Energy efficiency heating installation of country house in Northern Western region of Russia

Student Tatiana Igorevna Spiridonova
Saint-Petersburg State Polytechnical University
+7 (911) 988 5542, spiridonova-mail@yandex.ru
Saint-Petersburg
Russian Federation

Assistant Elena Vitaljevna Kurasova
Saint-Petersburg State Polytechnical University
+7 (921) 658 0931; toes@cef.spbstu.ru
Saint-Petersburg
Russian Federation

Student Irina Aleksandrovna Duvanova
Saint-Petersburg State Polytechnical University
+7 (921) 799 6988, duvanova.i@mail.ru
Saint-Petersburg
Russian Federation

Student Anna Olegovna Vilinskaya
Saint-Petersburg State Polytechnical University
+7 (904) 646 4712, willi-ann@yandex.ru
Saint-Petersburg
Russian Federation

Key words: investment, energy efficiency, thermal systems, boiler, heat pump.

The task of choice a heating installation on environmentally friendly fuel and optimum for the price for a country house of the North Western region of 200 sq.m. was set in article.

The thermal pump and the pellet boiler were considered for this purpose.

Both devices possess a number of rather similar advantages, which are durability more than 20 years, possibility of installation in a house, environmentally friendly fuel, etc. In conclusion authors decided that it is more favorable and for climatic reasons and according to starting and operational expenses to prefer to the thermal pump a pellet boiler.

1. Introduction

The heating system is created for rooms for creation a thermal comfort of housing. A number of factors depend on a choice of heating system, such as ecological safety, operational safety, operational costs, convenience in operation and at repair. Especially important functions of heating system are maintenance of settlement temperatures of heated rooms during the whole heating period and providing a sufficient stock of hot water.

Design of heating system in country houses should give special value as structure features of buildings in these houses and limitation in a power source choice are possible excellent from standard city. Here it is important to concentrate on one installation which will carry out a complex of actions, such as heating and water heating for daily needs.

We are sure that competent selection of heating installation it is possible to find suitable and conforming to demands made to it.

2. Literature review

Today development of the new heating installations in the construction market, a number of construction companies [9, 20] is engaged. Nevertheless, some bases of systems' selection of heating are actual for low residential buildings still [1 - 8, 27]. Energy efficiency of heating installations is special profile, which practiced by following scientists [10 - 20, 22 - 26]. Conditions of economic efficiency are considered in works [4, 7, 8, 17, 19, 28].

3. The main task

Research objective is selection optimum (economically expedient and energetically favorable) heating installation for a country house of 200 sq.m.

4. Types of heating installations

Two types of the heating installations for a country house, which combine heating function and preparation of hot household water. These functions are including in the thermal pump and the pellet boiler. The L-030-WLC thermal pump and pellet boiler Jaspi Tehnowatti 20 of the KAUKORA OY company will be used rather new in the construction market for comparison.

4.1. The thermal pump

This device is carrying out water heating in system of water supply, and also the heat carrier in heating system at the expense of transformation of the energy received for account of environment.

The principle of operation consists in the following:

1. External air (water) moves on the heat exchanger (evaporator).

2. The circulating working environment (coolant) is the substance transferring capacity from one temperature level to another. This substance takes away from heat source necessary heat for evaporation. Further, it passes from a liquid state in gaseous while the source is cooled on some degrees.

3. The compressor is a device for compression and air supply under pressure. There is an absorption and compression of a working environment that causes rise of the working medium to a higher temperature. Electric power use is necessary at this stage.

4. Energy with a coolant together goes to the condenser. In detail, condenser is the heat exchanger (between the thermal pump and the accumulator) transferring heat from a coolant to the water being in a contour of heating, and also hot water supply.

5. Then the “valvate group” on account of expansion, which available "excessive" residual pressure decreases enters process. Here cycle of thermal pump operation begins again.

