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THE PILOT PROJECT OF A GEOTHERMAL HEAT RECUPERATION CASCADE SYSTEM FOR FISH AND VEGETABLE BREEDING, THE PAS MEERI GEOTHERMAL LABORATORY (PODHALE REGION, POLAND)

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ABSTRACT

The article reveals a research run by PAS MEERI Geothermal Laboratory, concerning geothermal heat utilization for fish breeding and vegetable growing.

The investigation aims to evaluate technological ability and productive effect of water utilization having less than 40°C. The research is realized in a geothermal plant at Podhale Geothermal Laboratory.
The plant uses water of 80-90°C temperature that is commercially exploited by PEC Geotermia Podhalańska S.A. to heat buildings and apartments as well as to supply domestic water.
The water coming back from clients has temperature about 40 - 60°C (it depends on the demand), so the heat exchanger outlet geothermal water has a similar temperature range and is reinjected into the ground.
The mentioned temperature range (40 - 60°C) is a subject of a research project titled: "Geothermal water heat use in enhanced fish and vegetable breeding".
The above effort result is experiment and test structure construction for fish breeding and vegetable cultivation.
A particular fish species was chosen for the experiment: an african sheatfish that grows very fast but must be bred in warm water (the temperature over 25°C). The vegetable farming aimed to a significant vegetation period lengthening.
The project and research work together led to structures that use geothermal heat. The latter can be commercially used, especially by already existing geothermal plants.
The framed technique enables using so called "waste heat", unused in building and apartment heating networks.

INTRODUCTION

Since 1994, a Geothermal Plant has been working in Podhale region, Southern Poland (Fig. 1). The first stage was an experimental installation assembled by PAS MEERI, which consisted of two wells, Bańska IG-1 (production) and Biały Dunajec PAN-1 (injection), a heat exchanger system and a connecting pipeline to enable reinjection.

In addition to this installation, experimental heat recovery plants in the PAS area were built which consisted of : a wood drying stove, sill greenhouse, heat exchanger system building and six dwelling-houses, which originated from the heating network constructed in the first stage.

In 1995 - 1998 a fish-breeding building, foil tunnels equipped with soil heating and own heat exchanger system were annexed. Also a distributive network supplying over 250 dwelling-houses was developed (Fig. 2).
All the experimental objects were financed from State Comittee of Scientific Research means that were dedicated to the investigation. They have been working failure-freely till now, being an illustration of multidirectional, clean geothermal energy usage. Owing to that they work, they are also of a significant, instructive importance.

The Geothermal Laboratory units are visited by miscellaneous pupil groups from primary or secondary schools and by high school students during their apprenticeship or master's thesis.
Besides the above, the Geothermal Laboratory hosts many delegations every year, especially of local authorities, willing to learn of clean, ecological heat source and its usage techniques.
The Research Project 027-03 entitled: "Geothermal water heat usage due to intense vegetable cultivation and fish breeding" was stated by PAS proposal. The Project originated from other two independent projects junction. They proposed geothermal water energy usage to vegetable and fish breeding.
Waste energy usage, in case of geothermal installation working for heat engineering needs - low enthalpy back water heat usage, is important, sometimes essential, for thermophilic fish species breeding and foil-sheltered vegetable cultivation.
The main research project executor and task coordinator was PAS MEERI in Cracow, coexecutors were: PAS Institute of Ichthyobiology and Agriculture from Golysz (IIA)- in the field of fish breeding research and Institute of Environmental Engineering from Zabrze (IEE) - in the field of vegetable cultivation.
The mentioned project was interdisciplinary, involving three main fields: geothermal heat engineering, fishery and market-gardening. A condition to start the three research fields was installation and unit constructing that assemble research equipment, divided into three main parts:

- external heat installations
- foil tunnel units with installations
- fish breeding warmed unit with installations.

The above unit erection required elaboration of general desing, technical projects, branch projects such as installations of electricity and water supply system, lightning arrester, sewage system as well as main network connections.

It is worth to mark up that all equipment and parts were innovatory and prototypical.

Many special designs and projects were framed, e.g.:

- design of soil heating installation - so called Agrothermia
- desing of water supply and water managing, including its purification and recirculation in experimental fish breeding unit - so called Fish Breeding
- heat exchanger system project for both units and control-measurement system project.

