PROOF OF THE EFFICIENCY OF THE CO-EVOLUTIONARY METHOD OF HEAT AND COLD SUPPLY IN THE BLACK SEA REGION OF GEORGIA USING THE BATUMI HOTEL COMPLEX AS AN EXAMPLE

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In the article the co-evolutionary method of heating & cooling supply for Black Sea coastline is presented. This method is based on anomaly distribution of seawater temperature in Black Sea depending on depth; namely, the temperature in thermocline starting from 30-50 meters down to 150-200 meters equals to 6-8°C and practically is unchanged during a year. The experiment conducted during 2 years (2009-2010) confirms that within Batumi City sea area the depth temperature of seawater is equal to 8°C and practically in unchanged with increase of depth down to 150 meters.

The analysis performed by the authors and the calculation of the heating & cooling supply system (on example of one of hotel complexes of Batumi City) based on utilization of the seawater of black sea proofs the economical and ecological advantage of the proposed method over the existing ones, namely, electricity cost on air conditioning (cooling) is 11-12 times less than in case of conventional method.

Introduction

To establish an optimal method of hot and cold water supply with regard for electric power-saving, cost-effective and ecological priorities is quite an important task. In the conditions of Georgia, when choosing an efficient method of hot and cold water supply it is necessary to take into account the fact that nearly 90% of Georgia's population live in three climatic zones (the Black Sea region, the lowlands of Western and Eastern Georgia), where for heating system designs the rated air temperature in the wintertime is 2^0C for zone I, 4^0C for zone II and 7^0C for zone III.

This fact against the background of sharp and continuous growth of natural gas prices opens up vast possibilities in Georgia for using in heat supply systems air-water thermal pumps and, in certain favorable conditions, more efficient water-water thermal pumps. Such favorable conditions exist in the Black Sea region of Georgia. The Black Sea is a colossal source of heat for thermal pumps and cold for the air conditioning in the summer season.

Thermal pumps are intended for heating, ventilation and hot water supply, whereas, in addition to this, reversible thermal pumps are designed for producing cold.

About 20 million thermal pumps of various capacity are nowadays functioning in the world. According to the prediction of the World Energy Committee, by 2020 thermal pumps[1] will account for 75% of heat supply in the developed countries.

The efficiency of a thermal pump largely depends on a temperature range in which it operates. For example, for a temperature of -20^0C which is typical of Russia's latitudes, the supply of electric power to thermal pumps from a thermoelectric station does not lead to the saving of fuel due to the use of thermal pumps[2].

In Sweden, on the contrary, where the main electric power source is hydroelectric power stations and nuclear power plants, the use of thermal pumps operating on sea water even of 4^0C lowers the heat production price by 20% as compared with boiler houses.

[1] http://www.nsu.ru/asf/disclub/tepl_nasos/html
[2] http://esco-ecosys.narod.ru/2008_2/art111.htm

The climatic conditions of Ajaria are the most preferable ones for the effective use of thermal pumps, in particular: 1) the design temperature of outdoor air for a heating system is !2^{0}C; 2) the temperature of deep sea water (50 m below sea level) is $t_0 = 8^0$C and remains constant throughout the year – this gives a higher thermotransformation ratio of a thermal pump as compared with $t_0 = 4^0$C and, accordingly, an additional reduction of the heat production cost.

Moreover, the water temperature of 8^{0}C is optimal for being used in air conditioning fankoils either directly or via an inter-contour heat exchanger.

At the present time, this technique of air conditioning in the form of a two-contour system has already been realized in the USA (Cornell university)[3]. The electric power consumption in this system is 10 times less as compared with the traditional method (compression refrigerating machines) of air conditioning.

Some time ago one of the authors of the present paper proposed a one-contour conditioning system (ventilation by cooled air)[4], which consumes electric power nearly 15 times less as compared with the traditional method. However for the already designed and erected buildings preference should be given to the two-contour variant. Therefore in 2009 the heat and cold supply version which employs an inter-contour heat exchanger was proposed for the hotel complex of Batumi.

Literature data on the quantity and distribution of Black Sea water by depth cannot serve as a basis for designing a heat and cold supply system for this concrete part of the Black Sea water area. Therefore, naturally, with the investors' consent it was decided to carry out experimental studies in order to determine the sea water parameters and their distribution throughout the sea depth.

The first stage of these studies was carried out in the summer months of 2009. Tests were run in a depth variation range from 60 to 150 m. The following parameters we measured: water temperature, pressure and electric conductivity (for determining the sea water salinity); also, biological and chemical tests of sea water were performed at a depth of 80 m. The obtained results were submitted to the Customer (GIMG.LTD).

The sea water temperature which is the main parameter recorded at depths 50<H< 80 m was $t_w = 7.8\text{-}8.0^0$C.

However because of the changing character of waves, near-bottom and other currents it was necessary to repeat these marine tests, especially when that concerned water temperature measurements. Hence, with the Customer's (NERATUS) consent it was decided to run tests again in 2010 by analogy with experiments of 2009.

That decision proved to be absolutely justified because in the summer months of 2010 (especially in August) the air and water temperature in the surface layers of the Batumi sea water area had anomalously high values. Thus the importance of the results obtained by the studies carried out in 2010 much increased.

