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THE ANALYSIS OF THE TECHNOLOGICAL PROCESSES OF FLAX AND HEMP MELTING USING GEOTHERMAL WATER, FROM THE PERSPECTIVE OF THERMAL ENERGY CONSUMPTION

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Abstract. One of the viable solutions of applying modern technologies for flax and hemp melting is the use of geothermal water in the preparation of the hot water for the tanks. The aim of this paper is to adjust the thermal power potential of an existing geothermal source to the local needs for primary processing of the flax and hemp harvested in the areas contiguous to the location of the well no. 1720 in Sântandrei. In order to analyze this, we will establish the thermal energy needs (in fact, the thermal power needs), based on the size of the tanks used for flax and hemp melting using geothermal water, and on the environmental temperature.

1. Theoretical Considerations Regarding the Use of Geothermal Water for Flax and Hemp Melting

The aim of this paper of to adjust the thermal power potential of an existing geothermal source to the local needs for primary processing of the flax and hemp harvested in the areas contiguous to the location of the well no. 1720 in Sântandrei, establishing the thermal power needs based on the size of the tanks which are used for flax and hemp melting using geothermal water, and on the environmental temperature.The direct application of geothermal energy can involve a wide variety of final uses. The technology, the security, the economy and the ecological acceptability of the direct use of geothermal energy have been proved throughout the world. As compared to electricity production out of geothermal energy, the direct use has several advantages, such as a much higher efficiency of the energy, the developing time is much shorter and a lower capital investment is usually involved. Last but not least, the direct use can use both high temperature geothermal resources and low temperature resources, being thus available internationally to a much larger extent.

Generally speaking, the areas in which the direct use of geothermal energy is used are divided into 4 groups, namely: industrial uses; central heating; agricultural uses; balneology.

One of the viable solutions of applying modern technologies for flax and hemp melting is **the use of geothermal water** in the preparation of the hot water for the melting tanks. This technical solution suggests an energy source having a potential close to the one offered by the waste thermal energy of thermal power stations and iron-and-steel or chemical combines, but it eliminates the inconveniences related to them. The possibility of using a geothermal source which is placed close to the processing centre eliminates the subordinating character with regard to a fluctuant primary process, and all actions can be scheduled according to the momentary needs of the melting processes and not to the availability of the thermal wastes of another technological process. Then the location of the processing centre can remain in rural areas, provided that the geographical area should possess geothermal resources. As far as the possibility of utilization is concerned, we can say that some geothermal sources are very clean, and the water can be used directly in the melting tanks, or indirectly, in normal heat exchangers. In case the chemism of the geothermal waters does not allow for the direct use, surface heat exchangers will be used, made of materials which are proof against corrosion or deposits, or whose constructive solution foresees the possibility of periodical mechanical or chemical cleanings. Although they are more expensive than the exchangers used for clean waters, those used for corrosive waters are available, being designed for other diverse uses of geothermal waters, and they do not constitute a problem in case they are used for the primary processing of flax and hemps.

2. The Power Necessary Based on the Tank Size and on the Environmental Temperature

In order to be able to ideally dimension the tank or the tanks which are going to be used for melting, in the case of the well no. 1720 in Sântandrei, we will calculate the thermal power necessary for several tank sizes, starting from the minimum width of 2.5 m and finishing with the maximum width of 9.5 m, with a difference interval of 0.5 m, the length of the tank being the double of the width, and the depth being constant of 2.2 m, with a 1.8-m storage space on the height. We will calculate these values for several values of the atmospheric temperature: the first one will be the annual (multi-annual) average value, then an average temperature for the cold season and another average value for the warm season. By calculating the average value for three months of the monthly multi-annual average temperatures in Table **Tab. 1**, we can see that for spring and autumn, the temperature values are close to the annual average value for several years ($t_{a\ spring}$ = 10.66 °C, $t_{a\ autumn}$ = 10.76 °C, t_a = 10.2 °C), therefore no separate calculations are necessary for these seasons. For summer, we have an average value of $t_{a\ summer}$ = 20.93 °C, and for winter, an average value of $t_{a\ winter}$ = -0.33 °C. For winter calculations, we will take the vapour values of 0 °C. The average wind speed is not the same either from one season to another, being of 10.8 m/s in summer, of 13.2 in spring and autumn, and of 13.8 in winter. In what air humidity is concerned, not having other data, we will use an average-to-low value for the relative air humidity, of 40% for the annual average value, in spring and autumn, of 30% for summer and 50% for winter, when the number of fog days is higher.