Moreover the following programs were framed: controlled condition fish breeding, vegetable growing and development in defined conditons combined with seed and seedling selection, and a program of physical and chemical geothermal water in parallel, being a heat source for all heat receivers, parameter examination was framed.

THE RESEARCH COURSE

The research was run in three interdisciplinary fields, coordinated by the Geothermal Laboratory (LG):

- geothermal heat engineering - formed by PAS MEERI
- fishery - formed by PAS IIA
- market-gardening - formed by PAS IEE.

The above work resulted in systems that aim to effective geothermal energy use.

The best effects in this domain are generated by cascade geothermal water heat recuperation (in particular grades).

With regard to differentiated water temperature needs, while distinct processes, owing to their proper arrangement within heating network, one is able to use optimally the geothermal water inner enthalpy.

Temperature decrease of a heat carrier coming back to the source requires increased fuel amount used to sustain a constant outlet temperature value in conventional installations, where the heat supply is fuel combustion e.g. gas or coal furnace.

In case of geothermal heat use there in no further fuel expence.

Additional water cooling, allows more heat to recuperate.

Of course in case of an excessive exploitation a geothermal resource might be overcooled.

This problem must not be overlooked while geothermal plant design and constructing.

As far as the geothermal deposit used by Geothermal Station PAS LG is concerned, accordig to its numeric model it is found that outlet water temperature in the production hole, at the present exploitation rate (about 60 m^3/h), will decrease by 3^0C in 220 years.

Heating installation, in accorcance with cascade heat usage idea, has been devided into particular grades that use heat carrier (water in the case), the parameters adjusted to the requirements.

Partucular heat recuperation units are displayed below (Fig.3.).

Production hole geothermal outlet supplies the heat installation circuit water in two plate heat exchangers.

Owing to plate heat exchangers a profitable geothermal and plant water circuit separation effect is attained.

High-efficient plate exchangers (of efficiency over 95% according to the manufacturer) simultaneously allow effective heat exchange between geothermal and plant circuit water.

Circulating water after being warmed to 65 - 75^0C flows to a pump section. Afterwards the stream splits and supplies two independent circuits:

I. One of them covers heating needs (central heating and domestic waters) of Bańska Niżna village.

Buildings connected to the Bańska village heating system are typical one-family houses in Podhale region as far as thermal characteristics is concerned. The building technology is traditional (hollow tiles and bricks were used). There are 250 houses connected to the main network.

They are equipped with double-pipe heating installation of an open system. Usually cast iron fin heaters are used.

They are connected to a main circuit by heat exchanger compact system, consisting of: dismountable plate exchanger, circulation pump, pressure difference regulator and emergency cutoff device.

Domestic water preparation is performed by voluminous heatersof 150 l capacity, supplied from heat exchanger system.

Energy usage bills are based on a real power demand for a particular object.

Medium power need of a single house amounts 10-15 kW, the installation is provided to supply water of 90 / 70^0C.

The mentioned part of circuit water enthalpy is high enough to render direct outlet water flow into a plate heat exchanger profitless.

Therefore a part of it furnishes the heating system of two foil tunnels of 6x15 m size.

Soil inner heating installation was used in the mentioned tunnels.

At a depth of 30 cm under the soil surface, 20-30 cm far from each other, polyethylene tubes are placed (Φ 32 mm and Φ 25.2 mm).

The above solution resembles to floor heating used in space heating engineering.

Tunnel heating installation is equipped with own indirect heat exchanger (separating tunnel warm water circuit from installation one), collective container, pump section and parameter adjusting system.

Due to even demand distribution of surficial, cultivable soil layer temperature the water temperature decrease in heating grid is negligible- about 2^0C.

The above causes that heat power regulation can be uniquely done by grid water stream flow change.

Calculatory heat power requirement amounts to 29.6 kW for a single tunnel (totally about 59.2 kW).

The tunnel outlet water temperature is about 38 - 43^0C and is led into the plate heat exchangers.

II. The second part of the stream furnishes JAD type heat exchanger with 16 m^2 surface and 560 kW power (placed in an exchanger station). Following items are connected to it:

- central heating system and technological water preparing unit in thermophilic fish building. The latter is of 21.20 x 12.25 m size and built in energy-saving technology "Thermomur". It provides excellent heat-saving parameters.