Experimental Investigation of the Black Sea Deep Water Parameters for the Sea Water Area of the City of Batumi

On the basis of the analysis of results obtained in 2009 it was decided to repeat experiments "at a single point", i.e. at the depth H H, 50<H≤ 80 m at a distance of 700 m at most from the sea shore. With this aim in view, we concluded the contract with GEOMAR Co. Ltd which provided our expedition with a special ship and a motor boat and also with specialists who assisted the expedition members of *COSPE* in immersing and lifting from the sea depth a high precision measuring sensor. The experience gained due to the studies of 2009 was used to manufacture and test a special platform used to fixing the sensor and the anchor on the sea mirror. The platform was equipped with a light warning device.

The location of the platform with the measuring sensor and coordinate data in the sea water area of Batumi are shown in Figs. 1-3.

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[3] Cornell University Lake Source Cooling Project. www.gryphoneng. com/projects/cornell_3htm

[4] Black Sea coastal area air conditioning and cooling-effective system. J."Energia", no. 3, 1998, Tbilisi.

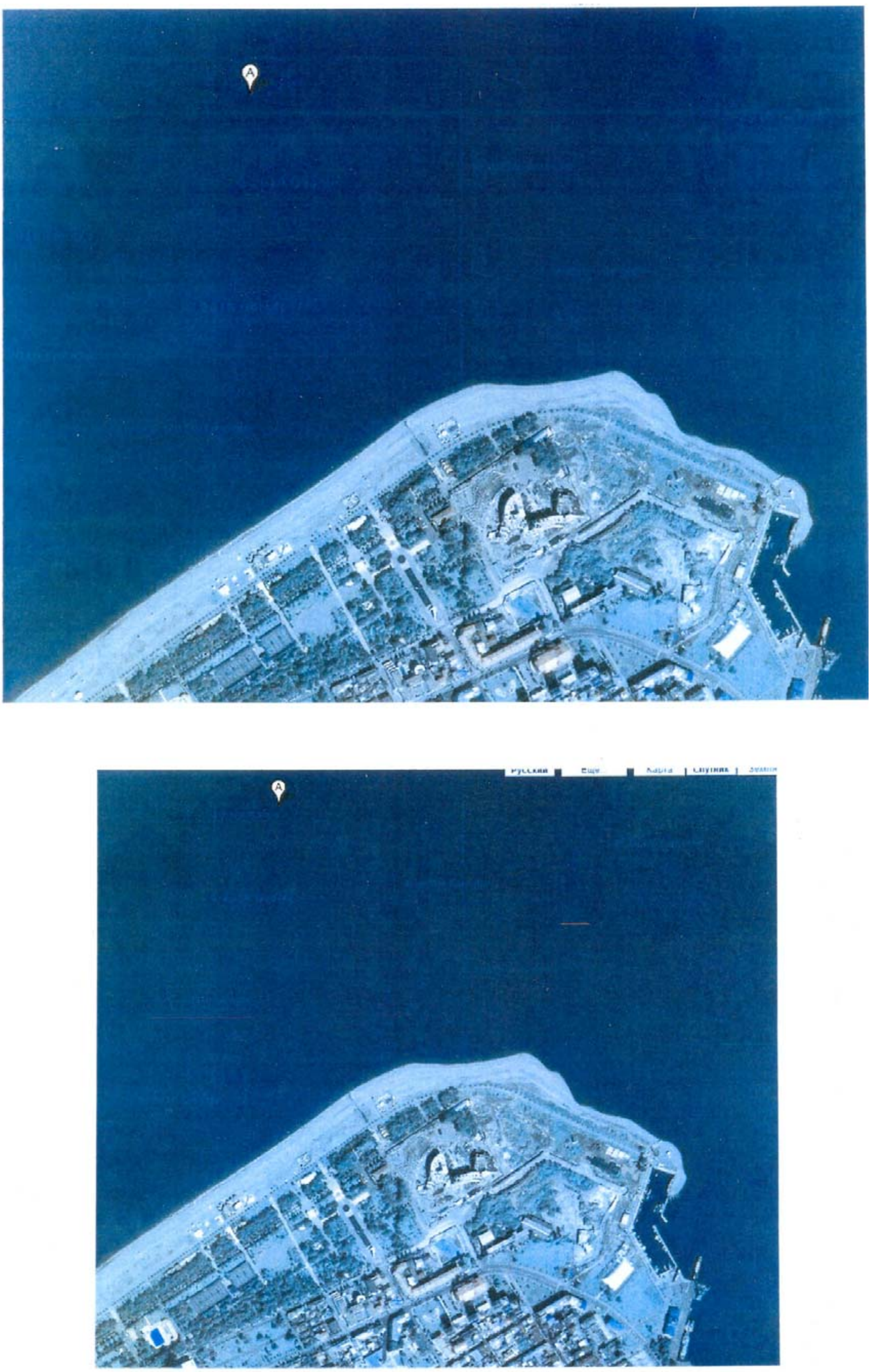

Fig. 1.

