with local communities and PGE's, dried agricultural products can last a very long time when marketed. This drying technology has also been able to improve cost efficiency and fuel use and maintain the environment both from preventing the use of trees for firewood, as well as reducing emissions from fossil energy. [Figure 1]

Figure 1: Agriculture Dryer

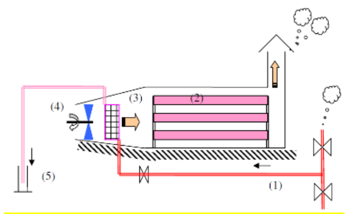

Figure 2: Schematic Diagram of Agriculture Dryer by Utilizing Brine

After success with agricultural dryers. A non-governmental organization called Yayasan Masarang with the cooperation of Pertamina Geothermal Energy built a large scale geothermal energy direct use facility for palm sugar factory [Figure 3] with the production capacity of 12 tons/day by utilizing flashed steam from the separated hot water (brine). At present, the facility is running with capacity of 1 ton/day only. The schematic diagram of the facility is as shown in figure 4. Brine from the separator is directed to a flasher to produce flashed steam of about 4 tons/hour, and it is utilized for the palm sugar processes. Some of the products are exported to the Netherlands.

Figure 3: Masarang Palm Sugar Factory

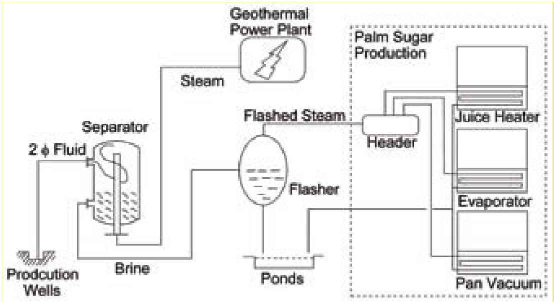

Figure 4: Schematic Diagram of Palm Sugar Production by Utilizing Brine

4. OTHER MAIN COMMODITIES

North Sulawesi has other potential commodities. There are Cloves and Flowers. Kakaskasen, can be cited as a center of floriculture development in Tomohon City even in North Sulawesi. One of the farms presented the source of income of Tomohon city residents is cut flower farming, where chrysanthemum flower is one of the main commodity for farmers in Tomohon city.

The Kakaskasen village until 2017 has a chrysanthemum production area which is managed by 45 heads of farm families. aware of the production data obtained by the Agricultural Extension Agency of North Tomohon Subdistrict where Kakaskasen Sub-District produces 69.550 stalks of chrysanthemum production annually.

Chrysanthemum flowers are harvested at the age of 13 weeks after planting. Chrysanthemum flowers can last 1 month at the planting house if you don't want to be harvested. Chrysanthemum flowers can be harvested up to 4 times. Chrysanthemum flowers in North Sulawesi are marketed in raw form, because in North Sulawesi chrysanthemum flowers have not been developed into processed products.

North Sulawesi province is the second largest producer of cloves in Indonesia by producing 20.202 tons of cloves in 2015. Clove crop yields are marketed to various countries. As with chrysanthemum flowers, almost all marketed cloves are still raw. Especially in North Sulawesi, there are no processed factories for clove commodities.