It is worth to mention that the building needs only about 60% of energy required to heat analogic object built in traditional way (a traditionally built one would need 23.55 kW of heat power contrary to present 14.15 kW).

Building walls are characterized by low thermal conductivity k=0.28 W/m²K (similar thermal conductivity is attained by ceramic wall 1.8 m thick).

An energy-saving plastic window joinery allowing further cutback of heat leakage was used.

Such building technology implementation is especially important due to high indoor temperature (28 - 30⁰C).

Demand of building structural component protection against condensation of air moisture that originates from eight breeding basin water evaporation force such temperature.

Thermophilic fish breeding house also needs heat power due to technologic water preparation.

A necessity of constant breeding basin water purification of organic pollution causes the process heating needs.

During the purification water cools. Constant resupply with previously warmed well water is also necessary.

The basin water should have constant temperature. Its value depends on bred fish species (average range is 25-30⁰C) for african sheatfish, tilapii nilowej and karpia koi.

To warm the technological water central heating system the heat of the backflow water is used.

It furnishes heat by flowing through heat exchanger placed inside a container supplying cleaned technologiczna water.

Having been partially cooled it flows down to the bottom heat source pump where it is cooled again.

- central heating and domestic warm water fabrication in the station building. Its heat needs amount about 13.2 kW (11.2 kW for central heating and 2 kW for doemstic water fabrication). The building is supplied with water of parameters 75/65⁰C.
- ware-house central heating. The ware-house is erected as steel structure insulated with rockwool and soft fiberboard (insulation layer is 100 mm thick), the outside is covered with trapezoid sheet. It is heated with Favier heater 48 m long. Its calculative heat demand amounts to 6 kW.
- drying stove heating. It is a DOKE-140 drying stove, 9 x 3 x 3.25 m sized. Indoor air circulation is forced by electric engine powered fan (power demand: 1.1 - 1.5 kW). The stove is heated by Favier type heater. Its power demand depends on dried wood packing ratio and varies between 21 and 120 kW. The indoor temperature is 40⁰C at supply water parameters 65/45⁰C.
- sill greenhouse central heating. It is a typical sill greenhouse, 12 x 18 m sized, of 907 m³ volume. A part of it is designed as drying stove, described above. The object is supplied with water of 45⁰C temperature that comes back from drying stove. Air temeperature range is 14 - 20 °C. Its calculative heat demand amounts 147.18 kW.

The water supplying the JAD heat exchanger flows into plate exchangers and has temperatures about 20 - 45⁰C (it depends on weather conditions).

The mentioned heating plant heat parameter measurement results are displayed, considering heat consumers.

Due the simultaneous exploitation period of all devices, full measurement involves seven month span: Dec. 1997 till June 1998 (all heating system units were already working then).

The data consist of an informational material allowing to formulate some resolutions concerning the period when they were attained.

According to measurement data a Sankey chart has been created (Fig.5, a data set used to its construction is shown in Table 1) for the mentioned system, due to energy distribution visualization.

The chart shows, that Bańska plant has a significant power reserve that might be used (the reserve equals to 46% of presently used power).

The reinjection water temperature is not high but still usable. Proposed and realized by PAS Geothermal Laboratory solutions can serve as example of the latter.

Such cascade installation model enables the most effective geothermal energy usage. The temperature of water forced into injection well in Biały Dunajec PAN - 1 is not high, but reaches 55⁰C and is still reasonably usable.

The formed model allows to handle the reserve. It has been evaluated that existing fish breeding and vegetable growing units use only about 10% of the "waste" heat.

So there are possibilities to develop the objects on the basis of the presently unused heat.

PRELIMINARY ECONOMIC ESTIMATION

The obtained results were a matter of economic analysis concerning fish breeding and vegetable growing installation effectiveness.

The investigation was run for every field independently. The analysis is based on data obtained during fish breeding and vegetable growing: Nov. 1997 - June 1998.

The span is too short to run full economic investigation, optimizing fish and greens breeding.

Anyway, conditional estimation of productive capacity and sale resulting income was performed.

The results were compared to primary costs (essential to reach supposed productivity). So the research concerned primary costs and possible income.

The fish and greens breeding cost calculation did not include depreciation of the objects that will augment the total cost in final settlement of accounts.

