Energy conservation and the use of the heat of refrigeration of ice arenas to heat the school of figure skating of St. Petersburg

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Abstract. A variant has been proposed for using the system for utilizing the heat of condensation of heat engines, most of which has not been used and released into the environment, for air heating of ice arenas. An analysis of unused heat energy was made using the example of a refrigerating machine, which, in addition to cold production, also produces a significant amount of heat that is generated during the compression of the refrigerant in the compressor to the pressure and condensation temperature, and in most of the existing refrigeration units, thermal energy is not used and transferred to the environment using air condensers or cooling towers located on the street. The analysis of the economic efficiency of the use of heat recovery systems, for various technical needs. A study was carried out on the actual implementation of the system of partial utilization of the condensation heat of refrigerating machines, which is aimed at air heating of ice arenas at the St. Petersburg State Budgetary Institution of the specialized school of Olympic reserve on figure skating (hereinafter referred to as the “Institution”).

1. Introduction
Energy saving is today considered one of the most relevant areas of Russia's development in connection with the entry into force of Federal Law No. 261 of November 23, 2009 on Energy Saving [1] and Energy Efficiency and on amendments to certain legislative acts of the Russian Federation [2].

The purpose of the current study is to analyze the economic efficiency of using heat recovery systems released into the environment from heat engines (Figure 1) for various technical needs [3-6].

The objectives are to conduct a study on the introduction of the system for utilization of heat energy from heat engines [7,8] released into the environment [9] for various technical needs, related to the need to reduce thermal pollution [10], as well as the continuous increase in energy prices
Figure 1 Refrigeration room

Before the modernization of the heating system of ice arenas at the St. Petersburg State Budgetary Institution of the specialized school of Olympic reserve on figure skating (hereinafter referred to as the “Institution”), the heating was carried out at the expense of the air conditioning system, fan heaters and radiators (during the heating season).

Air conditioners of ice arenas (Figure 2) include a section for the first heating of air (heat from GUP TEK), a section for drying (a cooling circuit from refrigerators) and a section for a second heating (a circuit of forcondensers of refrigerators).

![Ventilation room. Air conditioners ice arenas.](image)

It is worth noting that in the Institution it is impossible to completely abandon the use of the primary circuit for heating air conditioners in ice arenas, for maximum loading of the second circuit, because of the possible freezing of the heat exchanger, as well as the operation of the automation system, therefore air gets to the secondary circuit already heated (above +25°C). It is also not possible to load the second heating circuit as much as possible, since a significant increase in the temperature of the elements of the installation can cause damage to the engine, bearings, parts made of synthetic materials [10].

Including supply/exhaust pipelines to the ice arenas made at a height of more than 6 meters from the floor level, which does not allow to fulfill the regulatory requirements regarding the air temperature in the ice arena at a height of 1.5 m from the ice (+6 +12 °C) [11], when using air conditioning ice arenas.

However, it is possible to heat the air in ice arenas at a height of 1.5 m from the ice, during the inter-heating period, using the VEABA W61 fan heaters (Figure 3) installed on the Institutional ice arenas.

![Main Arena. Fan Heaters](image)

2. Materials and Methods.
2.1. Equipment
Institution in which the research is carried out:
- St. Petersburg State Budgetary Institution of the specialized school of Olympic reserve on figure skating, located at St. Petersburg ul. Tupolevskaya, Building 4

Equipment:
- three ice arenas (2 arenas – 30x60 sq.m. And 1 arena 20x24 sq.m., Total area 4100 sq.m.)
- three BE/SMED-BT2402 chillers manufactured by Climaveneta, each containing two Bitzer CSH 8571-140Y-40D semi-hermetic screw compressors with a total cold output of 900 kW.
- Three air condensers FRIGA-BOHN ECA08P9 P10C3 (Figure 4)
- Six Alfa Laval CPS/S 145 forcondenser
- Wilo IL50 / 170-7.2 / 2 Circulation Pump
- Twenty fan heaters VEABA W61

![Air Condenser. Roof](image)

2.2. Analysis of the economic feasibility of a design decision on the introduction of energy-saving technologies, which consists of two subsections.
1. Analysis of the economic effect of the complete failure of the use of heat from the heat supplying organization GUP TEK SPb, for the hydraulic system of heat fans, air heating of ice arenas during the heating period. 7 months (from January to April and from October to December)
2. Analysis of the economic effect of the complete failure to use the heat pump (chiller), which was used only in the inter-heating period. 5 months (from May to September)