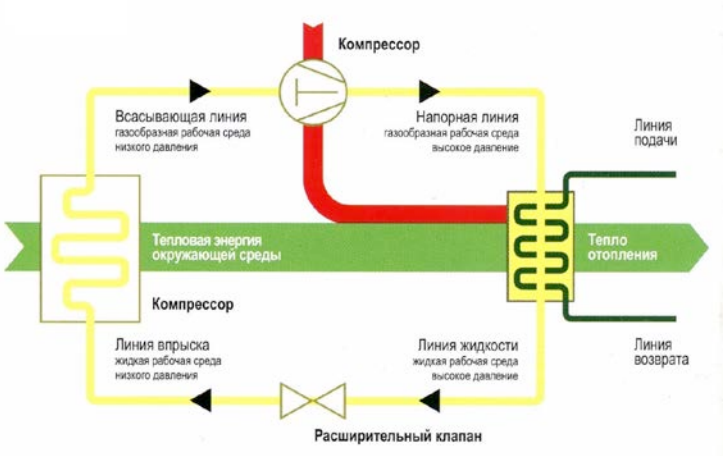

Figure 1. Heat pump’s principle of operation [20]

Advantages:

1. The economic efficiency declared by many producers. Really, at first sight, cost of 1 kilowatt-hour of thermal energy received at use of the thermal pump is the lowest, also varies from 0,45 to 0,80 rub. For comparison possible cents are presented in figure 2.
2. The automatic operation which isn't demanding use of human resources in course of work.
3. It does not damage environment because mainly used natural resources.

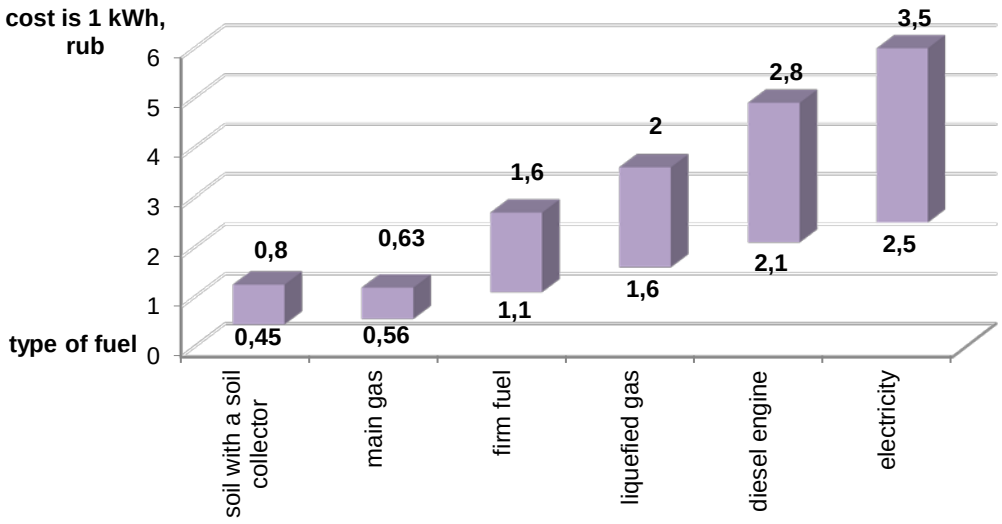

Figure 2. Cost is 1 kWh by data [18]

Disadvantages:

Firstly, it is high cost of installation. It is a question of the pump with heat source is soil. It is known that geological researches not cheap pleasure for the Russian consumers. The cost of drilling of one cleft in St. Petersburg varies from 70 000 rubles to 350 000 rubles depending on depth and an environment (a type of soils, etc.). Installation costs of the pump to geological surveys are added.

Secondly, thermal pumps are not autonomous. There is a dependence on electric energy (see above the 3rd stage of the thermal pump operation).

Third, it can work unprofitable.

It is considered that thermal pumps are good not for all territories. There is an integrated characteristic *Gd* which depends on climatic conditions.

Using groundwater heat pump installations takes place in the northwest region of Russia in the geologist - the climatic conditions which are differing from Central European: lower than soil temperature (for example, up to the depth of 10 m, 4÷7 °C instead of 10÷15 °C), is 1,5÷2,0 times more integrated characteristics of the heating period. Integrated characteristics can be used for a cumulative assessment of the local climatic features. It influences resultant annual heat consumption of heated objects. Such characteristics represent the areas concluded between straight lines of standard temperature of internal air of heated rooms, and broken lines of change of average monthly temperature of external air in this district in graphic interpretation [21].

Quantitatively integrated characteristics of the heating period are estimated like sum of average daily differences of internal and external air temperature for the heating period, measured in day-degrees, designated by a D_d °C·day. Also it pays off on a formula:

$$D_d = (t_{int} - t_{ext}) * \mathrm{T}_h \quad (1)$$

t_{int} and t_{ext}– are average for the heating period of internal temperature and external air, °C; T_h– duration of the heating period, days [21].