Vegetable growing economic estimation

The research based on run breeding experiments that concerned forecrop, main crop and aftercrop.

Forecrop and aftercrop involved: lettuce, kohlrabi, cabbage, "pekińska", and radish. Main crop involved: tomato, cucumber and sweet pepper.

The possible sale analysis used present vegetable price and cost of seed, fertilizer etc. in the Geothermal Laboratory environs, Podhale market.

Analyzed cases showed that primary costs are very elevated. Their structure showed that the highest ratio belonged to personnel, electricity and heat energy costs respectively (totally over 95%).

The above deliberation reveals that it is essential to run detailed optimization analysis concerning vegetable breeding, e.g. studying yearly tomato breeding monoculture allocated with culture area increase comparing to experimental ones.

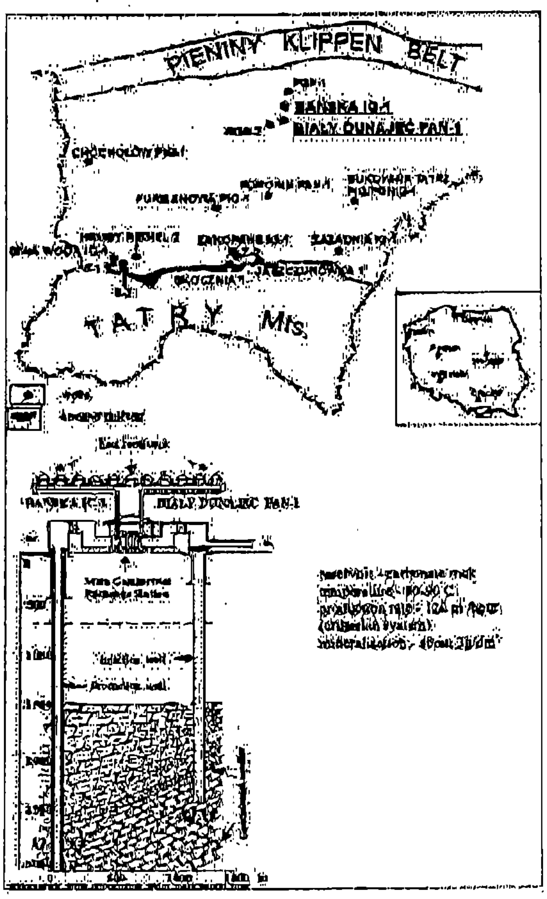
The second option to reach greens breeding profitability is automation of following systems: heating, irrigative and electric as well as personnel reduction.

Fish breeding economic estimation

The investigation was run considering two fish breeding options: eight breeding basins producing 20 tons of fish per year (present situation) or ten breeding basins producing 25 tons yearly (what is technically and technologically possible and easy to attain within existing project).
Both options include fodder price of 0.8$/kg. Cost structure displays that fodder ratio is dominant. It forms 50 - 54% of total cost.
Due to show a possibility to improve this factor a 0.5$/kg fodder possession case has been analyzed. This the price of fodder directly furnished by fodder manufacturer who produces for his own needs.

When the latter condition is fulfilled a financial effect of both technological options (8 and 10 basins) is very gainful. The particular primary cost component ratio is also more advantageous.
An additional resolution is a statement that primary costs generally depend on:
first of all - a fodder cost (minimum 39.6%, maximum 54%) and operating cost (21.6% - 29.7%).
Both components make almost 70% of total cost. Simultaneously component ratio of technical and technological sphere, e.g. electricity, heating, water and sewage make less than 30% of total cost.
It should be mentioned that affirmed building and heating system technology reveals to be very economical while labor amounts only to 2.7 - 3,6% of total operation costs.

