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Study of Geothermal Utilization for Milk Pasteurization in Pangalengen, Indonesia

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ABSTRACT

Indonesia has a lot of potential geothermal resources ranging from low to high enthalpy and generally are located in mountainous areas with agricultural lands. One of them is geothermal resources in Wayang Windu – Pangalengan where is a region known for dairy farms. Until now the milk pasteurization process conducted in rural dairy industries at pangalengan, West Java are still using steam produced by boilers which use diesel oil as fuel. As the market price of diesel oil is increasing, the production cost of milk pasteurization is also getting higher. For this reason a study was conducted to assess the possibility of utilizing Wayang Windu geothermal brine for milk pasteurization process in a dairy industry at Pangalengan.

Analysis of this study includes the analysis of the energy balance, basic design process and thermal equipment. By designing a specific and simple heat exchanger and using about 27 kg/s brine we can generate steam which is sufficient to pasteurize 6,000 liters milk per day.

1. INTRODUCTION

In Indonesia, the utilization of geothermal energy directly (direct use) is still very low than some developed countries such as America, Europe, Japan and New Zealand who have utilized geothermal energy for non-electric in a variety of fields, from agriculture to tourism. Though Indonesia has a lot of potential geothermal resources ranging from low to high enthalpy and generally is located in mountainous areas with fertile land, making it suitable for agriculture, agro-industry or tourism around it. In these areas, geothermal energy can be used for various direct use applications like for the processes of drying and preserving agricultural products (e.g. tea, coffee, cocoa, grains), sterilization of growing medium (e.g. mushrooms, potatoes), farming (e.g. chicken laying hens, chicken broilers, pasteurized of milk, shrimp, fish , etc.), space heating, bathing and spa resort.

Some geothermal fields that have been developed in Indonesia has characteristics of a water dominance such as Wayang Windu, Gunung Salak, Lahendong, Sibayak, Dieng and several other geothermal fields. In general, there is brine from a separator in existing power plants which still contain high heat, but unfortunately the residual heat from the brine has not been utilized. The hot brine is injected directly back into the well. Whereas the hot brine can be use for various direct use applications before injected to the well.

The purpose of this study is expected to obtain a milk pasteurization system by utilizing brine from the separator in existing power plant to produce 6,000 liters/day of milk pasteurized.

2. DIRECT USE APPLICATION IN INDONESIA

Currently, utilization of geothermal energy in Indonesia focus on the development of electricity generation. However, the government has released regulation No. 27/2003 which states that geothermal energy must also be developed for direct use, but up to now its implementation is still very low.

Agency for the Assessment and Application of Technology (BPPT) has began to investigate methods to apply geothermal energy to the agriculture sector like palm sugar processing, copra drying, tea drying and to sterilized the growing medium used in mushroom cultivation. However, except the palm sugar processing, the other activities are still at the research stage having not yet become commercial.

A paper by Surana et al.(2010) indicates additional direct use installations in the country as follows:

2.1 Bathing and swiming

The most common and traditional usage of geothermal energy in Indonesia is for balneology, bathing and heated swimming pools. For example: a heated swimming pool from a hot spring which is commercially exploited in Cipanas, Garut and Cibolang, Pangalengan of West Java province and the utilization of steam by Pertamina Geothermal Energy to heat up freshwater for domestic and office use in Kamojang Geothermal Field.

2.2 Agriculture

<u>2.2.1 Palm sugar processes in Lahendong Field</u>

Lahendong geothermal field is surrounded with a palm sugar plantation which is managed by about 3,500 farmers. 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 production (Figure 1) with the 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.

Figure 1: Direct-use for palm sugar production in Lahendong Field (Surana et al, 2010)

The schematic diagram of the facility is as shown in Figure 2. 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 Netherland.