These characteristics can be judged on the heat pump: the larger by D_d in this territory, so there is less advantageous to install a heat pump in connection with the lowering of its performance. For example, for Denmark D_d makes 2779 °C.day, for Germany 3163 °C.day, for Norway 3600 °C.day, for Russia 5000 °C.day [21].

Duration of the heating period it agrees for St. Petersburg makes 220 days, t_{int} is in an interval of 20-22 °C (GOST 30494-96), and t_{ext} of-1,8 °C. Values are chosen for the period with an average daily temperature of external air no more than 8 °C, according to Construction Norms and Regulations 23-01.

Thus, it is possible to calculate D_d value for St. Petersburg:

$$D'_d = (22 - (-1{,}8)) * 220 = 5236\text{°C·day}$$

Therefore, there is a probability that for Denmark and Germany houses installation of the thermal pump will be more profitable, than for houses of Russia (St. Petersburg).

4.2. Pellet boiler

It is a device that heats the water in the water system with coil hot water (DHW) and space heating via radiators and / or heating of floors due to the energy of combustion of wood fuel granules (pellet granules).

There are some types of pellet boilers. It will be considered by Jaspi Pelletti 20 combo boiler in this article.

Pellet granules are considered as renewable biofuel, pressed on a special press (granulator) from waste of woodworking production, namely sawdust and shaving.

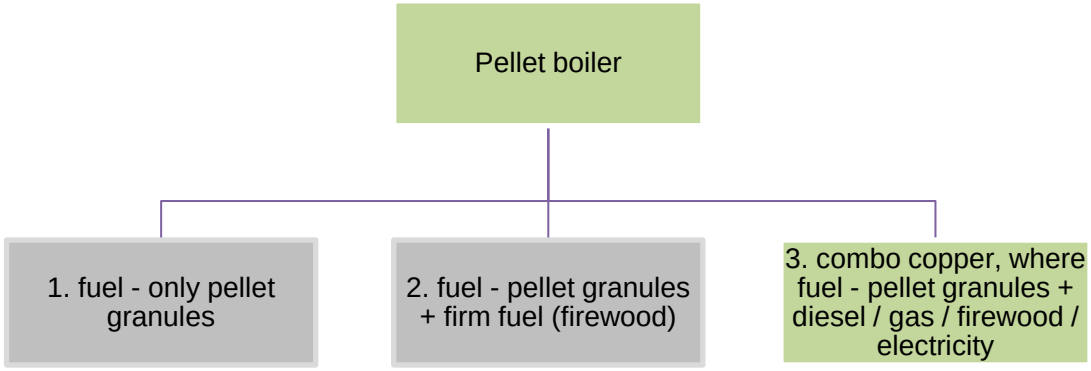

Figure 3. Types of pellet boilers depending on used fuel

The principle of a pellet boiler's work is rather simple and clear: [9] (figure 4)

1. For the beginning operation of the device the boiler with a torch and the giving screw in a tank, united by an integral design from steel is necessary.
2. Heating of a boiler is carried out by automatic movement of pellet boiler on the giving screw in a torch. Further, torch heats a boiler.
3. Combustion products through walls of the heat exchanger transfer to the heat carrier warmly, and then, chilled leave through a flue.
4. The boiler thermostat (or torches) as the device which is carrying out maintenance of constant temperature, carries out automatic start-up and a stop of work of a boiler.

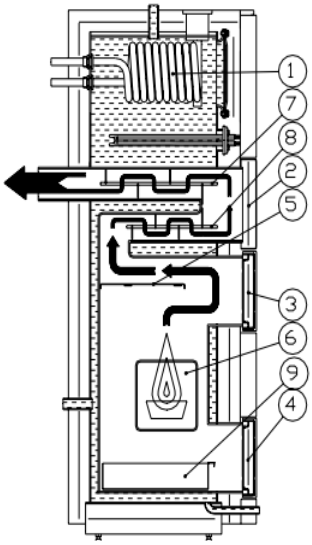

Figure 4. Scheme of work of a pellet boiler Jaspi Pelletti 20

Explanations to figure 3 [9]

1 – GVS coil, 2 – The cleaning hatch, 3 – the service Hatch, 4 – the Hatch of care of a fire chamber, 5 – the Turbulent plate of a fire chamber, 6 – the Hatch of a pellet torch, 7 – the Top turbulent plate, 8 – the Bottom turbulent plate, 9 – the Box for ashes.

