Utilization of flue-gas heat in Riga city heat sources

Dr Sc Ing. Āris Žīgurs;
M.oec; Aivars Cers; B.sc.ing Juris Golunovs;
Dr.habil.sc.ing. Daniels Turlajs;
B.sc.ing. Sergejs Pļiskačevs.

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Introduction

The brochure „Utilisation of flue-gas heat in Riga city heat sources“ has been prepared as a report addressed to Riga Municipality Agency “Riga Energy Agency” (REA) and for the purpose of participation of AS „RĪGAS SILTUMS“ (RS) in the initiative on Sustainable Energy Europe with the aim to change the future habits of use of fuel and its structure, which is supported by the European Commission (SUSTAINABLE ENERGY EUROPE; A European campaign to change the landscape of Energy).

In Riga district heating is the dominating type of heat supply. Riga Heat Supply Concept 2006 – 2016 defines the major directions of development of the city heat supply, which have to be followed in planning and implementing measures for ensuring heat supply, development of the district heating system, including modernisation of heat sources, improvement of the quality of services, improvement of energy efficiency, planning and implementation of decrease of energy consumption, as well as setting of heat prices.

The Joint Stock Company “RĪGAS SILTUMS” is the main supplier of heat in Riga. In order to satisfy the needs of the city it purchases approximately 70% of heat from the power plants CHP-1 and CHP2 of the subsidiary Riga TES of the Joint Stock Company „Latvenergo“. The rest of heat amounting to approximately 30% is produced by RS in its own heat sources. Natural gas is used as the basic fuel in district heating system and wood chips are used in the cogeneration unit of the heat plant „Daugavgrīva“. 
During last 15 years a lot of work has been done for rehabilitation and improvement of the district heating system. The Joint Stock Company „RĪGAS SILTUMS” continued implementation of the modernisation program, attracted required investments and in the result in several heat sources technical measures were implemented for utilisation of flue-gas heat, thus, efficiency of heat production facilities was improved. At the heat plant „Imanta”, cogeneration plants Keramikas Street 2a, Viestura prospekts 20, as well as at automated gas-fired boiler houses Trijādības Street 5 and Nautrēnu Street 24 equipment for utilisation of flue-gas heat was installed and is in operation permitting to produce additional heat without burning any additional fuel. The equipment for utilisation of flue-gas heat, which is installed at the boiler KVGM-100 at the heat plant “Imanta”, deserves special attention. Boilers of this type were widely used in the former soviet countries in the Eastern Europe and are still in operation there. Therefore, the best practice example for increasing energy efficiency at the heat plant „Imanta” is of international importance.

Project goals and implementation

In the course of implementation of this project it is planned to carry out a research on utilisation of flue-gas heat at the heat sources of the joint stock company „RĪGAS SILTUMS”, efficiency of the installed economisers and drawn conclusions within the European Commission international initiative on Sustainable Energy Europe with the aim to change the future habits of use of fuel and its structure (SUSTAINABLE ENERGY EUROPE; A European campaign to change the landscape of Energy). The work within the project was commenced on November 1, 2009 and Riga Energy Agency (REA) and the joint stock company “RĪGAS SILTUMS” participate as partners in the implementation of the project. Condensing type economisers, which have been installed by RS at the heat plant “Imanta”, at cogeneration plants located at Keramikas 2a and Viestura 20, at automated gas-fired boiler houses located at Trijādības 5a and Nautrēnu 24, are used as data sources for the project. Capacities of the installed economisers range from 110 kW up to 10 MW at the heat plant „Imanta”, which is the biggest device of this type in Latvia.

Technological aspects of the project and challenges

The performed research on the use of passive condensing type economisers with natural gas-fired high capacity water heating boilers is topical for the East Europe region, where boilers of this type were introduced with the aim to provide peak heat load capacities and currently at many heat sources the issue of improving efficiency of this equipment is very topical. The gained experience will permit to achieve considerable additional fuel savings and to improve efficiency of boiler equipment. The present report contains a summary of the results of reconstruction and research related to operation of medium and high capacity water heating boilers with passive condensing type economisers. Much broader overview of best practice examples of reconstruction of high capacity water heating
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boilers is provided by publication included in the list of sources under No. 4; it provides basic recommendations for preparation for installation of condensing type economisers.