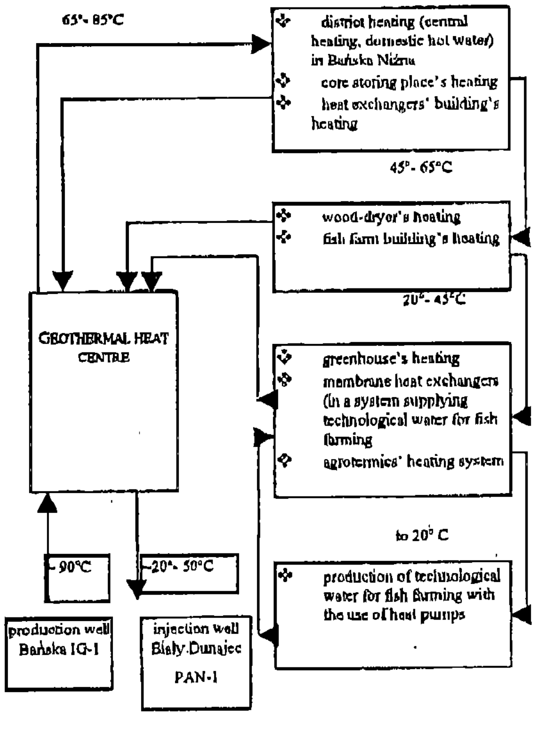
Fig.1. Localisation and working scheme of geothermal dublet in Bańska-Biały Dunajec



CONCLUSION

The task aim, that is to develop new technologies of both recuperation and usage of geothermal heat furnished by water of temperature about 40 - 50°C, was achieved successfully.
The technologies have been tested in a semitechnical field. Elaborated post-executive records enable a technology reproduction in other heating plants, where significant unused heat amount still exists.
The solutions reported here Improve the economic efficiency of such plants. A problem is important especially for the plants that invest a lot in long-term pay-back schemes.
The solution is innovatory not only for Poland but can be implemented in other countries, where geothermal heat utilization is developing
The Project could have been completed on a proper level owing to the three interdisciplinary PAS teams:
PAS MEERI - the general Project Realizer, represented by: Prof. Roman Ney, the paper author together with Geothermal Laboratory employees and PAS IIA from Gołysz represented by: Doc. Jan Szumiec and Mirosław Kuczyński, Ph.D. and PAS IEE from Zabrze represented by: Doc. Czesława Rosik-Dulewska and Mariusz Grabda, M.Sc.
The paper is based on the unpublished three year Research Project realization records. The study is placed in the PAS MEERI Geothermal Laboratory Archive. It was performed by The Laboratory Team:
Wiesław Bujakowski, Ph.D. eng. - the LG Manager
Antoni Barbacki, Ph.D. eng.
Leszek Pająk, M.Sc. eng.
Grazyna Hołojuch, M.Sc. eng.
Agnieszka Kazanowska, M.Sc. eng.
Barbara Uliasz-Misiak, Ph.D. eng.

Fig.2. Cascade system of geothermal energy utilisation in Geothermal Laboratory MEERI PAS in Podhale region