Advantages:

1. Low starting expenses means which is necessary for boiler installation.

2. It is autonomy. The pellet boiler doesn't depend on other types of fuel. Moreover, if there is a speech about a combo boiler, each type of fuel can be used in turn and independently from each other.

3. There is environmentally friendly biofuels in the process of use.

4. High heating capacity of pellet is comparable with coal, is rather steady of climatic conditions regardless.

Disadvantages:

1. Capacious dry bunker is necessary for storage pellet granules. They shouldn't adjoin to the earth or concrete. It is desirable to enclose under them boards.

2. Work process isn't completely automated: it is necessary to fuel independently a boiler, and also to clear a box for ashes.

5. Comparison of heating installations

Let's compare the thermal pump and pellet combo boiler, based on the specifications presented in table 1.

The main requirements to the boiler room organization for a country house of 200 sq.m.

	Heat pump L-030-WLC	Pelletny combo copper JaspiPelletti 20 (Kaukora Oy)
Power	8,1kW	20kW
Requirements to a site	300 sq.m. without capital constructions	-
Requirements to the individual thermal point (ITP) house / room	2 sq.m in any room of the house	the certain room with ventilation
Capital expenditure for boiler room installation		
Design of system of heating and boiler room, rub.	35 000	35 000
Cost of the equipment, rub.	462 657* +70 000 – 350 000 rub on well drilling	136 311
Operational expenses		
Consumption of thermal power of kW/hour	20400	61200
Efficiency/Coefficient of transformation of the pump *	COP=3,2 (varies from 3 to 6) **	КПД=90%
Total the general operational expenses in year, rub	**54060**	**64200**
Total the general operational expenses within 15 years + capital expenditure, rub	**1378557÷1658557**	**1134311**
Operation term	15-20 years	Not less than 20 years

* Boiler / thermal pump, binding (circulation pulser, group of safety, broad tank, shutoff valves), boiler, flue, soil (borehole) contour/gas-holder / fuel capacity by data [31];

** The COP = 3,2 – shows efficiency of the thermal pump.

6. Conclusion

1. It is important to approach a choice of heating installation responsibly. Nowadays, the special attention should be devote to novelties, carefully studying their properties and comparing them with expenses for the purpose of receiving optimum at the price and high-quality, environmentally safety installation.

2. Two heating installations (the thermal pump and pellet boiler) were considered in article. Both devices possess a number of rather similar characteristics like durability about 20 years, possibility of installation in a house, organic fuel. According to our assessment for the residential country house located in vicinities of St. Petersburg. It is more favorable and for climatic reasons and according to starting and operational expenses to prefer pellet boiler. But, the choice always remains only for the consumer.

3. As a result of research it was chosen optimum (economically expedient and energetically favorable) pellet boiler of the 20 kW Jaspi Pelletti 20 (Kaukora Oy) for a country house of 200 sq.m.