Currently the global economy has started to recover from the worst economic depression of last decades and the price of oil and other energy fuels gradually approaches the unprecedented price level, which was reached shortly before the crisis set in when the price reached the historically maximum level above 145 USD/barel.

![Oil prices 2007 - 2010](source: Financial Times)

Figure No.1. Oil prices 2007 - 2010. (Source: Financial Times)

Taking into account the gained experience power companies have to prepare for the next increase of fuel prices well in advance and to implement measures for improving energy efficiency. Improvement of energy efficiency presents the basic task – utilisation of flue-gas heat by means of installing condensing type economisers.

Condensing type economisers are widely used for reducing temperature of flue-gas and for improvement of environmental conditions, as well as saving financial resources for purchase of fuel. Usually condensing type economisers of water heating boilers allow to increase efficiency of boilers from 94% to 100% and in some cases even up to 107%. It should be noted that it refers to the lowest burning heat of fuel and not the maximum level.

One of the advantages of condensing type economisers, when those are compared to other heat exchange devices of flue gas, is a possibility to utilise latent (hidden) heat. Latent heat is the amount of heat, which is absorbed by the system at transition of phases (melting, evaporation, etc.) or when reverse transition of phases takes place (crystallisation, condensation, etc.), latent heat is discharged. Advantages of latent heat exchange are described in Figure No. 2.
In Figure No. 2 it can be seen that along with decrease of temperature of flue gas at the stage from C to B the efficiency increase is small, however, starting from B (temperature of flue gas around 58°C) change of efficiency is much more rapid. This is related to rapid increase of the volume of utilisation of latent heat, which decreases at the level below 37°C.

History of research of condensing type economisers

Depending on the design condensing type economisers can be either active or passive. Possibilities of use of condensing type economisers in Latvia have been studied by scientists of Riga Technical University prof. Igors Iljins, Dr.sc.ing. Maija Rubīna, Dr.sc.ing. Pāvels Popovs, Dr.habil.sc.ing. prof. Dagnija Blumberga and others.

Research certifies that quantitative heat supply control principles were widely used in the East European countries. High temperature potential was introduced into heat networks, temperature of flue gas behind boilers was high and removal of latent heat in economisers was achieved by means of supplementary water spraying in the flue gas system of the heat exchange device directly onto the grid of pipes of the heat exchange device. This type of heat supply did not permit to ensure low return temperature T2 of district heating and active condensing type economisers were the only possibility for ensuring condensing mode of operation in the heat exchange device because condensing of humidity of flue gas ceases at the temperature of flue gas of 58 - 60°C.

Active condensing type heat exchange devices were widely introduced in the heat supply system of Latvia in the 70-ies of the 20th century. Contact-active heat exchange devices with active filling developed by Latvian experts are better known to the public by their Russian name KTAH (See Figure No.3).
Unfortunately, available materials for forming the active filling usually were of low quality and the service time of these heat exchange devices was short. Also utilisation or use of the condensate presented problems due to the low pH level. At present active condensing type economisers are widely used for reducing temperature of flue gas in operations with fossil fuel types because temperature of flue gas is usually higher with fossil fuels and additional measures for ensuring condensation are required.

Another obstacle for broad use of condensing type economisers was related to the design of stacks used in energy. It was not possible to connect condensing type economisers with deep cooling to brick or concrete stacks without adding hot flue gas or stainless steel lining of a stack, because stainless steel products were not available at that time.

DH water temperature at the outlet from the active filling is restricted by the temperature of the humid thermometer of flue gas. When natural gas with air abundance coefficient of 1.0 – 1.5 is burnt, temperature of the humid thermometer of flue gas amounts to 55 - 65°C.

Temperature of flue gas at the outlet from KTAH is assumed to be 8 - 10°C above the inlet temperature of DH water to the economiser. After separation of flue gas additional 7 - 10% of not cooled flue gas are added for the purpose of decreasing humidity of final flue gas prior to letting it in the stack.
Modern economisers with active filling usually are simplified. They do not demand use of large amounts of cold water or bypass of flue gas, because humidity does not impact modern stacks, thus, water consumption at power utilities has dramatically decreased.