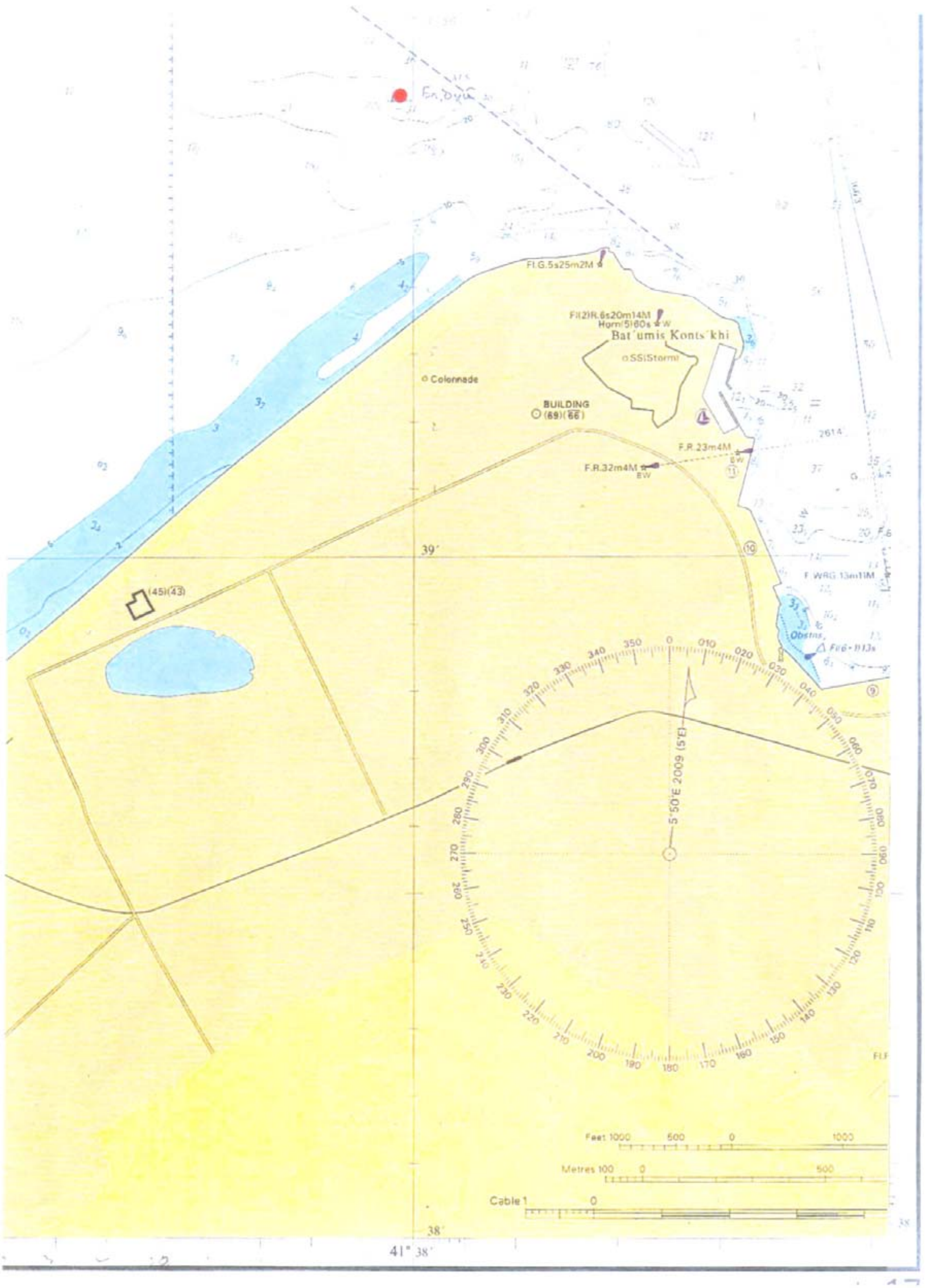
Fl.G.5s25m2M
Fl(2)R.6s20m14M
Horn(5)60s
Bat'umis Konts'khi
Colonnade
BUILDING
(69)(66)
F.R.23m4M
F.R.32m4M
(45)(43)
39'
5°50'E 2009 (5'E)
Feet 1000 500 0 1000
Metres 100 0 500
Cable 1 0
38'
41° 38'

Fig. 2.

Fig. 3.

The aim of the study consisted in determining experimentally the following parameters of deep sea water at a distance of 5 m from the sea bottom: 1) temperature and 2) electric conductivity with the aim of defining the salinity.

The knowledge of the real salinity of sea water is highly important for prediction of corrosion processes in the inter-contour heat exchanger.

The sea water parameters were measured by the high-precision sensor which also measured precisely the depth of its position in different sea layers. As a result of two-month experiments the number of measurements was 4591. The time interval between parameter measurements was 15 min.

The analysis of the obtained data testified to the fact the average temperature of deep water was as follows:

1) from 15.08.2010 17:00 h to 28.08.2010 14:00 h $\bar{t}_w = 8.113^0$C for the average depth of sensor position $\overline{H}$ =72.013 m;

2) from 28.08.2010 15:45 h to 18.09.2010 15:45 h $\bar{t}_w$ =8.081^{0}C for $\overline{H}$ =67.660 m and $\bar{t}_w$ =7..949^{0}C for $\overline{H}$ =82.962 m;

3) from 18.09.2010 to 02.10.2010 $\bar{t}_w$ =7.956^{0}C for $\overline{H}$ =75.7 m.

Naturally, the water temperature was subjected to fluctuation, but its average temperature remained equal to 8.113^{0}C.

The lowest water temperature t_w=7.949^{0}C was recorded at the depth $\overline{H}$ = 82 m, whereas in 2009 such a low temperature value was recorded at the depth $\overline{H}$ = 65 m – this was explained by a more intensive warming of the surface layers of the sea due to an anomalously high (and durable) air temperature in the summer of 2010 in the city of Batumi.