Литература

1. Morten B. Blarke.Towards an intermittency-friendly energy system: Comparing electric boilers and heat pumps in distributed cogeneration // Applied Energy. Vol.91. Issue 1. 2012. Pp. 349–365.
2. Tai Lva, Linghao Yua, Jinmin Songb. A Research of Simplified Method in Boiler Efficiency Test // Energy Procedia. Vol.17. Part B. 2012. Pp. 1007–1013.
3. Zhongsheng Niua, Kau-Fui V. Wonga. Adaptive simulation of boiler unit performance // Energy Conversion and Management. Vol. 39. Issue 13. 1998. Pp. 1383–1394.
4. Energy-saving judgment of electric-driven seawater source heat pump district heating system over boiler house district heating system / Shu Haiwena, Duanmu Lina, Li Xianglia, Zhu Yingxinb // Energy and Buildings. Vol.42. Issue 6. 2010. Pp.889–895.
5. Feng Li, Guozhong Zheng, Zhe Tia. Optimal operation strategy of the hybrid heating system composed of centrifugal heat pumps and gas boilers // Energy and Buildings. Vol. 58. 2013. Pp. 27–36.
6. Daniel Setrak Sowmya, Racine T.A. Prado. Assessment of energy efficiency in electric storage water heaters // Energy and Buildings. Vol. 40. Issue 12. 2008. Pp. 2128–2132.
7. Влияние уровня тепловой защиты ограждающих конструкций на величину потерь тепловой энергии в здании / Ватин Н. И., Немова Д. В., Рымкевич П. П., Горшков А. С. // Инженерно-строительный журнал. 2012. №8(34). С. 4-14.
8. J. Brenn, P. Soltic, Ch. Bach. Comparison of natural gas driven heat pumps and electrically driven heat pumps with conventional systems for building heating purposes // Energy and Buildings. Vol. 42. Issue 6. 2010. Pp. 904-908.
9. Электрическое отопление и тепловые насосы Jaspi Jsc. [электронный ресурс] URL: www.kaukora.fi (дата обращения 29.04.2013)
10. Бабич А. С., Сотникова О. А., Головинский П. А. Аккумулирование теплоты в гелиогрунтовых системах теплоснабжения с тепловыми насосами // Научный вестник воронежского государственного архитектурно-строительного университета. Строительство и архитектура. 2009. № 1. С. 50-57.
11. Аверьянова О. В. Климатические системы с тепловыми насосами и водяным контуром // Инженерно-строительный журнал. 2009. № 2. С. 19-22.
12. Шинкевич Т. О., Попкова О. С., Шинкевич О. П. Компрессионные тепловые насосы в системах отопления // Политематический сетевой электронный научный журнал кубанского государственного аграрного университета. 2011. № 68. С. 125-136.
13. Бутузов В. А. Перспективы применения тепловых насосов // Промышленная энергетика. 2005. № 10. С 8-15.
14. Романова Е. В., Орлов А. Ю. Возможности использования тепловых насосов в процессе сушки // Вестник тамбовского государственного технического университета. 2008. № 3. Т. 14. С. 591-596.
15. Позин Г. М., Уляшева В. М. Распределение параметров воздуха в помещениях с источниками тепловыделений // Инженерно-строительный журнал. 2012. № 6. С. 42-47.
16. Motuzienė V., Valančius K., Rynkun G. Complex analysis of energy efficiency of public buildings: case study of VGTU // Инженерно-строительный журнал. 2012. № 2. С. 9-17.
17. Авсюкевич А. Д. Энергоэффективность и энергосбережение в системах теплоснабжения // Строительство уникальных зданий и сооружений. 2013. № 2. С. 40-54.
18. Электрическое отопление и тепловые насосы «Штибель-элтрон» [электронный ресурс] URL: www.stiebel-eltron.ru (дата обращения 29.04.2013)
19. Птухина И. С., Лисков А. А., Птухин И. А. Развитие стоимостного инжиниринга в строительстве // Строительство уникальных зданий и сооружений. 2012. № 5. С. 17-20.
20. Chua K. J., Chou S. K., Yang W. M. Advances in heat pump systems: A review // Applied Energy. 2010. Vol. 10. Pp. 3612-3622.
21. Семенов Б. А., Соловьёв В. А. Проблемы и особенности использования грунтовых тепловых насосов для автономного теплоснабжения объектов в центральных регионах России // Вестник СГТУ. 2009. №1. С. 167-172.
22. Самарин О. Д., Тищенкова И. И. Исследование регулируемых параметров в автоматизированных климатических системах в целях энергосбережения // Инженерно-строительный журнал. 2013. №2. С. 13-18.
23. Позин Г. И., Уляшева В. М. Распределение параметров воздуха в помещениях с источниками тепловыделений // Инженерно-строительный журнал. 2012. №6. С. 42-47.