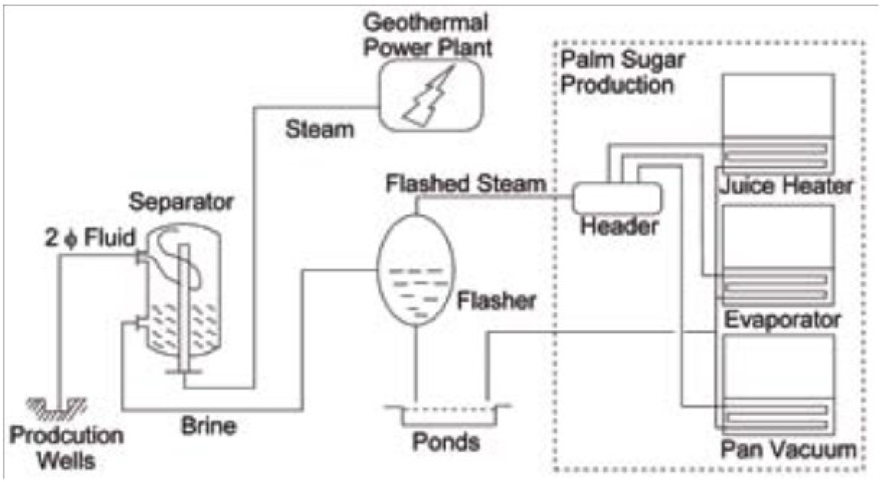

Figure 2: Schematic diagram of palm sugar production byutilizing brine (Surana et al, 2010)

<u>2.2.2 Copra and cocoa in Way Ratai field</u>

Way Ratai is an undeveloped geothermal field in Lampung Province, located in a coconut plantation area. There are many natural shallow wells in it with temperature range between 80 – 98ºC. BPPT (Agency for the Assessment and Application of Technology) implemented a pilot plant for the utilization of natural geothermal well for coconut meat drying (copra) in this field in 2003 – 2004, with the capacity of 200 kg coconut meat per batch. The facility consists of a downhole heat exchanger, a drying room, a pump, and a freshwater tank. The schematic diagram of the facility is as shown in Figure 3. The downhole heat exchanger is put into a natural geothermal well with the depth of 2 m and the temperature of 80 - 95ºC (Figure 4), and the freshwater is flowed into it. The freshwater is heated up and directed to the drying room which is kept at the temperature of 50ºC to dry up the coconut meat by natural draft conductive heat exchange. The quality of the copra produced in this facility is much better compared to the conventional one because there is no smoke contamination on it.

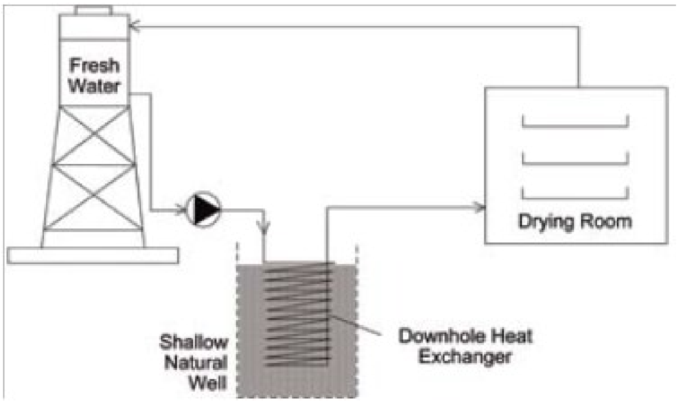

Figure 3: Schematic diagram of copra drying by utilizing shallow natural well (Surana et al, 2010)

Figure 4: Downhole heat exchanger in natural geothermal well (Surana et al, 2010)

In 2008, near the location of the copra drying, BPPT also implemented a pilot plant of cocoa drying by utilized the shallow geothermal well. The well is made artificially from an existing hot water seepage on the ground with a temperature in a range from 85ºC - 95ºC.

2.2.3 Mushroom cultivation in Kamojang field

BPPT with the cooperation of Pertamina Geothermal Energy implemented a pilot plant of the geothermal energy direct use for mushroom cultivation in Kamojang Geothermal Field (West Java). The facility consists of a steam generator heat exchanger, an autoclave, a freshwater tank, an inoculation room, incubation rooms and production rooms. The schematic diagram of the facility is as shown in Figure 5 below. Dry steam from a small capacity well with the temperature of 110-120ºC is directed to a steam generator to heat up fresh water. The heated fresh-steam is used to sterilize the mushroom growing media, or as so called “bag-log”, and also for space heating to keep the incubation room warm. The geothermal steam is to substitute the use of fossil fuel (kerosene) which is getting very expensive every year.