The results obtained by repeated experiments confirmed that the use of deep sea water for air conditioning (in the water cooling regime) and also as a source of heat for the thermal pump is beyond any doubt justified from the standpoint of thermodynamics. The recorded temperature

$\bar{t}_w = 8^0C$ agrees with the fully approved and economically profitable temperature range $8\text{-}10^0C$ for the air conditioning system where deep-well waters are used.

Comparative Analysis of the Co-evolutionary Method and the Accepted Traditional Design of Heat-and-Cold Supply to the Hotel Complex of the City of Batumi

I. The main climatic data of Batumi used for designing the air conditioning system:

1. **Maximal air temperature $t_{max} = 31.0^0C$.**
2. **Average air temperature of the hottest month at 13 h $\bar{t} = 27.1^0C$.**
3. **Maximal air humidity $\varphi_{max} = 62.2\%$.**
4. **Average relative air humidity of the hottest month at 13 h $\bar{\varphi} = 73.5\%$.**
5. **Rated air temperature $t_r = 29.6^0C$.**
6. **Rated relative humidity $\varphi_r = 65\%$.**

<u>Conditioned air temperature</u>

1. **Inside the building in the summer season $t_{min} = 22.2 + 0.33\,(t_r\text{-}21) = 25^0C$.**
2. **According to sanitary regulations, the value of relative air humidity should be taken equal to $\varphi = 55\%$.**
3. **The effective air temperature which is a combination of temperature and relative air humidity for the Batumi conditions is:**
   $t_{ef} = 21 \div 22^0C$ in summer;
   $t_{ef} = 18 \div 19^0C$ in winter.
4. **The limit values of the effective temperature of conditioned air are:**
   $t_{ef.l} = 17 \div 23^0C$ in summer;
   $t_{ef.l} = 17 \div 21^0C$ in winter.

II. Main aspects of the accepted project[5] of the heating, hot water supply, ventilation and air conditioning system of the Batumi hotel complex

<u>1.Heat supply system</u>

By calculations of the Turkish specialists (the approved project) the main heating and hot water supply system of the hotel complex has the capacity Q=10.2 MWt = 8.8 Gcal/h. This thermal power is provided by three steel boilers operating on natural gas in a temperature range from 90 to 70^0C. The heat output of each of the boilers in the wintertime is designed to be 3.2 MWt.

In the summer season only one boiler will be operated to satisfy the need of the hotel complex for hot water.

The boilers are designed to be mounted in the technical room A-0101, i.e. inside the building, which is forbidden by the legislation of Georgia because there exists a hypothetical risk of their explosion.

The accepted project of the heating and hot water supply system is prepared at a good professional level. However its essential drawback, in addition to the one mentioned above, is the use of natural gas for the reasons as follows:

A. As predicted by the leading international experts, the cost of natural gas will go on rising from year to year and by 2020 will be $\$500 \div 700$ per 1000 m^3 ;

B. With the boilers' heat capacity being equal to 10.2 MWt, the emission of greenhouse gas CO_2 into the atmosphere of the resort city of Batumi will be 1580 t of CO_2 per month, taking into account that the calorific power of natural gas is Q_H = 8500 kcal/m^3 (the specific value of CO_2 emission at natural gas combustion is 2.13 t/m^3).

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[5] The project has been prepared by the specialists of a Turkish company.

In the nearest future, in Georgia, like in the EU countries, penalty sanctions will be applied to CO_2 emissions.

2. Cold supply system

The capacity of the cold supply system of the hotel complex is approximately 9000 kWt. It is equipped with:

A. Four water-cooled chillers, each having the capacity of 1800 kWt;

Б. Two air-cooled chillers which are located at the roof level and the total capacity of which is 1800 kWt.

Like in the case of heat supply, the project of cold supply is prepared at a good professional level. It should be noted that the water-cooled chillers are in principle air-cooled installations, which complicates the cold supply system. However this is the forced solution of the engineering problem.

III. Main aspects of the heat and cold supply system of the hotel complex using deep water of the Black Sea

The uniqueness of the Black Sea consists in the fact that at depth values 30÷50 m below sea level the water temperature is 6-8^{0}C and remains constant to depths 150÷200 m.

In the course of two years we carried out experiments in the sea water area of Batumi and established that in this particular area of the Black Sea the water temperature at 50 m below seal level is 7.8-8.0^{0}C and is practically constant even in the hottest months of the year (July—September).

Therefore, taking into account the above facts, we proposed a new scheme of heat and cold supply to the hotel complex. The new scheme is based on the use of deep sea water (t= 8^{0}C) as a source of heat for the evaporators of the reversible chillers (thermal pumps) in the wintertime and for the hot water supply all round the year, whereas in the summertime deep sea water is used for cooling the water from fankoils and other air conditioning devices. Accordingly, no natural gas is used in this new design solution, i.e. in the new heating, hot water supply and ventilation schemes there are steel boilers (3 pcs).

A chiller and a thermal pump differ little from each other. A reversible chiller working in the heating regime is actually a thermal pump.

Let us consider for clearness the heat- and cold-supply separately.