Table 1: Clove farming in Indonesia

No.	Provinsi / *Province*	Jumlah *Total*	
		Luas Areal *Area* (Ha)	Produksi *Production* (Ton)
1.	ACEH	22.476	4.577
2.	SUMATERA UTARA	3.172	640
3.	SUMATERA BARAT	8.189	1.877
4.	R I A U	-	-
5.	KEPULAUAN RIAU	15.432	2.445
6.	J A M B I	165	29
7.	SUMATERA SELATAN	287	57
8.	KEP. BANGKA BELITUNG	19	2
9.	BENGKULU	1.327	88
10.	LAMPUNG	7.746	1.059
	SUMATERA	58.812	10.773
11.	DKI JAKARTA	-	-
12.	JAWA BARAT	33.769	6.898
13.	BANTEN	12.957	3.320
14.	JAWA TENGAH	42.348	6.608
15.	D.I. YOGYAKARTA	3.150	450
16.	JAWA TIMUR	45.474	9.879
	JAWA	137.698	27.155
17.	B A L I	15.404	4.223
18.	NUSA TENGGARA BARAT	2.603	106
19.	NUSA TENGGARA TIMUR	14.604	3.018
	NUSA TENGGARA	32.610	7.347
21	KALIMANTAN TENGAH	5	-
22.	KALIMANTAN SELATAN	405	80
23.	KALIMANTAN TIMUR	-	-
24	KALIMANTAN UTARA		
	KALIMANTAN	1.300	352
25.	SULAWESI UTARA	74.825	20.202
26.	GORONTALO	9.091	604
27.	SULAWESI TENGAH	67.545	14.692
28.	SULAWESI SELATAN	56.075	18.940
29.	SULAWESI BARAT	2.596	668
30.	SULAWESI TENGGARA	29.427	14.169
	SULAWESI	239.559	69.275
31.	M A L U K U	43.772	20.326
32.	MALUKU UTARA	20.732	4.357
33.	PAPUA	576	3
34.	PAPUA BARAT	634	53
	MALUKU + PAPUA	65.714	24.739
	I N D O N E S I A	535.694	139.641

5. METHODOLOGY

The steaming process referred to in this journal is the process of extracting organic material through heating in the reactor chamber. The extraction method is executed instead of using additional heat from the combustion chamber but using heat transfer from geothermal brine which still has a relatively high operating temperature. The basic principle utilized is heat transfer in the fluid, especially the process of heat-transfer in conduction and thermodynamics diagrams phase.

5.1 Conduction Heat Transfer

Conduction is heat transfer through stationary matter by physical contact. This heat transfer occurs because of the difference in temperature on the 2 walls of the material flowing perpendicular to the plane of temperature difference which is carried out through solid electron molecules that are stationary. In this formula, conduction is the process of heat transfer with the function of temperature and distance.

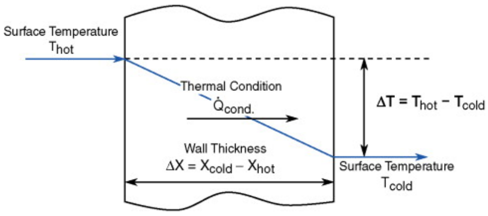

Figure 5: Illustration of conduction heat transfer

So that the equation is obtained as follows:

$$\dot{Q} \sim \frac{(A)(\Delta T)}{\Delta x} \text{ or } \dot{Q} = kA\frac{(T_h - T_c)}{\Delta x} = -kA\frac{(T_c - T_h)}{\Delta x} = -kA\frac{\Delta T}{\Delta x} \quad (1)$$

In this equation, thermal conductivity (k; w/mK) merupakan transport property, and Parameter A is the cross-sectional area (m2) of the plane and Δx is the wall thickness (m).

Based on this equation, the design of the steaming process follows the calculation rules of the formula in selecting materials for reactor fabrication.

5.2 Thermodynamic Diagram Phase

Phase diagrams are graphical representations of substances under different conditions of temperature and pressure. A typical phase diagram has pressure on the y-axis and temperature on the x-axis. At certain pressures and temperatures, a material can undergo a phase change due to the presence of latent heat. Latent heat is the energy absorbed or released from a substance or a solid or vice versa.

Changing in phase is the effect of the existence of one of the physical properties of matter, namely being. The physical properties of substances themselves are properties that can be observed directly without changing the composition of substances, such as appearance, color, solubility, electrical conductivity, and magnetism, melting point and boiling point.

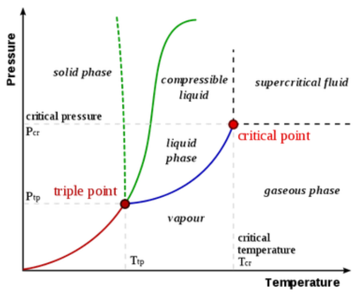

Figure 6: Diagram Phase

In physics principles, this phase change can be simplified in the following formula:

$$Q = mL \quad (2)$$

Where Q,m,L are heat, material mass, and latent heat, respectively.

The characteristics of latent heat is used by the extraction and condensation stage of steaming process. The latent heat approach of organic material is used to get the right parameter settings to do the reactor design.