Table 1. The multi-annual monthly average values of the meteorological values of interest for the area of Oradea

Meteorological parameter	Jan. I	Feb. II	Mar. III	Apr. IV	May V	Jun. VI	Jul. VIII	Aug. VII	Sep. IX	Oct. X	Nov. XI	Dec. XII	An. Aver. Val.
Duration of insolation-hours	65.2	84.8	145.8	191.8	245.0	261.0	286.0	266.0	209.0	175.0	76.0	51.0	2056
Maximum air temp.	15.2	19.0	26.4	29.6	33.4	34.5	36.0	36.8	32.6	29.3	22.8	19.8	36.8
Average air temp.	-2.1	0.9	5.2	10.9	15.8	19.0	24.0	19.8	16.0	10.5	5.8	0.2	10.2
Minimum air temp.	-22.8	-20.4	-14.6	-3.1	-0.6	1.9	7.0	5.0	-6.7	-8.3	-14.2	-21.0	-22.8
No. of frost days	25.5	19.0	12.3	2.2	0.2	0.0	0.0	0.0	0.2	3.1	8.7	21.8	93.0
Precipitations, l / month	39.0	32.0	33.0	45.0	59.0	85.0	67.0	58.0	40.0	37.0	47.0	53.0	595.0
No. of days with precipitation	11.9	10.8	11.0	12.3	13.0	12.3	10.7	9.4	8.4	7.8	11.7	13.6	133.0
Wind speed, m / s	13.3	14.1	14.0	13.2	12.0	11.7	13.3	11.1	10.9	12.7	13.0	13.9	12.8
No. of fog days	9.0	5.1	2.1	0.5	0.8	0.6	0.7	0.5	0.9	2.5	5.4	9.5	37.6

The other numerical values which were used are those adopted in the numerical example of the minimum size tank. For multi-annual temperatures different from the average temperature, the saturation pressure values and the vaporization heat values were taken from. The tabular calculation was done using an Excel worksheet. The results are written in **tables 2, 3, and 4**.

Table 2. **The thermal power necessary based on the tank size and on the multi-annual average temperature**

ta =	10.2	°C	tw =	36	°C	qv(tw) =	2416.1	kJ/kg
pa =	0.0124	bar	pw =	0.0594	bar	φ =	0.4	
k =	1.697	W/m2K	wv =	12.8	m/s			
width	length	surface	volume	Qev	Qcv	Qrad	Qcd	Qb2
m	m	m^2	m^3	kW	kW	kW	kW	kW
2.5	5	12.5	27.5	40.79562	10.3612	1.800488	1.269695	54.22708
3	6	18	39.6	58.74569	14.9202	2.592702	1.654982	77.91361
3.5	7	24.5	53.9	79.95941	20.3081	3.528956	2.084052	105.8805
4	8	32	70.4	104.4368	26.5248	4.609249	2.556904	138.1278
4.5	9	40.5	89.1	132.1778	33.5705	5.833581	3.073539	174.6555
5	10	50	110	163.1825	41.4451	7.201951	3.633956	215.4635
5.5	11	60.5	133.1	197.4508	50.1486	8.714361	4.238156	260.5519
6	12	72	158.4	234.9827	59.6809	10.37081	4.886138	309.9207
6.5	13	84.5	185.9	275.7784	70.0422	12.1713	5.577903	363.5698
7	14	98	215.6	319.8376	81.2324	14.11582	6.313451	421.4993
7.5	15	112.5	247.5	367.1605	93.2515	16.20439	7.092781	483.7092
8	16	128	281.6	417.7471	106.099	18.437	7.915894	550.1995
8.5	17	144.5	317.9	471.5973	119.776	20.81364	8.78279	620.9701
9	18	162	356.4	528.7112	134.282	23.33432	9.693468	696.0212
9.5	19	180.5	397.1	589.0887	149.616	25.9990	10.64793	775.352