**Determination of the economic effect of the complete rejection of the use of heat from the heat supplying organization GUP TEC St. Petersburg, for the hydraulic system of fan heaters, air heating of ice arenas during the heating season. 7 months (from January to April and from October to December)**

\[
C_{\text{year.eff.of heat}} = T_{\text{year.work}} \times Q_{\text{recycling}} \times C_{\text{therm.energy}} \times K_{\text{use of heat}} - C_{\text{operating costs of the system}}
\]

where:
- \(C_{\text{year.eff.of heat}}\) – total annual effect in case of heat rejection of GUP TEK, mln. rur.;
- \(T_{\text{year.work}}\) – time of the heating season, hours/year;
- \(Q_{\text{recycling}}\) – heat recovered on forcondensators, kW;
- \(K_{\text{use of heat}}\) – the coefficient of using the heat of condensation is set equal to "0.5", because of the inability to use the system to 100%;
- \(C_{\text{therm.energy}}\) – cost of heat energy, rur/kW;
- \(C_{\text{operating costs of the system}}\) – the cost of the system, rur.;

\[
T_{\text{year.work}} = \frac{18\text{hours \cdot 7\text{days \cdot 4\text{weeks \cdot 7months}}}}{\text{year}} = \frac{3880\text{hours}}{\text{year}}
\]

\[
Q_{\text{recycling}} = 6 \text{ forcondensators} \times 75\text{ kW} = 450\text{ kW}
\]

\[
C_{\text{therm.energy}} = 2,087\text{ rur./kW with VAT. (1 Gcal =1,163 MW =1163kW. At a cost of 1 Gcal, 2427 rubles. with VAT, we get the cost of 1kW of heat energy = 2427/1163 = 2,087 rubles/kW)}
\]
operating costs of the system - for the operation of the system only a circulating pump with a capacity of 7.5kW is needed, that is, $N_{\text{consumption of the heat recovery system}} = 7.5\text{ kW}$.

Due to the fact that our Institution pays for the consumed electric energy in the fourth price category of JSC «PSK», then:

• cost of 1 kW * hour of electrical energy $C_{\text{el.en.}} = 1.84\text{ rubles/kW*hour}$,
• the cost of 1 kW for the transmission of electrical power $C_{\text{el.power transm.}} = 1583\text{ rubles / kW}$
• the cost of 1 kW of consumed electric power $C_{\text{cons.el.power}} = 775\text{ rubles/kW}$

• the cost of the operation of the heat recovery system of condensation will be:

$C_{\text{operating costs of the system}} = T_{\text{year.work}} \times (N_{\text{consumption of the heat recovery system}} \times C_{\text{el.en.}}) + 7\text{ months} \times (N_{\text{consumption of the heat recovery system}} \times (C_{\text{el.power transm.}} + C_{\text{cons.el.power}}))$

$C_{\text{operating costs of the system}} = (3880.8 \times (7.5\text{kw} \times 1.84)) + 7 \times (7.5\text{kw} \times (1583 + 775)) = 177350\text{ rubles}$

The total annual economic effect of using the heat recovery system in case of failure during the heating period from the heat of the SUE TEC for fan heaters will be (Figure 5):

$C_{\text{year.eff.of heat}} = 3880.8\text{ hours/year} \times 450\text{ kW} \times 2.087\text{ rur/kW} \times 0.5 - 177350\text{ rur.}$

$= 1,65\text{ mln. rur./7months or 235714 rur/months}$

**Figure 5** Payment for heat energy $G_{\text{cal}}$, before and after the implementation of the system, rubles/month.

Determination of the economic effect of the complete failure to use a heat pump (chiller), which was used only in the inter-heating period. 5 months (from May to September)

$C_{\text{heat pump savings}} =
(T_{\text{year.work}} \times ((N_{\text{aver.pow.cons.heat pump}} + N_{\text{aver.pow.cons.circ.pump}}) \times C_{\text{el.en.}}) + 5\text{months} \times ((N_{\text{aver.pow.cons.heat pump}} + N_{\text{aver.pow.cons.circ.pump}}) \times (C_{\text{el.power transm.}} + C_{\text{cons.el.power}}))

where: $C_{\text{heat pump savings}}$ — savings from the use of a heat pump, rub.;
$T_{\text{year.work}}$ — the time of operation of the heat pump in the inter-heating period, hours/year;
$N_{\text{aver.pow.cons.heat pump}}$ — average power consumption of the heat pump;
$N_{\text{aver.pow.cons.circ.pump}}$ — average power consumption of a single motor of a circulation pump, kW;
$C_{\text{el.en.}}$ — cost of electric energy, rubles/kWh;
$C_{\text{el.power transm.}}$ — the cost of 1 kW for the transmission of electrical power;
$C_{\text{cons.el.power}}$ — cost of 1 kW of consumed electrical power;

$T_{\text{year.work}} = \frac{18\text{hours}}{\text{day}} \cdot \frac{7\text{days}}{\text{week}} \cdot \frac{4\text{weeks}}{\text{month}} \cdot \frac{5\text{months}}{\text{year}} = 2772\text{ hours/year}$

$C_{\text{heat pump savings}} = (2772 \times ((33\text{kw} + 7.5\text{kw}) \times 1.84)) + 5 \times ((33\text{kw} + 7.5\text{kw}) \times (1583 + 775)) = 684064\text{ rur./5months or 136 812 rur/months}$
Figure 6 Payment of electrical energy before and after the introduction of the system, rubles/month.