5.3 Working Process

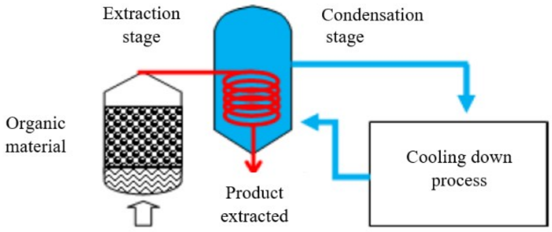

Figure 7: Extraction and condensation process

Based on the theoretical approach, the steaming process is described as in the picture above. Organic material will go through the extraction process in reactor. Then the extraction product, in the form of steam, will flow to the tubing and then experience condensation obtaining the essential oil. This steaming reactor was modified to get a heat source from geothermal brine by tapping on the outlet separator pipeline before heading to the cooling pond. This process is adjusted to the amount of brine that could flow around the reactor tube blanket to then accelerate the transfer of heat to the reactor's inside. Furthermore, the extracted steam will condense at temperatures below the freezing point of water.

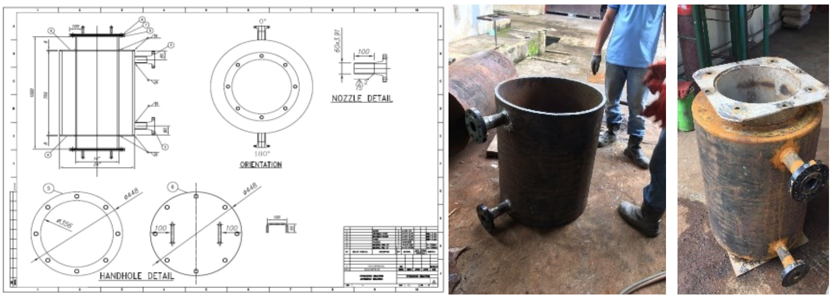

Figure 8: Design and fabrication

The reactor is fabricated in an internal workshop using surplus project materials in Lahendong area. The components used include as follows:

Table 2: Components of reactor

No	Component	Material Type	Thermal conductivity (k)
1	Gasket	Klingerit	0.42 W/mK
2	Hand hole cover	A 240 304	17 W/mK
3	Hand hole flange	A 240 304	17 W/mK
4	Cover	A 240 304	17 W/mK
5	External pipe 24 in	A 216 Gr. B	51 W/mK
6	Internal Pipe 14 in	A 312 TP316	16.3 W/mK

The selection of designs and components is based on the estimated capacity of the material to be extracted as an initial experiment. The result of this design is then tested through penetrant test on welded connection only. Other tests were not carried out because the operational conditions would later be carried out at atmospheric pressure.

Furthermore, monitoring and evaluation of reactor fabrication is conducted during testing and commissioning. Temperature is measured by *Thermogun* which was evaluated every 60 min. Then the pressure is monitored by installing a pressure gauge on the top of the reactor.

The condenser unit used is a refurbished unit from the geothermal sampling process so that the design and fabrication standards have followed market standards. This unit consists of a tube and coil tubing that stay on the inside of the tube. According its design, extraction steam will flow inside the coil tubing and condense due to absorption of heat by a mixture of water and ice that fills the tube.

For the initial experiment, Chrysanthemum plants are used to extract 1 kg of water dissolved in 15 liters of water. The steaming process lasts 120 minutes.

5. RESULT AND CONCLUSION

After extracting 1 kg of chrysanthemum with 10 liters of fresh water, within one hour the temperature at the reactor reached 82 ° C and the water had begun to come out of the condenser. The water start to release the fragrant of chrysanthemum flowers. But to distinguish between water and essential oils is still quite difficult, only the water produced is yellowish and sweet-scented of flowers. In 2 hours of extraction processing, 600ml of yellowish water is produced with a distinctive fragrance of chrysanthemum flowers.

Figure 9: Extraction process of Chrysanthemum

From this steaming process, it can be concluded that, this method could produce essential oils with a longer product life compared to unprocessed chrysanthemum flowers. The durability of this processed flower can be a additional advantage for farmers for any flowers that could not be bought by consumers. Moreover, due to heat source of geothermal brine, local farmers do not need additional costs to use this facility. To sum up, farmers do not need to worry about their excessive product of chrysanthemum because it could be extracted to be various derivative product without any additional cost occurred.

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