Table 3. **The thermal power necessary based on the tank size and on the annual average temperature for summer**

ta =	20.94	°C	tw =	36	°C	qv(tw) =	2452	kJ/kg
pa =	0.0246	bar	pw =	0.0594	bar	φ =	0.3	
k =	1.697	W/m2K	wv =	10.8	m/s			
width	length	surface	volume	Qev	Qcv	Qrad	Qcd	Qb2
m	m	m^2	m^3	kW	kW	kW	kW	kW
2.5	5	12.5	27.5	34.20993	5.103081	1.107768	0.741148	41.16193
3	6	18	39.6	49.2623	7.348437	1.595185	0.966048	59.17197
3.5	7	24.5	53.9	67.05146	10.00204	2.171225	1.216505	80.44123
4	8	32	70.4	87.57742	13.06389	2.835885	1.492518	104.9697
4.5	9	40.5	89.1	110.8402	16.53398	3.589167	1.794089	132.7574
5	10	50	110	136.8397	20.41232	4.431071	2.121216	163.8043
5.5	11	60.5	133.1	165.5761	24.69891	5.361596	2.4739	198.1105
6	12	72	158.4	197.0492	29.39375	6.380742	2.852141	235.6758
6.5	13	84.5	185.9	231.2591	34.49683	7.488509	3.255939	276.5004
7	14	98	215.6	268.2058	40.00816	8.684899	3.685293	320.5842
7.5	15	112.5	247.5	307.8894	45.92773	9.969909	4.140205	367.9272
8	16	128	281.6	350.3097	52.25555	11.34354	4.620673	418.5294
8.5	17	144.5	317.9	395.4668	58.99162	12.80579	5.126698	472.3909
9	18	162	356.4	443.3607	66.13593	14.35667	5.65828	529.5116
9.5	19	180.5	397.1	493.9914	73.68849	15.99617	6.215419	589.8915

Table 4. The thermal power necessary based on the tank size and on the annual average temperature for winter

ta =	0	°C	tw =	36	°C	qv(tw) =	2501	kJ/kg
pa =	0.0061	bar	pw =	0.0594	bar	φ =	0.5	
k =	1.697	W/m2K	wv =	13.8	m/s			
width	length	surface	volume	Qev	Qcv	Qrad	Qcd	Qb2
m	m	m2	m3	kW	kW	kW	kW	kW
2.5	5	12.5	27.5	46.51627	15.5871	2.389364	1.771668	66.2644
3	6	18	39.6	66.98343	22.44542	3.440685	2.309278	95.17882
3.5	7	24.5	53.9	91.17189	30.55072	4.683154	2.907979	129.3137
4	8	32	70.4	119.0817	39.90298	6.116773	3.567773	168.6692
4.5	9	40.5	89.1	150.7127	50.5022	7.741541	4.288658	213.2451
5	10	50	110	186.0651	62.3484	9.557458	5.070636	263.0416
5.5	11	60.5	133.1	225.1387	75.44156	11.56452	5.913706	318.0585
6	12	72	158.4	267.9337	89.7817	13.76274	6.817867	378.296
6.5	13	84.5	185.9	314.45	105.3688	16.1521	7.783121	443.754
7	14	98	215.6	364.6876	122.2029	18.73262	8.809466	514.4325
7.5	15	112.5	247.5	418.6464	140.2839	21.50428	9.896904	590.3315
8	16	128	281.6	476.3266	159.6119	24.46709	11.04543	671.451
8.5	17	144.5	317.9	537.7281	180.1869	27.62105	12.25506	757.7911
9	18	162	356.4	602.8509	202.0088	30.96616	13.52577	849.3516
9.5	19	180.5	397.1	671.6949	225.0777	34.50242	14.85757	946.1327

Using the data contained in the three tables, we can draw the curves in **fig. 1**. As it was to be expected, the thermal power necessary rises together with the tank size and with the difference between the optimal melting temperature and the (average) environmental temperature. We can see that a tank having sizes which are close to the maximum sizes recommended in the specialized literature, with the following dimensions: *L · w · h = 19 m · 9.5 m · 2.2 m*, having therefore a volume of almost 400 m^3, loses 946.12 kJ every second in wintertime, which means more than 50% more than it loses in summertime. If we require that the whole thermal power potential of the geothermal well should be used only for melting the stems, whether they are flax or hemp stems, and we suppose that the geothermal water leaves the equipment with a temperature which is 10 °C higher than the environmental temperature (open secondary circuit), which is of -0.33 °C in winter, then the thermal power potential of the well in wintertime is calculated according to the rel. (1):

$$\dot{Q}_s = \dot{m} \cdot C \cdot (t_s - t_e) = 30 \cdot 4.186 \cdot (76 - 10) = 8288.3\ kW \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

which means that a certain number of tanks can be built and operated simultaneously:

$$n = \frac{\sigma \cdot \dot{Q}_s}{\dot{Q}_{b2\max inwint ertime}} = \frac{1 \cdot 8288.3}{946.12} = 8.76 \tan ks \qquad (2)$$

i.e., a number of eight 400-m^3 tanks, without exhausting the whole source potential.