24. Аверьянова О. В. Экономическая эффективность энергосберегающих мероприятий // Инженерно-строительный журнал. 2011. №5. С. 53-59.
25. Корниенко С. В. Оценка влияния краевых зон ограждающих конструкций на теплозащиту и энергоэффективность зданий // Инженерно-строительный журнал. 2011. №8. С. 5-12.
26. Криницкий Е. В. Информационная модель здания // Инженерно-строительный журнал. 2010. №2. С. 16-18.
27. Недвига П. Н. Возможности использования тепловых аккумуляторов и низкопотенциального тепла земли при отоплении индивидуальных домов // Инженерно-строительный журнал. 2010. №3. С. 11-14.
28. Абдуллаев Г. И. О. Основные направления повышения надежности строительных процессов // Инженерно-строительный журнал. 2010. №4. С. 59-60.
29. Woods K., Ortega A. The thermal response of an infinite line of open loop wells for ground coupled heat pump systems // International Journal of Heat and Mass Transfer. 2011. Vol. 54. Issues 25–26. Pp. 5574-5587.
30. Effect of size on ground-coupled heat pump performance / Alalaimi M., Lorente S., Anderson R., Bejan A. // International Journal of Heat and Mass Transfer. 2013. Vol. 64. Pp. 115-121.
31. Сравнение стоимости установки тепловых насосов и традиционных систем отопления [электронный ресурс] http://www.refkomspb.ru/sravn.phtml (дата обращения 13.09.2013).

References

1. Morten B. Blarke.Towards an intermittency-friendly energy system: Comparing electric boilers and heat pumps in distributed cogeneration // Applied Energy. Vol.91. Issue 1. 2012. Pp. 349–365.
2. Tai Lva, Linghao Yua, Jinmin Songb. A Research of Simplified Method in Boiler Efficiency Test // Energy Procedia. Vol.17. Part B. 2012. Pp. 1007–1013.
3. Zhongsheng Niua, Kau-Fui V. Wonga. Adaptive simulation of boiler unit performance // Energy Conversion and Management. Vol. 39. Issue 13. 1998. Pp. 1383–1394.
4. Energy-saving judgment of electric-driven seawater source heat pump district heating system over boiler house district heating system / Shu Haiwena, Duanmu Lina, Li Xianglia, Zhu Yingxinb // Energy and Buildings. Vol.42. Issue 6. 2010. Pp.889–895.
5. Feng Li, Guozhong Zheng, Zhe Tia. Optimal operation strategy of the hybrid heating system composed of centrifugal heat pumps and gas boilers // Energy and Buildings. Vol. 58. 2013. Pp. 27–36.
6. Daniel Setrak Sowmya, Racine T.A. Prado. Assessment of energy efficiency in electric storage water heaters // Energy and Buildings. Vol. 40. Issue 12. 2008. Pp. 2128–2132.
7. *Vlijanie urovnja teplovoj zashhity ograzhdajushhih konstrukcij na velichinu poter' teplovoj jenergii v zdanii / Vatin N. I., Nemova D. V., Rymkevich P. P., Gorshkov A. S. // Inzhenerno-stroitel'nyj zhurnal. 2012. №8 (34). S. 4-14.* (rus)
8. J. Brenn, P. Soltic, Ch. Bach. Comparison of natural gas driven heat pumps and electrically driven heat pumps with conventional systems for building heating purposes // Energy and Buildings. Vol. 42. Issue 6. 2010. Pp. 904-908.
9. Jaspi Jsc. [web source] URL: www.kaukora.fi (date of reference: 29.04.2013)
10. *Babich A. S., Sotnikova O. A., Golovinskij P. A. Akkumulirovanie teploty v geliogruntovyh sistemah teplosnabzhenija s teplovymi nasosami // Nauchnyj vestnik voronezhskogo gosudarstvennogo arhitekturno-stroitel'nogo universiteta. Stroitel'stvo i arhitektura. 2009. № 1. S. 50-57.* (rus)
11. *Aver'janova O. V. Klimaticheskie sistemy s teplovymi nasosami i vodjanym konturom // Inzhenerno-stroitel'nyj zhurnal. 2009. № 2. S. 19-22.* (rus)
12. *Shinkevich T. O., Popkova O. S., Shinkevich O. P. Kompressionnye teplovye nasosy v sistemah otoplenija // Politematicheskij setevoj jelektronnyj nauchnyj zhurnal kubanskogo gosudarstvennogo agrarnogo universiteta. 2011. № 68. S. 125-136.* (rus)
13. *Butuzov V. A. Perspektivy primenenija teplovyh nasosov // Promyshlennaja jenergetika. 2005. № 10. S 8-15.* (rus)
14. *Romanova E. V., Orlov A. Ju. Vozmozhnosti ispol'zovanija teplovyh nasosov v processe sushki // Vestnik tambovskogo gosudarstvennogo tehnicheskogo universiteta. 2008. № 3. T. 14. S. 591-596.* (rus)
15. *Pozin G. M., Uljasheva V. M. Raspredelenie parametrov vozduha v pomeshhenijah s istochnikami teplovydelenij // Inzhenerno-stroitel'nyj zhurnal. 2012. № 6. S. 42-47.* (rus)
16. Motuzienė V., Valančius K., Rynkun G. Complex analysis of energy efficiency of public buildings: case study of VGTU // Инженерно-строительный журнал. 2012. № 2. С. 9-17.