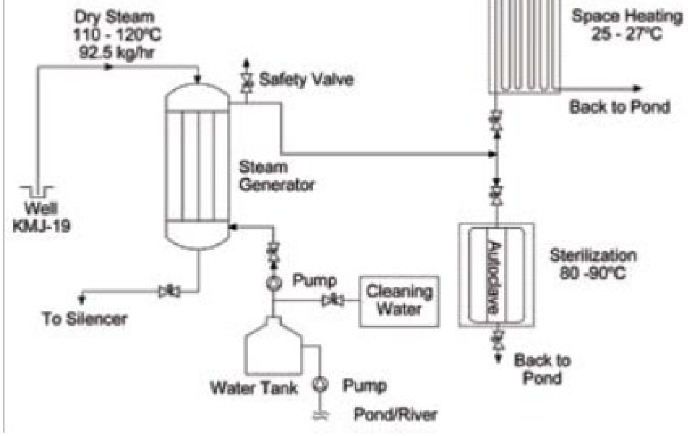

Figure 5: Schematic diagram of mushroom cultivation by utilizing steam from small production well (Surana et al, 2010)

2.2.4 Catfish farming

Another direct use application is cat fish farming at Lampung Province. They are mixing the fresh water from a river with natural geothermal hot water (natural outflow) to grow large cat fish. The farmer reported that the fish grow better in the geothermal fluid and fresh water mixture.

3. MILK PASTEURIZATION INDUSTRY IN PANGALENGAN

The objective of pasteurization is to preserve milk by slowing the growth of bacteria through heating up the milk until require temperature. Pasteurization conditions are designed to effectively destroy the organism Mycrobacterium tuberculosis and Coxiella burnettii. In general, pasteurization process using steam produced by boilers which use diesel oil as fuel, but in Klamath Falls, Oregon- USA and Oradea, Romania, the pasteurization process operated by utilized geothermal fluid as describe by Lund (1997) in his paper. In this study, the author tried to analyze the possibility of geothermal utilization for pasteurization process in milk treatment at KPBS-Pangalengan.

In Codex Standard (CAC/RCP 57-2004) it states the definition of pasteurization is the microbiocidal heat treatment aimed at reducing the number of any pathogenic micro-organisms in milk and liquid milk products, to a level at which they do not constitute a significant health hazard. Pasteurization can either be carried out as a batch operation (“batch pasteurization”or “LTLT-pasteurization” (low temperature, long time)), with the product heated and held in an enclosed tank, or as a continuous operation (“HTST-pasteurization”(high temperature, short time)) with the product heated in a heat exchanger and then held in a holding tube for the required time. The minimum pasteurization conditions are those having bactericidal effects equivalent to heating every particle of the milk to 72°C for 15 seconds (HTST pasteurization) or 63°C for 30 minutes (LTLT pasteurization).

Currently, the most common method of pasteurization is by means of heat exchangers designed for the HTST process (high temperature short time). This process involves heating the milk to a certain temperature, holding at that temperature under continuous turbulent flow conditions for a sufficiently long time, to ensure the destruction and/or inhibition of any hazardous micro-organisms that may be present. An additional outcome is the delay of the onset of microbiological deterioration, extending the shelf life of milk. To save energy, heat is regenerated, i.e. the chilled milk feeding the exchangers is heated by the pasteurized milk leaving the pasteurization unit.

According to validations carried out on whole milk, the minimum pasteurization conditions are those having bactericidal effects equivalent to heating every particle of the milk to 72°C for 15 seconds (continuous flow pasteurization) or 63°C for 30 minutes (batch pasteurization).To ensure that each particle is sufficiently heated, the milk flow in heat exchangers should be turbulent, i.e. the Reynolds number should be sufficiently high.

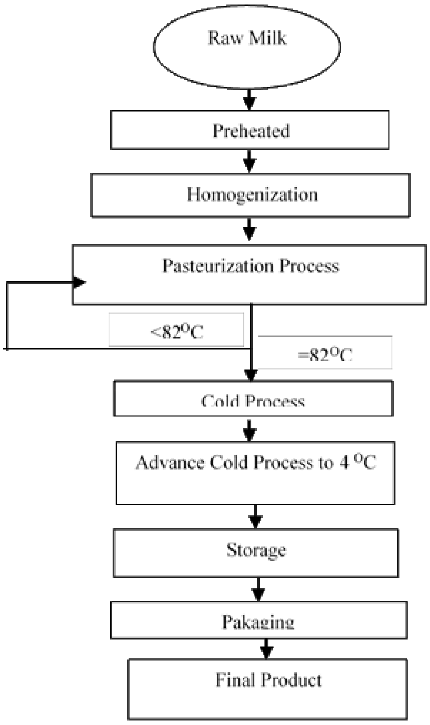

Figure 6: Flow chart of pasteurize milk production at KPBS.