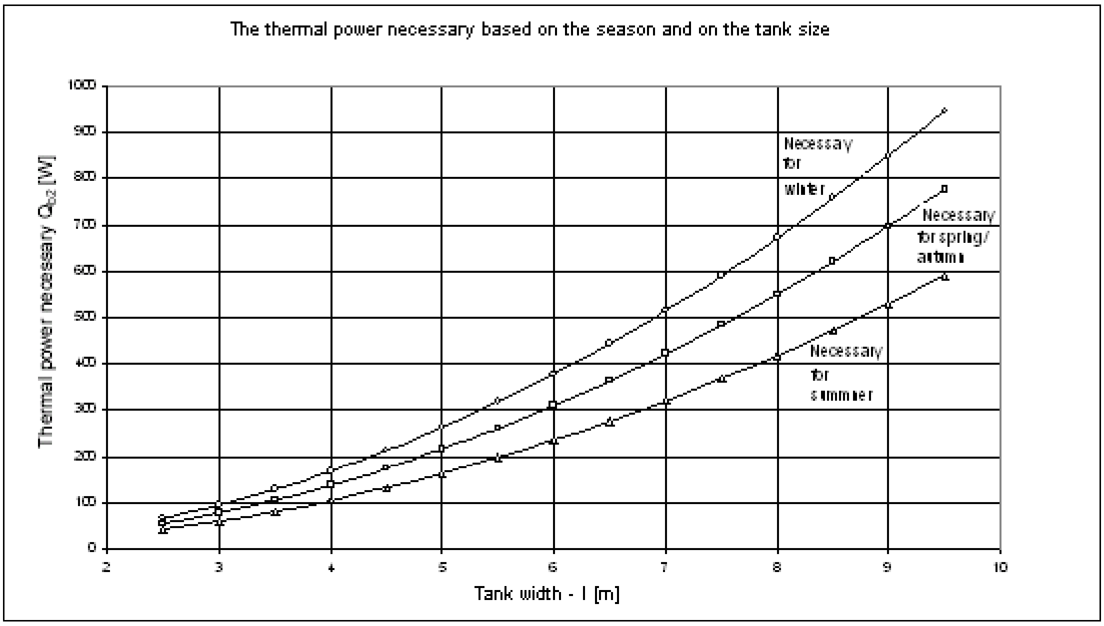

Figure 1. The thermal power necessary based on the season and on the tank size

If we divide the thermal power potential by half between melting and drying (σ = 0.5), then it is obvious that only four 400-m^3 tanks will be able to operate simultaneously for melting. We shall calculate the time necessary for the heating of the four tanks in wintertime. The potential used for the fours tanks is as follows:

$$\dot{Q}_{b1} = 0.5 \cdot \dot{Q}_s = 0.5 \cdot 8288.3 = 4144.15\ kW \quad (3)$$

which means that a thermal power of 1036 kW is available for one tank.

Then we will calculate the minimum value of thermal power loss to the environment, for one tank:

$$\dot{Q}_{b2\min} = \dot{Q}_{ev\min} = \dot{m}_{ev\min} \cdot q_v = \frac{e_{ev\min} \cdot L \cdot l}{1000} \cdot \rho \cdot q_v = \frac{0.435 \cdot 19 \cdot 9.5}{1000} \cdot 1000 \cdot 2501 = 196.4\ kW \quad (4)$$

where the minimum level decrease has the following value:

$$e = 0.02083 \cdot [(p_a - \varphi \cdot p_a) \cdot 760]^{0,8} (1 + 0.85\, w_v) = 0.435 \quad mm/h \quad (5)$$

calculated using the following values: $t_w = t_a = 0\ °C$, $p_a = 0.006108\ bar$ (from [3]), $\varphi = 0.6$ şi $q_v = 2501$ kJ/kgK, and the wind speed has the following winter value: 13.8 m/s. Under these circumstances, the average power which is necessary during the process of heating the water contained in one tank, in order to compensate for the losses to the exterior, will be calculated using the following relation:

$$\dot{Q}_{b2aver} = \frac{\dot{Q}_{b2\max} + \dot{Q}_{b2\min}}{2} = \frac{946.12 + 196.4}{2} = 571.26\ kW \quad (6)$$

and out of the following relation:

$$\dot{Q}_{b1} = \frac{Q_{inc}}{\tau_{inc}} + \frac{\dot{Q}_{b2\max} + \dot{Q}_{b2\min}}{2} \quad (7)$$

we extract the heating time value:

$$\tau_{inc} = \frac{Q_{inc}}{\dot{Q}_{b1} - \dot{Q}_{b2aver}} = \frac{[(1000 \cdot 19 \cdot 9.5 \cdot 2.2 \cdot -25992) \cdot 4186 + 80 \cdot 19 \cdot 9.5 \cdot 1.8 \cdot 2510] \cdot (36 - 0)}{(1036.04 - 571.26) \cdot 10^3}$$
$$= 125378\ s \quad namely\ a\ 34\ hour\ interval$$

3. Conclusions

This is a **maximal interval**, which supposes the initial filling of the tanks with water having a temperature close to the freezing temperature. Actually, the hot air in the cooling tower can be used for preheating the feeding water, or for the preparation of the hot water before introducing it in the tanks. The heating time can be reduced by half, (17 hours, about two changes) if we use the whole thermal power potential of the source, without using drying in parallel. The discontinuous character of the melting operation, which is done by stem batches, makes it impossible to establish a *fixed* optimal regime for using the thermal power potential; the technological melting and drying processes, in case they take place in parallel, should be scheduled so that the potential peak of one of the processes should correspond to a lower loading of the other process. For instance, if a tank (or more tanks) needs to be heated in wintertime for initiating the melting process of a new stem batch, a reduction of the melted stem quantity sent to the drying tower is recommended. For each situation, a thorough schedule of the operations is necessary during an interval of 4 or 5 days, namely as long as it takes for a melting cycle to be able to optimally exploit the thermal power potential of the geothermal source.

The advantages of using geothermal water as an energy source for applying the modern flax and hemp melting technologies are obvious, the most important being the following:

- it eliminates a series of equipment which would have been necessary in modern technologies for ensuring the thermal power: burners, furnaces, hot water boilers or steam generators, etc.
- the removal of costs concerning fuel: acquisition, transport, storing and manipulation.
- for certain moderated chemism sources, geothermal water with a temperature reduced to 35-38 °C can be used directly for melting flax and hemp. This water comes from a previous use (for instance the preparation of hot air for drying). In this case, costs related to heat exchangers necessary for the melting equipment are eliminated.
- the processing centre is not related to the demographic character of the (urban or rural) area, but only to the exploitable geothermal potential
- the technology is less polluting than other solutions which suppose fuel burning; the chemical composition of the geothermal waters in the area of Oradea eliminates the chemical pollution risk
- geothermal energy can be considered to be a renewable resource in case exploitation is connected to a re-injection collector

The disadvantages of using geothermal water are relatively insignificant, but they should be taken into account in order to evaluate the opportunity of adopting this solution for a certain centre of primary flax and hemp processing. The most important disadvantages are the following:

- the centre's processing capacity is limited to the thermal potential of the well (water flow of a certain temperature); the natural flow (artesian) of the well can be substantially raised (even doubled) by mounting a pumping system, either one having a pump fixed on the well head, or – a more economical one – having a plunger pump, but in this case the advantage of the reduced cost of the equipment is eliminated
- the cost of geothermal water; although it is a cheap resource, geothermal water is not

free of charge. The possibility of using geothermal water should be analyzed for each case in part, by way of comparison to the classical solution, which supposes the burning of fossil fuels; the solution which in time proves to be the most economical one and which usually supposes the use of geothermal water should be chosen
- the solution cannot be used anywhere, but only where a geothermal water source is available or where the geological potential indicates the fact that a boring can be done under advantageous economical conditions
- certain geothermal water sources, having a more pronounced chemism, cannot be used directly for melting, and the making of a secondary circuit is necessary which should prepare hot water of 35-38 °C; the heat exchangers are most of the times normal water–water exchangers, but sometimes exchangers made of special corrosion-proof materials are necessary and/or which should offer possibilities of periodic cleaning of the deposits. These are more expensive than normal exchangers
- additional expenses for re-injection in order to completely eliminate the chemical and thermal pollution of the environment

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