17. *Avsjukevich A. D. Jenergojeffektivnost' i jenergosberezhenie v sistemah teplosnabzhenija // Stroitel'stvo unikal'nyh zdanij i sooruzhenij. 2013. № 2. S. 40-54.* (rus)
18. Stiebel Eltron [web source] URL: www.stiebel-eltron.ru (date of reference: 29.04.2013)
19. *Ptuhina I. S., Liskov A. A., Ptuhin I. A. Razvitie stoimostnogo inzhiniringa v stroitel'stve // Stroitel'stvo unikal'nyh zdanij i sooruzhenij. 2012. № 5. S. 17-20.* (rus)
20. Chua K. J., Chou S. K., Yang W. M. Advances in heat pump systems: A review // Applied Energy. 2010. Vol. 10. Pp. 3612-3622.
21. *Semenov B. A., Solov'jov V. A. Problemy i osobennosti ispol'zovanija gruntovyh teplovyh nasosov dlja avtonomnogo teplosnabzhenija ob#ektov v central'nyh regionah Rossii // Vestnik SGTU. 2009. №1. S. 167-172.* (rus)
22. *Samarin O. D., Tishhenkova I. I. Issledovanie reguliruemyh parametrov v avtomatizirovannyh klimaticheskih sistemah v celjah jenergosberezhenija // Inzhenerno-stroitel'nyj zhurnal. 2013. №2. S. 13-18.* (rus)
23. *Pozin G. I., Uljasheva V. M. Raspredelenie parametrov vozduha v pomeshhenijah s istochnikami teplovydelenij // Inzhenerno-stroitel'nyj zhurnal. 2012. №6. S. 42-47.* (rus)
24. *Aver'janova O. V. Jekonomicheskaja jeffektivnost' jenergosberegajushhih meroprijatij // Inzhenerno-stroitel'nyj zhurnal. 2011. №5. S. 53-59.* (rus)
25. *Kornienko S. V. Ocenka vlijanija kraevyh zon ograzhdajushhih konstrukcij na teplozashhitu i jenergojeffektivnost' zdanij // Inzhenerno-stroitel'nyj zhurnal. 2011. №8. S. 5-12.* (rus)
26. *Krinickij E. V. Informacionnaja model' zdanija // Inzhenerno-stroitel'nyj zhurnal. 2010. №2. S. 16-18.* (rus)
27. *Nedviga P. N. Vozmozhnosti ispol'zovanija teplovyh akkumuljatorov i nizkopotencial'nogo tepla zemli pri otoplenii individual'nyh domov // Inzhenerno-stroitel'nyj zhurnal. 2010. №3. S. 11-14.* (rus)
28. *Abdullaev G. I. O. Osnovnye napravlenija povyshenija nadezhnosti stroitel'nyh processov // Inzhenerno-stroitel'nyj zhurnal. 2010. №4. S. 59-60.* (rus)
29. Woods K., Ortega A. The thermal response of an infinite line of open loop wells for ground coupled heat pump systems // International Journal of Heat and Mass Transfer. 2011. Vol. 54. Issues 25–26. Pp. 5574-5587.
30. Effect of size on ground-coupled heat pump performance / Alalaimi M., Lorente S., Anderson R., Bejan A. // International Journal of Heat and Mass Transfer. 2013. Vol. 64. Pp. 115-121.
31. *Sravnenie stoimosti ustanovki teplovyh nasosov i tradicionnyh sistem otoplenija* [web source] http://www.refkomspb.ru/sravn.phtml (date of reference 13.09.2013). (rus)

Данная статья публикуется в рамках работы по проекту

530603-TEMPUS-1-2012-1-LT-TEMPUS-JPCR

This article is published in the framework of project

530603-TEMPUS-1-2012-1-LT-TEMPUS-JPCR