**Passive condensing type economisers**

Passive condensing type economisers are heat exchange devices with sufficiently large heating surfaces, on which flue gas returns all the latent heat or a certain portion of it to the heat carrier, which is usually water, without any additional application of water.

The Joint Stock Company „RĪGAS SILTUMS” has experience in use of condensing type economisers for natural gas-fired water heating boilers with capacity 1.1; 1.4; 2.6; 5; 9 and 116 MW;

Connections of passive economisers may differ depending on peculiarities of configuration and load of a boiler house. In Figure No. 4 a connection of two parallel condensing type economisers to a boiler of medium capacity and direct connection to the DH network at the boiler house of Trijādības Street is shown. In Figure No. 5 the location of economisers in the boiler house is presented.

![Figure No.4. Application of condensing type economisers in medium capacity boiler houses with direct connection to the DH network.](image)

Based upon the above described principle with direct connection both low and medium capacity boiler houses operate and there is the highest expected effect.

Operation of condensing type economisers at cogeneration plants, where usually for the purpose of not losing power generation capacity the cogeneration unit is not able to deliver water temperatures exceeding 90°C to the network at low
outdoor temperatures, is much more complicated. Thus, water heating boilers have to perform the role of increasing T1, and this automatically has a negative impact upon the operation mode of the condensing type economiser. At the heat plant „Imanta” and also at cogeneration plants Keramikas 2a and Viestura 20 boilers and condensing type economisers devices perform the role of increasing the network temperature at low outdoor temperatures.

Figure No.5. Location of condensing type economisers at the boiler house Trjādības 5.

The number of hours during which an economiser operates at the maximum possible capacity has an essential impact upon the efficiency of economisers. The experience in operation of boiler economisers certify that it might be necessary to stop a boiler for at least eight hours at least once a quarter and also during the heating season for performing various preventive measures at rotation mechanisms (smoke pumps, ventilators), automation inspection and preventive maintenance of gas devices.

The biggest passive condensing type economiser in Latvia 4 X 200-36-200, which is installed at a standard boiler KVGM with the installed heat capacity of 116 MW, was selected for detailed tests and research. Reconstruction of burners of the boiler was performed by means of installing four low NOx burners. Complete volume of pre-reconstruction works is reflected in the publication No. 4. Data collection and processing was made easier by the data collection and processing system MDS 2009, which is installed at RS and permits to use statistics data on operation of the boiler house equipment over a long period of time both as tables and also as graphs.

**Modes of operation of KVGM 100 passive condensing type economiser**

In Latvia natural gas-fired water heating boilers KVGM-100 are the biggest ones and the map of their operational modes is shown in Table No. 1. There are three boilers of this type in the Heat Plant Imanta. In the below map of operational
modes (Figure No. 6) it can be seen that the efficiency of the boiler is stable and high up to 60 MW. When the set capacity level is reached the efficiency can decrease by up to 2% at the maximum load. Maximum loading of the boiler increases the risk of stoppage in case of power failures, which can cause unwanted pressure in heat supply. The data certify that the boiler operates in a stable mode at 75% of the installed capacity of the boiler, thus, it is reasonable to maintain continuous basic load of the boiler at 90 MW, which was studied during the time period from 01.11.2009, when the economiser was put into operation, until 02.02.2010.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Min.</th>
<th>5.8</th>
<th>20</th>
<th>40</th>
<th>57</th>
<th>61.8</th>
<th>60</th>
<th>60</th>
<th>80</th>
<th>100</th>
<th>116</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler’s water flow</td>
<td>t/h</td>
<td>5.8</td>
<td>20</td>
<td>40</td>
<td>57</td>
<td>61.8</td>
<td>60</td>
<td>60</td>
<td>80</td>
<td>100</td>
<td>116</td>
</tr>
<tr>
<td>Water temperature before the boiler</td>
<td>°C</td>
<td>58–60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water pressure after the boiler</td>
<td>bar</td>
<td>not less than 0.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of gas burners</td>
<td>piece</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel pressure before the burners (rostrum)</td>
<td>mbar</td>
<td>2-60</td>
<td>4-80</td>
<td>4-80</td>
<td>4-80</td>
<td>140</td>
<td>140</td>
<td>140</td>
<td>140</td>
<td>140</td>
<td>140</td>
</tr>
<tr>
<td>Air pressure before the burners (rostrum)</td>
<td>mm of wat. col.</td>
<td>3.5-4</td>
<td>3.5-4</td>
<td>3.5-4</td>
<td>3.5-4</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>Vacuum in the furnace</td>
<td>mm of wat. col.</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Flue gas temperature</td>
<td>°C</td>
<td>2-60</td>
<td>4-80</td>
<td>4-80</td>
<td>4-80</td>
<td>140</td>
<td>140</td>
<td>140</td>
<td>140</td>
<td>140</td>
<td>140</td>
</tr>
<tr>
<td>Oxygen content in the flue gases (rostrum)</td>
<td>%</td>
<td>12.5</td>
<td>5.40–5.60</td>
<td>7.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel consumption (t/h)</td>
<td></td>
<td>960</td>
<td>2200</td>
<td>4482</td>
<td>6865</td>
<td>1315</td>
<td>1497</td>
<td>6773</td>
<td>9685</td>
<td>11024</td>
<td>13475</td>
</tr>
<tr>
<td>Consumption of the equivalent fuel (kg e.f/1 MW)</td>
<td>130.5</td>
<td>128.6</td>
<td>128.8</td>
<td>129.3</td>
<td>128.1</td>
<td>128.2</td>
<td>128.8</td>
<td>129.4</td>
<td>130.8</td>
<td>132.2</td>
<td></td>
</tr>
</tbody>
</table>