1. Heat supply

As is known, the reversible chiller (or a thermal pimp) generates heat Q_1 the value of which is [(1+ε)/ε] times larger than the generated refrigeration value Q_2 (where $\varepsilon = Q_2/L$ is the refrigeration coefficient of the chiller); L is the power of the electric motor of the chiller. Therefore the chillers used in the accepted project, the total refrigeration capacity of which is Q_2=9000 kWt, are able to generate heat for heat supply of a larger value as compared with the value calculated in the accepted project (Q_1=10200 kWt) even for ε=2. In the conditions of the city of Batumi, the refrigeration coefficient of modern chillers with condensers, even if they are directly air-cooled in the real cycle ε =2.8 (see e.g. the chiller DAIKIN EWAQ130DAYNN), i.e. for Q_2=9000 kWt, in the accepted project the required electric capacity of the chillers' drive when they operate in the air conditioning mode in summer will be $L_{чл}$=(9000:2.8)=3.21 MWt.

When the source of heat is deep sea water of constant temperature 8^0 and the temperature of the upper source of heat is 55^{0}C, the thermotransformation coefficient of the thermal pump is

$$\varphi = \frac{T}{T - T_0} a = \frac{(273.15 + 55)}{(55 - 8)} 0.7 = 4.9 . \quad (1)$$

Here the coefficient *a* takes into account the total value of all losses: thermodynamic cycle losses, electric motor losses and losses caused by the external irreversibility during heat transfer in the evaporator and the condenser of the reversible chiller (thermal pump).

For chillers with a screw compressor and with modern heat-exchanging equipment a ≈ 0.7.

According to the accepted project, the thermal load (heat demand) for heating and ventilation in winter is $Q_{от}$ = (10162-3147)=7015 kWt, whereas that for hot water supply all the year round is $Q_{гв}$ =3147 kWt.

Therefore, when the duration of the heating season is $\tau_{от}$ =2600 h, the electric power consumption by heating and ventilation by means of a thermal pump is $Э_{от} = Q_{от}\cdot \tau_{от} / \varphi = 3.72\cdot 10^6$ kWt.h, and by the hot water supply where the nonuniformity coefficient is 2.0, we have the value $Э_{гв} = Q_{гв}\cdot 8400/2\cdot\varphi = 2.70\cdot 10^6$ kWt.h.

The total value of annual electric power consumption by heat supply is

$$\Sigma Э_{тс} = Э_{от} + Э_{гв} = 6.42\cdot 10^6 \text{ kWt.h.}$$

In the accepted project, the annual natural gas consumption by heat supply with the aid of boilers is

$$\Sigma M_{тс} = M_{от} + M_{гв} = (Q_{от}\cdot \tau_{от} + Q_{гв}\cdot\tau_{гв}))/ Q_H = 4.8\cdot 10^6 \text{ m}^3.$$

Here Q_H is the lowest combustion heat of natural gas -- Q_H = 8000 kcal/m^3; $\tau_{гв}$ = 8400 h (days per year) is the quantity of hours of hot water supply per year.

The current electric power and natural gas prices in Batumi are:

for electric power $C_Э$ = \$0.0647/ kWt.h;

for natural gas C_O = \$0.304/m^3.

Therefore the operating expenses for heat supply in the case of using natural gas is $З_{пг} = \Sigma M_{тс}\cdot C_0 = \$1.46\cdot 10^6$ /year.

The operating expenses for heat supply by means of thermal pumps consist of expenses for the electric power consumed by the electric motors of thermal pumps - $З_{тс} = \Sigma Этс\cdot C_Э = \$0.41\cdot 10^6$ /year and expenses for deep sea water transportation to the evaporators of thermal pumps and the follow-up discharge of the waste water back into the upper layers of the sea.

The consumption per second of deep sea water for heating and ventilation for $\Delta T = 8-3=5^0$C in the thermal pump evaporators is

$$G_{OT} = Q_2^{OT} / C_P \cdot \Delta T = Q_{OT} \frac{\varphi - 1}{\varphi} / C_P \Delta T = 266.7 \text{ kg/s.}$$

Here C_P is the water specific heat capacity. The sea water requirementsd per second in the case of hot water supply is

$$G_{ГВ} = Q_{ГВ} / C_P \cdot \Delta T = Q_2^{ГВ} \frac{\varphi - 1}{\varphi} / C_P \Delta T = 119.6 \text{ kg/s.}$$

Water requirements in the case of heating and ventilation is $G_{OT}^{ГОД} = G_{OT} \cdot 2600 = 2496312$ t/year, and in the case of hot water supply with the hourly nonuniformity coefficient being equal to 2 water requirements are estimated to be

$$G^{Year} = G_{ГВ} \cdot 8400 / 2 = 1808352 \text{ t/year.}$$

To define the pay-back term of the proposed new progressive technology of heat supply, it is necessary in the first place to determine the relative cost of the sea water pipeline with a pumping station. Since the pipeline is used for transporting both heat and cold, we represent the total cost of the pipeline and the pumping station $C_{мт}$ with two respective components

$$C_{MT} = C_{MT}^{TC} + C_{MT}^{XC},$$

so that the share of the cost of the sea water pipeline with the pumping station attributed to heat supply is

$$C_{MT}^{TC} = C_{MT} /(1 + C_{MT}^{XC} / C_{MT}^{TC}) = C_{MT} /(1 + \mu), \quad (2)$$

where C_{MT}^{XC} is the share of the cost attributed to cold supply, i.e. to the air conditioning of indoor premises of the hotel complex in summer.