Milk produced by KPBS consists of two types are pasteurized milk with flavor and without flavor. But the principle of pasteurization process is the same. The difference is in the preparation stage where the pasteurized milk with flavor, after the preheated process, has some sugar and flavor added and then heated again in the pasteurization unit. Here is the flow chart of pasteurize milk production at KPBS.

According to information from KBPS, we obtained data about pasteurized milk production as follows:

Table 1. Data of pasteurized milk production

Average volume of pasteurized milk production	6,000 liter/day
Hot water inlet temperature to pasteurizer unit	90°C
Hot water outlet temperature from pasteurizer unit	80°C
Milk inlet temperatur to pasteurizer unit	60°C
Milk Outlet temperatur from pasteurizer unit	82°C
average fuel consumption for boiler unit	90 liter/day

4. DESIGN OF PASTEURIZATION SYSTEM BY GEOTHERMAL FLUID

From the flow chart and data as above, we've designed the heat exchanger to replace the boiler function by utilized brine from the separator at existing power plant. The schematic diagram of the facility is as shown in Figure 7 below.

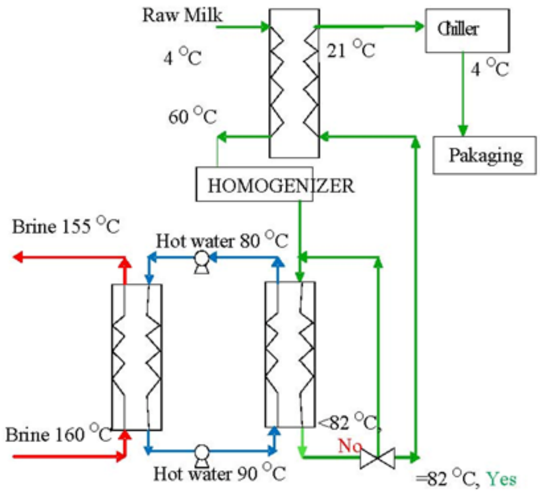

Figure 7: The schematic diagram of pasteurization system by geothermal fluid

Because of the distance between the reinjection pipes of the geothermal fluid with the location of milk treatment plant is very far, about 10 km, and to avoid silica scaling caused by the temperature decrease along the distribution pipe, the author chose to utilize the hot fresh water from the brine reinjection well location to the milk treatment plant. The other reason is to avoid poisoning caused by pipeline leaks that might occur.

To generate the required hot water in the pasteurizer unit, the author tried to design a shell and tube heat exchanger, that were positioned near the brine reinjection well location. It will transfer heat from the brine to the freshwater so that the water temperature will rise accordingly the temperature required by pasteurization process on KPBS.

With the temperature required in the pasteurization process on KPBS, it can be calculated the mass and energy balance so that we will find the hot water required for to the process.

$$M_{water} .Cp_{water} .(T_{in\ water} - T_{out\ water}) = M_{milk} .Cp_{milk} (T_{in\ milk} - T_{out\ milk})$$

The result of the calculation is that the water required for the pasteurization process is 1.17 kg/s and the heat energy required is equal to 49.2 kJ/s.

If the pipes that distribute hot water to the pasteurization unit contain fluid temperature higher than the air temperature outside of pipe it will result in a heat loss during the fluid flow process. The rate of heat loss depends on the thickness of pipe insulation, conductivity coefficient of the material and the inside and outside temperature.

To determine the initial water temperature to be supplied to the pasteurization unit, we first made the assumption that the outlet temperature from brine – water heat exchanger is 134°C. By continuous iteration we obtained the result that the temperature decline along the pipe is 3.62°C/ km and heat loss is 18.12 watts/m. So that we can find the outlet temperature of hot water that goes back to the heat exchanger is 51.2oC. To be able utilize the hot water as far as 10 km it will need considerable pressure, and the phase of water must be constant in liquid phase.

The result of difference pressure calculation at a long pipe can be seen in Table 2.