**Total annual savings from the operation of the heat recovery system.**

\[
C_{\text{total savings}} = C_{\text{year eft. of heat}} + C_{\text{heat pump savings}} - C_{\text{operating costs of the system}}
\]

\[
C_{\text{total savings}} = 1,65\text{mln.rur.} + 684064\text{ rur.} - 177350\text{ rur.} = 2,15 \text{mln.rur./year}
\]

2.3. **Implementation costs:**

Costing for the implementation of the condensation heat recovery system for refrigerating machines (Figure 5)

The cost of equipment and installation work on the implementation of the system of partial utilization of the heat of condensation of refrigerating machines, for the air heating system of ice arenas - \( C_{\text{expenses}} = 115,131.42 \text{ rubles.} \)

The cost of operating the system per year (the work of a single electric motor 7.5 kW) – 307028 rubles. in year. \((6652.8\times(7.5\text{kW}\times1.84))+12\times(7.5\text{kW}\times(1583+775))=307028.64 \text{rur/yr}\)

Figure 7 The introduction of the system of utilization of the heat of condensation of refrigerators into the existing hydraulic system of air heating of the fan heaters of the ice arenas.

2.4. **The payback period for capital costs is:**

\[
C_{\text{payback period}} = \frac{C_{\text{expenses}}}{C_{\text{total savings}}} = \frac{115131\text{rur}}{2.15\text{mln.rur}} = 1 \text{ month.}
\]

3. **Introduction**

The results of the study showed that to increase the energy efficiency of engineering systems, the high costs associated with equipment replacement and capital construction are not necessary.

In the future, it is planned to introduce a system for the complete utilization of the condensation heat of refrigerating machines, the almost complete absence of thermal pollution of the environment and the use of a system in addition to air heating of ice arenas for:

1. Thawing snow in the pit of snowmelt of ice-picker combines (currently in the Institution is carried out manually due to hot water from the GVS, and during the heating period due to the radiators in the pit of snowmelt)
2. Ground heating systems against freezing under ice arenas (at present, this system can only be used during the heating season)
4. Conclusions
The introduction of a system of partial utilization of the heat of condensation of refrigerators, for
heating ice arenas at the expense of fan heaters, showed the following savings:

1. In case of refusal from the heat supplied by the SUE TEK to heat the coolant for fan heaters of
ice arenas in favor of using the system of utilization of the heat of condensation of
refrigerating machines, we obtain savings of 1 million 910 thousand rubles in year.

2. Reduction of thermal pollution [13] of the city of St. Petersburg from the Institution by not
less than 1746360 kW per year.

References
[1] Russian Federation. Laws. On energy saving and on increasing energy efficiency and on
introducing amendments to certain legislative acts of the Russian Federation dated 11.23.2009 No.
261-FL. - Access mode: http://base.consultant.ru.
[2] Energy Saving: State Standard of the Russian Federation of November 30, 1999 No. 485-st
(approved by a Resolution of the State Standard of Russia). [Electronic resource]. - Access mode:
http://base.consultant.ru.
[3] V. Polyakova, T. Kalinina, K. Kichin. Analysis of the energy efficiency of heat pumps in heat
supply systems according to the territorial-climatic basis. Young Scientist. 27, 142-146. 2016.
URL https://moluch.ru/archive/131/36474/.
[4] O. Averina, E. Moskaleva, T. Morozkina. Criteria for assessing energy efficiency. Young Scientist.
8, 427-429. 2014.URL https://moluch.ru/archive/67/11289/.
[5] Energy saving technology: Textbook / Yu. D. Sibikin, M. Yu. Sibikin. - 3rd ed., Pererab. and add. -
M .: Forum: SIC INFRA-M, 2013. - 352 p.Thermal pollution causes global warming, 2001, Bo
Nordell, Lulea, Sweden
[6] Thermal pollution causes global warming, 2001, Bo Nordell, Lulea, Sweden
[7] Belokon NI, Thermodynamics, 1954, p. 117.
[8] Saveliev I.V. The course of general physics. T. 1. Mechanics. Molecular physics. - M., Science,
1987. - p. 341
[9] Kantalinsky V.P., Patrakeeva E.A. Research on heat recovery methods at a production plant.
Improving the efficiency of power plants // International collection of scientific papers, Kaliningrad,
2002, p. 18 - 25.
[10] Thermal pollution causes global warming, 2001, Bo Nordell, Lulea, Sweden
[11] Technical and operational documentation. Units for ventilation and air conditioning of the type
CV-A (internally) and CV-D (outdoor). VTS CLIMA. P.25
[12] A collection of rules CR31-112-2007 Part 3 table 6.2
[13] A. Soldatov, O. Skotnikova. Utilization of thermal emissions from NPP – creation of an energy-
biological complex. Proceedings of International Student Scientific Conference "Polar Lights", 1999