In determining the relative cost of the pipeline with the pumping station it is well justified to take into consideration the condition that

$$\mu = G_{XC}^{Год} / G_{TC}^{Год} = G_{XC} \cdot \tau_{XC} /(G_{OT} \cdot \tau_{OT} + G_{ГB} \cdot \tau_{ГB}), \quad (3)$$

where $G_{XC}^{Год}$ and $G_{TC}^{Год}$ are respectively the annual sea water requirements for cold supply and for heat supply: G_{XC} is sea water requirements per second in the case of cold supply; τ_{XC}=2400 h is the duration of cold supply to the hotel complex.

When the refrigeration power is 9000 kWt and the deep sea water is heated in the inter-contour heat exchanger up to 8-12^{0}C, we have G_{XC} =537.4 kg/s = 1934.64 t/h; Accordingly, $G_{XC}^{Год}$ = 4643136 t/year, $G_{TC}^{Год}$ =4304664 t/year, and the ratio of these values is μ =1.08.

By the estimation of theTurkish company "Kaptan", the turn-key cost of the pipeline with the pumping station is

$$C_{мт} = 2.381 \cdot 000E = \$3.285780.$$

Thus, when calculating the capital investment needed for the main parts of the proposed new heat supply system, by (2) and (3) the components of the cost of the sea pipeline (supplying and discharging) with the pumping station are $C_{MT}^{TC} = \$1579702$ for heat supply, and to $C_{MT}^{XC} = C_{MT} - C_{MT}^{TC} = \$1706078$ for cold supply.

Taking into account the resistance of the thermal pump evaporator and the water height over the diffuser which discharges the used water into the sea, the sea water pump capacity is

$$N_H^i = \frac{\Delta P_Д}{\rho \cdot \eta_H} G_i. \quad (4)$$

Here ρ is the sea water density; η_H = 0.85 is the pump output; ΔPa is the actual pressure differential; G_i is sea water discharge per second.

Electric power consumption in the case of sea water transportation for the needs of heating and ventilation is

$$Э_H^{OT} = N_H^{OT} \cdot \tau_{OT} = 138{,}4 \cdot 2600 = 359840 \text{ kWt.h};$$

and for the needs of hot water supply

$$Э_H^{ГB} = N_H^{ГB} \cdot \tau_{ГB} = 62{,}1 \cdot 8400 / 2 = 260820 \text{ kWt.h}.$$

Accordingly, the total annual cost of sea water transportation in the case of heat supply is

$$\Sigma З_H = (Э_H^{OT} + Э_P^{ГB}) C_Э = \$40156.7.$$

Table 1 presents the results of calculations which enable us to compare the heat supply scheme and method of the accepted project with the proposed project. As seen from the table, the estimated pay-back term of the proposed new scheme of heat supply to the hotel complex is

$$t_{рас} = \frac{K_1^{TC} - K_2^{TC}}{З_2^{TC} - З_1^{TC}} = \frac{3{,}72 \cdot 10^6}{(1{,}46 - 0{,}45)10^6} = 3.7 \text{ year}. \quad (5)$$

Summary Table of Heat Supply to the Hotel Complex of the City of Batumi

Table 1

№	Accepted project		Proposed project	
	Operating costs	Capital investment into main units and equipment of the hotel complex	Operating costs	Capital investment into main facilities and equipment of the hotel complex
	$	$	$	$
1	Annual costs of natural gas $З_{пг} = 1.46 \cdot 10^6$	Steel boilers $З_{Бл} = 10200 \cdot 40 =$ $= 0.41 \cdot 10^6$	Annual costs of electric power for thermal pumps $З_{тс} = 0.41 \cdot 10^6$	Sea water pipeline with pumping station (turnkey project) $C_{МТ}^{ТС} = 1579702$
2	-	-	Annual costs of electric power requirements for sea water pump $З_{Н}^{ТС} = 0.04 \cdot 10^6$	Reversible chillers (thermal pumps) $З_{чл} = 102000 \cdot 250 =$ $= 2.55 \cdot 10^6$
	Total:		Total:	
	$З_2^{ТС}$	$К_2^{ТС}$	$З_1^{ТС}$	$К_1^{ТС}$
	$1.46 \cdot 10^6$	$0.41 \cdot 10^6$	$0.45 \cdot 10^6$	$4.13 \cdot 10^6$

2. Cold supply

As different from the heat supply system operating on sea water, for which deep sea water is delivered directly to the evaporators (with titanium tubes) of the thermal pumps, the supply of cold to the hotel complex is effected by cooling clean water from the fankoils (and other heat-exchanging equipment) by means of the inter-contour heat-exchanger. The operation duty temperature of the fankoils in summer is $9/14^0$C (such fankoils are manufactured industrially), and deep sea water is heated in the first contour from 8 to 12^0C. Sea water requirements for the refrigeration load of 9000 kWt is $G_{хч} = 537.4$ kg/s, whereas the annual requirements are

$$G_{XC}^{Год} = G_{XC} \cdot \tau_{XC} = G_{XC} \cdot 2400 = 4643136 \text{ t/year.}$$

The annual electric power consumption for the sea water transportation pump, i.e. in the case of air conditioning in the summertime is

$$Э_{XC}^{Год} = N_{XC} \cdot 2400 = 669385 \text{ kWt.ч},$$

whereas in the accepted project, i.e. in the case of air conditioning by means of chillers the annual electric power consumption in the accepted project is

$$Э_{чл}^{Год} = 7714286 \text{ кВт.ч.}$$

Thus, when sea water is used for the air conditioning in summer, we need electric power 11.5 times less than in the case of the traditional air cooling method.