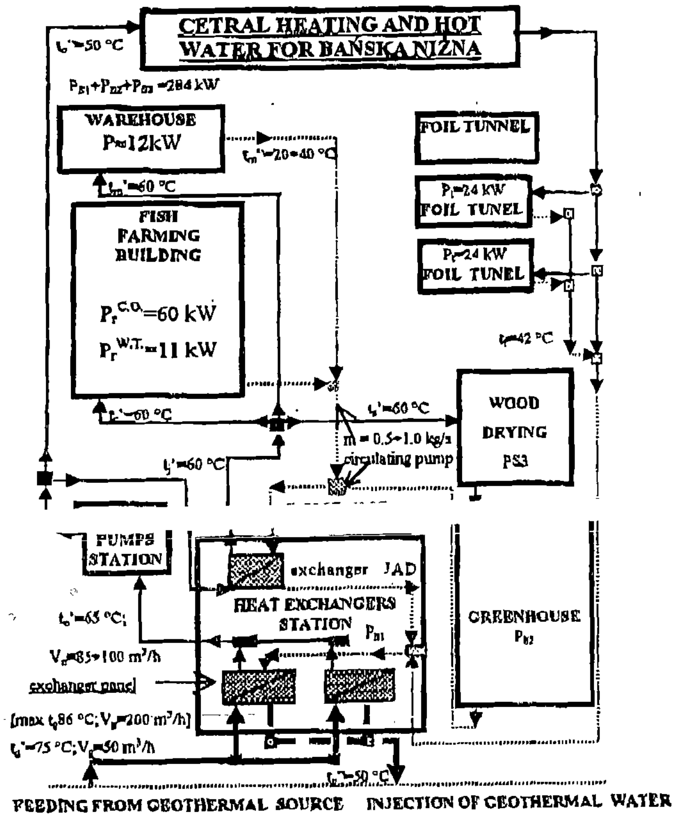


Fig.3. Scheme of instalation working in Geothermal Laboratory MEERI PAS

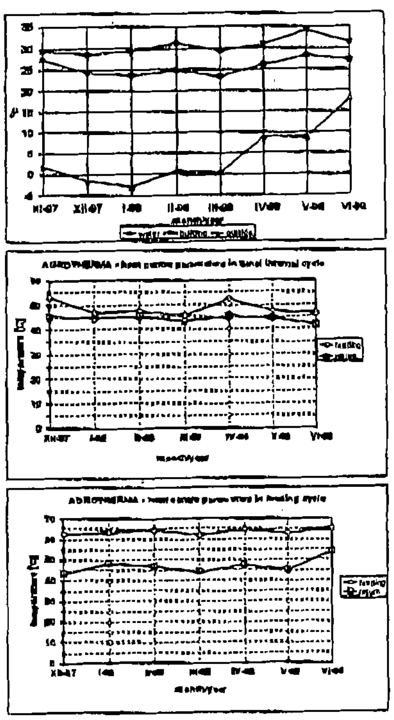


Fig.4. Twenty-four hours temperature change, recored for Geothermal Laboratory objects

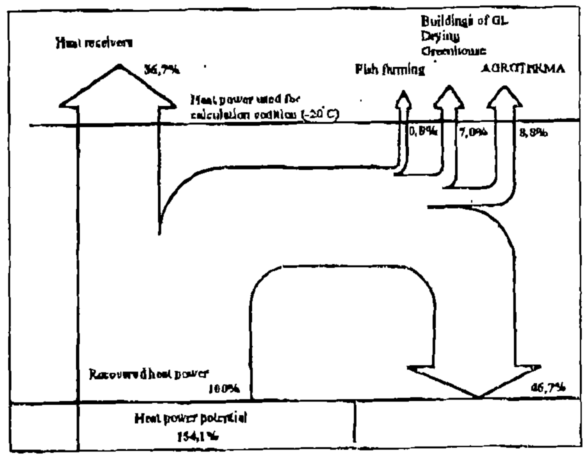


Fig.5. Sankey diagram of flow energy in geothermal heat-generating plant in Banska

Tab. 1. Data set used to Sankey chart composition

Heat power distribution of Bańska Geothermal *Station*

(external conditions -20°C)

		Tz	Tp	Q	P		
Potential heat power of .		°C	°C	m³/h	KW.	%	1/
Bańska Geothermal Station		79,9	5,0	50,0	4 261,8	154,2	2/
Recuperated heat power		79,9	37,5	52,8	2 764,2	100,0	3/
Heat power input		79,9	57,3	52,8	1 473,4	53,3	4/
	Network receivers				1 015,4	36,7	5/
	Geothermal Lab				194,0	7,0	6/
	AGROTERMA	49,3	42,4	28,5	242,8	8,8	7/
	Fish breeding house				21,2	0,8	8/
Absorptive pipeline heat loss		57,3	37,5	52,8	1 290,8	46,7	9/

Remarks:

1/ For heat power calculations water density was set 0.98 kg/dm³, specific heat was set 4.18 kJ/kg K

2/ Maximal Station heat power was calculated under condition of cooling to + 5°C

3/ Recuperated heat power was calculated assuming dt between outlet and inlet holes, at Tz –17°C, and subsequently was corrected by 1.085 coefficient (–17 to –20°C transfer)

4/ Receiver heat power consumption was calculated assuming dt between outlet and inlet of heat exchanger in Geothermal Laboratory, at outdoor temperature of –17°C, and subsequently was corrected by 1.085 coefficient (–17 to –20°C transfer)

5/ Network receiver power inlet was calculaded as difference between measured LG exchanger power and local receivers' one

6/ The measured value was corrected by 1.085 coefficient

7/ The measured value was corrected by 1.085 coefficient

8/ Power inlet calculated according to OZC DANFOSS programme, increased by a value measured at a heat pump

9/ Heat power loss of supplying pipeline was calculated assuming dt between geothermal water LG exchanger outlet and temperature measured in Bialy Dunajec absorptive head, and subsequently was corrected by 1.085 coefficient