Table 2. Difference pressure at a long pipe

Parameter	Value	unit
Initial Temperature	134	C
Density (ρ)	931.4028	kg/m^3
Viscosity (μ)	0.000206	pa.s
Velocity (V)	0.580304	m/s
Pipe Diameter	0.052502	meter
Pipe Material	Steel	
Pipe roughness (e)	0.00045	meter
e/D	0.008571	
Reynolds number (Re)	137.716	turbulent
Friction coefficient (f)	0.036486	
Pessure difference (ΔP)	13.07814	bar
Outlet pressure (P_B)	1	bar
Inlet pressure (P_A)	14.07	bar

According to the calculation we will need a pump to utilize 1.17 kg/s of hot water as long as the10 - 12 km pipe has a pressure difference of 13.07 bars. If the pump efficiency is 80%, the needed pump power is then 2 kW. Another pump to pump back of hot water from pasteurization unit to Heat exchanger will need the same power of 2 kW so total electricity for operating the pumps is 4 kW.

The brine consumption to generate 1.17 kg/s of hot water is 18.78 kg/s and as the known resources of brine is 27 kg/s it is sufficient to generate it.

5. DESIGN OF HEAT EXCHANGER

Heat exchangers have always been an important part to the operation of many systems. A heat exchanger is a device built for efficient heat transfer from one medium to another in order to carry and process energy. A typical heat exchanger, usually for higher pressure applications is the shell and tube heat exchanger. Shell and tube type heat exchanger is an indirect contact type heat exchanger as it consists of a series of tubes, through which one of the fluids runs. The shell is a container for the shell fluid.

To be able to transfer heat from brine to freshwater, the authors designed a shell and tube heat exchanger by considering the temperature data of the above calculation. From the calculation results obtained information that the shell side pressure drop is 0.019 bar and 0.05 on the side of the tube. Overall heat transfer coefficient of the shell side is 3,589 watt/m2K and 10,033.8 watt/m2K on the tube side. Average flow velocity on the tube side is 1.72 m/s, and 0.29 m/s on the shell side. The total heat transfer that occurs is 406.88 kW.

Dimensions of the shell and tube heat exchanger designed are as follows: shell size 0.257 m x 1.2 m, or in other words a shell diameter of 10 inches and a length of 1.2 meters. While the tube is ¾ in diameter with a length of 1.2 m and the number of tube is 55 pieces. The construction of the shell and tube arrangement is shown in Figure 8 and Figure 9 below.