Table 2 presents the results of calculations for the cold supply system which enable us to compare the main specifications of the proposed scheme with the accepted design of air cooling in the summer season.

The accepted project employs chillers with water cooling condensers; however, the heated water is then air-cooled by means of the heat exchangers mounted on the hotel roof (this creates essential inconveniences during the operation). Therefore the cost of the chillers in the accepted project is higher as compared with the cost of reversible chillers in the proposed new heat and cold supply scheme. Though this fact is not taken into account in Table 2, we all the same see from the table that when instead of the traditional cold supply method the progressive method of using cold sea water we achieve essential savings

1) $455805 in operating expenses;

2) $443922 in capital investment.

Summary Table of Data on Cold Supply to the Hotel Complex of the City of Batumi

Table 2

№	Accepted project		Proposed project	
	Operating costs	Capital investment into main facilities and equipment of the hotel complex	Operating costs	Capital investment into main facilities and equipment of the hotel complex
	$	$	$	$
1	Costs (annual) of electric power = $0.50 \cdot 10^6$	Chillers (6 рст) with refrigerating capacity c 9000 kWt $К_{чл}=2.55 \cdot 10^6$	Annual costs of electric power (for the drive of the sea water pump) $З_{Н}^{XC}=0.043 \cdot 10^6$	Sea water pipeline with pumping station (turnkey project) $C_{MT}^{XC}=1706078$
2	-	-	-	Inter-contour titanium heat exchanger GEA (Germany) $К_{TO}=0.40 \cdot 10^6$ (2 pcs)
	Total:		Total:	
	$З_2^{XC}$	$К_2^{XC}$	$З_1^{XC}$	$К_1^{XC}$
	$0.50 \cdot 10^6$	$2.55 \cdot 10^6$	$0.043 \cdot 10^6$	$2.1 \cdot 10^6$

Data presented in Tables 1 and 2 are summarized in Table 3.

Summary Table of Data on Heat and Cold supply to the Hotel Complex of the City of Batumi

Table 3

№	Accepted project		Proposed project	
	Operating costs	Capital investment into main facilities and equipment of the hotel complex	Operating costs	Capital investment into main facilities and equipment of the hotel complex
	$	$	$	$
1	Annual cost of natural gas $З_{пг}=1.46 \cdot 10^6$	Steel boilers $З_{Бл}=10200 \cdot 40 =$ $= 0.41 \cdot 10^6$	Annual costs of electric power for thermal pumps $З_{тс}=0,41 \cdot 10^6$	Sea water pipeline with pumping station (turn-key project) $C_{MT}^{TC}=3.28 \cdot 10^6$
2	Annual cost of electric power for chillers $\Sigma ч=0.50 \cdot 10^6$	Chillers (6 pc) With refrigeration capacity 9000 kWt $Кчл=2.55 \cdot 10^{6*}$	Annual cost of electric power for the sea water pump $\Sigma З_{Н}=0.83 \cdot 10^6$	Reverse chillers (thermal pumps) $З_{чл}=102000 \cdot 250=$ $=2.55 \cdot 10^{6*}$
3	-	-	-	Intercontour titanium heat exchanger GEA (Germany) $К_{TO}=0.40 \cdot 10^6$ (2 pcs)
	Total:		Total:	
	$\Sigma З_2$	$\Sigma К_2$	$\Sigma З_1$	$\Sigma К_1$
	$1.96 \cdot 10^6$	$2..6 \cdot 10^6$	$0.49 \cdot 10^6$	$6.23 \cdot 10^6$

Remark: * is the cost without taking into account the mounting costs.

According to Table 3, as compared with the accepted project the estimated pay-back time of the proposed new system of heat and cold supply system is

$$t_{\text{рас}}^{\text{сист}} = \frac{\Sigma K_2 - \Sigma K_1}{\Sigma З_2 - \Sigma З_1} = \frac{6.23 - 2.96}{1.96 - 0.49} = 2.2 \text{ years.}$$

The guaranteed service life of the thermal pumps is 30÷35 years.

In the remaining years of operation of the thermal pumps (30-2.2)=27.8 years the total profit will amount to

$$\Sigma P_{г} = (1.96\text{-}0.49) \cdot 10^6 \cdot 27.8 = \$40.9 \cdot 10^6,$$

and the annual profit to

$$P_{г} = \$1.47 \cdot 10^6.$$

It should be noted that the transition to the proposed new scheme of heat and cold supply does not demand any modifications of the heat exchanging equipment in the hotel building, also any architectural and constructional alterations.

It should be specially emphasized that the removal of smoke flues of the boilers of the accepted project has not only a weighty ecological effect, but also essentially improves the esthetic appearance of the hotel complex building.

The lay-out schemes of all pipelines and their diameters are identical for the cold supply system. To change the air conditioning temperature from 7/12 to 9/14^{0}C, the heat exchange surface of the fankoils must be only by 10÷23% depending on the cooling water quantity in the above-mentioned equipment, but the same fankoils operated at 45/55^{0}C are also for heating. It will also be required to increase the size of static radiators and heat exchangers for air ventilation. However, by our estimates, the rise in the cost of thi equipment is compensated by removing from the scheme six air-water type heat exchangers of the chillers mounted on the building roof and, accordingly, eight pipes used for circulation of water heated in the condensers of four chillers.