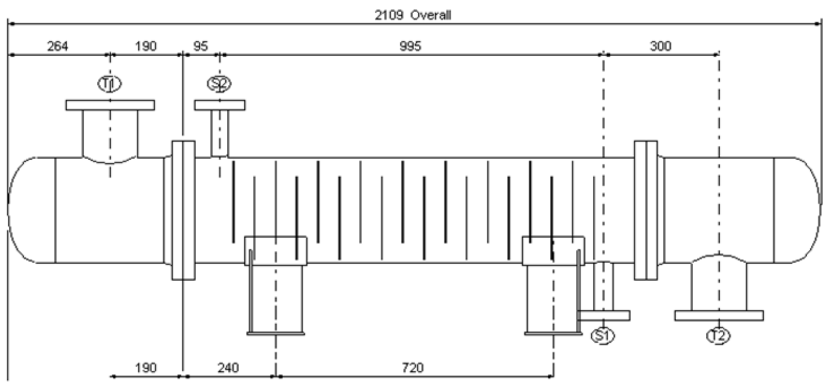

Figure 8: Form of shell construction

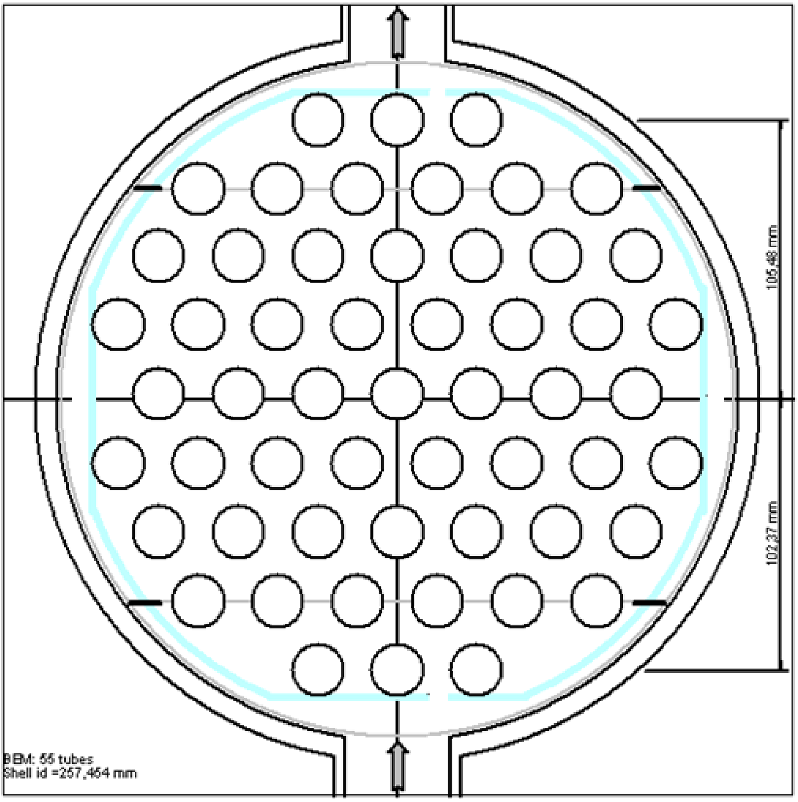

Figure 9: Tube arrangement configuration

In taking the decision to implementing the replacement of a boiler with a heat exchanger which utilizes geothermal fluid is not only seen from the technical aspects alone, but must be seen also from the aspect of cost that will be spent. The calculation of the investment cost to boiler replacement by heat exchanger and hot water distribution pipe from reinjection well locations to milk treatment plant can be seen in Table 3.

Table 3. The investment cost to built heat exchanger and distribution pipe

Item Specification	Volume	Cost per unit US$	Summary Cost US $
Pump 5 m$^{3/}$h, 14 bar, 2 kW	2 unit	1,500	3,000
Shell &Tube Heat Exchanger 257 mm x 1200 mm	1 unit	15,000	15,000
carbon steel pipe, NPS 2, SCH 40, 2.964 lb/ft (4.4 kg/m)	159 ton	2,000	317,120
IsolasiPolyurethane, k= 0.03, panjang 12 km, tebal 2 in	207 m^3	540	111,780
		Total	446,900

If we compare the boiler price, for the same life cycle the boiler is cheaper than the investment cost of heat exchanger and distribution pipe, but operating cost can be considered as significant savings. If the fuel cost spent to operate the boiler is about US$ 26,865/year, then by using the shell and tube heat exchanger can be eliminated fuel cost, other expenses is the cost of electricity to operate the pump that will pump hot water to and from the shell and tube heat exchanger. The cost is around US$ 381/year. From the calculation above, the cost can be saved by replacing boilers with shell and tube heat exchanger unit is equal to US$ 26,484/year. However IRR for this investment is not very attractive to an investor.

6. NEW MILK TREATMENT PLANT

Considering the distance between reinjection well and the milk treatment plant location, causes expensive piping cost, so the author choose another alternative to make a new milk treatment plant close to the reinjection well. This consideration is also based on the existing number of cow breeders around the site.

Total investment cost for a new milk treatment is approximately US$ 1,000,000. If the operational and maintenance cost per month is about 5% of total investment, and assumed that the source of funding is 50% from a loan for 15 years of loan term, with 10% discount rate and interest at 12%. Then by calculating Net Present Value (NPV) and IRR, so payback periods for this investment is less than 2 years. This alternative is considered quite reasonable and attractive to investors.

7. CONCLUSIONS AND RECOMMEDATIONS

The conclusion is that the brine from a separator in an existing power plant can be used for the pasteurization process or another agriculture process. By designing a specific and simple heat exchanger and using about 27 kg/s brine we can generate steam which is sufficient to pasteurize 6,000 liters milk per day.

In order to accelerate the development of direct use in Indonesia, it is recommended to implement some actions such as the following:

- Government regulations on geothermal direct use development must be issued soon. Some aspects which should be included in the regulations about direct use of geothermal.
- Engineering standard for various applications, basically by grouping into edible and non-edible products, in order to prevent geothermal fluid contamination (for safety reason).

8. ACKNOWLEDGEMENTS

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