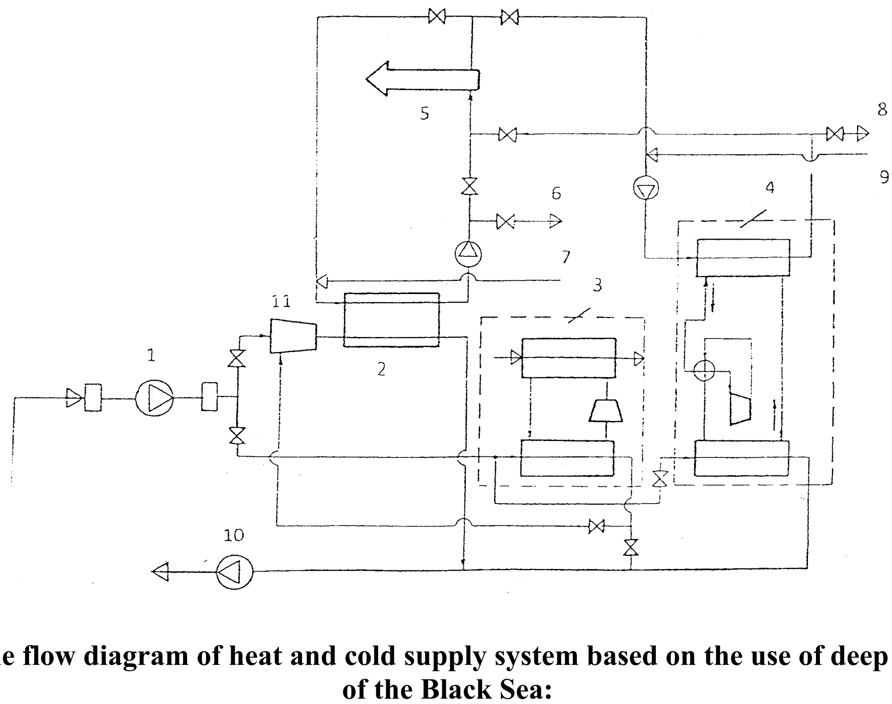

Fig. 4. The flow diagram of heat and cold supply system based on the use of deep sea water of the Black Sea:

1 – deep sea water pump; 2 – inter-contour heat-exchanger; 3 – thermal pump for hot water supply; 4 – reversible thermal pump; 5 - fankoil; 6, 7 – respectively, pipeline for delivering cooled water to heat-exchangers of ventilation equipment and withdrawing waste water from them; 8, 9 – respectively, pipeline for supply of hot water (heated up to до 55^{0}C) to heat-exchangers of ventilation equipment and withdrawing waste water from them; 10 - pump for discharging waste water back into the sea (to the depth of 20-30 m); 11 – ejector

The flow diagram of heat and cold supply to the hotel complex using deep sea water (with two thermal pumps as an example) is shown in Fig. 4. Among other peculiar features of the proposed scheme we should mention its ability to operate the reversible thermal pumps as chillers in the summer season in the case of force-major, for example, in the case of damage of the deep sea water pipeline.

Conclusions

1. Experiments carried out in the course of 2 years confirmed the surmise based on the well known sources in the area of scientific and experimental studies that in the sea water area of Batumi the deep sea water temperature at depths over 50 m is 8^0C and is practically constant.

2. The analysis and calculations of the heat and cold supply system based on the use of deep sea water testify to the fact that for the climatic conditions of Batumi and in view of the ratio of natural gas and electric power prices in Georgia, this system has -- due to its economic and environmentally friendly characteristics -- an advantage over the traditional method of cold production by means of steam-jet refrigerating compressors and heat production by means of organic fuel combustion. In particular, for the air conditioning in summer the electric power consumption is 11.5 times less than in the case of the traditional method of cooling the building premises, whereas in the proposed innovation project the annual operating expenses on heat supply are 3.2 times less than in the case of heat supply by means of boilers operating on natural gas.

3. The estimate pay-back term of the new heat and cold supply system is 2.2 года.

4. When heat supply is effected by using deep sea water, there is no need for fuel, including natural gas, the combustion of which leads to the emission of carbon dioxide in a quantity of 63-65 t per 1000 m^2 during the entire heating season in Batumi.

5. The environment protection is the prerogative of the Government of Georgia. Therefore in view of the intensive development of tourism in the Black Sea region of Georgia, the state authorities are obliged to popularize the implementation of the coevolutionary heat and cold supply technology for buildings under construction, the more so that this initiative on the part of the Government will bring multi-million revenues to private companies in the course of operation of the proposed new system of heat and cold supply.

It should be emphasized that besides hotel, sports and residential complexes it is economically profitable and ecologically advantageous to use deep water of the Black Sea also in large vegetable storage buildings to produce refrigerated temperature (up to до 15^0C), also in tea leaf processing technologies, which is especially important for Georgia.

***Editorial Board's remark*: The project on the use of deep water layers of the Black Sea for air conditioning was developed by Prof. V. Jamarjashvili in the early 80s of the last century at the Power Engineering Institute of Georgia which ceased to exist at the end of 2010. This issue again became topical after Georgia gained independence in the early 90s and in the late 90s the results from the scientific reports were announced in our journal. In the meantime, an analogous project on the use of deep lake water was implemented in Canada (Toronto) in 2004. Subsequently, that project was awarded the Leonardo da Vinci prize which is an analogue of the Nobel prize in the engineering area. Thus, if Georgia had a proper level of implementation of new technologies in engineering, then it would have been Georgia and not Canada to receive the above-mentioned prize.**

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