Table No. 1. The map of operational modes of the boiler KVGM-100 without a condensing type economiser

In November, 2009 at the Heat Plant „Imanta” a passive condensing type economiser 4x200-36-200 manufactured by the Danish company “DET” was put into operation behind the water heating boiler KVGM-100 No. 3 (Figure No. 6). The rated heat capacity of the economiser amounts to 10 MW. Prior to the installation of economiser the stack was reconstructed by inserting CORTENA corrosion resistant material D=1900 mm smoke passages and D=1700 mm stack shells.

Figure No. 6 Condensing economiser of the boiler KVGM
In the below Figure No. 7 the scheme of connection and operational mode of the passive economiser of the boiler KVGM-100 at the outdoor temperature of +8.9°C is presented.

![Economiser Diagram](image)

Figure No. 7. Operation of the passive economiser of the boiler KVGM 100 at $T_{out}=+8.9°C$

When the monthly analysis of December, 2009 was performed (see Figure No. 8) it was discovered that the daily average efficiency of the boiler at stable boiler capacity of 90 MW (the capacity of the economiser excluded) was high at $T_2 \leq 43°C$, however, the return of latent heat was decreasing dramatically at the temperature $T_2 = 49 °C$ and above.

![Graph](image)

Figure No. 8. Operation of the condensing type economiser of the boiler KVGM 100 in December, 2009
The considerable increase of the outlet boiler water temperature $T_k2$ for the purpose of fulfilling the temperature schedule requirements, which can change from 100°C at Tout 0°C up to 130 - 150°C at Tout -10°C and below, should be mentioned as additional factors, which restrict the return of latent heat at low outdoor temperature. At $T_2 \geq 52°C$ the capacity of the economiser decreases by at least 40% compared to $T_2=40°C$. When the volume of condensate discharge was evaluated the direct correspondence between the condensed water volume and the capacity of the economiser was identified. For boilers of this capacity level tons of condensate correspond to the utilised capacity of the economiser. Therefore, at weather conditions characterised by low outdoor temperature the volume of condensate can be even up to 70% below the average statistical heating season temperature, however, with much higher proportion of absorbed CO2. Statistical data on average monthly outdoor and return water temperatures from last heating seasons are presented in Table No. 2.

<table>
<thead>
<tr>
<th></th>
<th>October</th>
<th>November</th>
<th>December</th>
<th>January</th>
<th>February</th>
<th>March</th>
<th>April</th>
<th>T2 accrod.to schedule °C</th>
<th>T2 real 2008/2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004/2005 y.</td>
<td>7.7</td>
<td>0.8</td>
<td>1.4</td>
<td>-0.1</td>
<td>-5</td>
<td>-3.7</td>
<td>6.5</td>
<td>44</td>
<td>37.5</td>
</tr>
<tr>
<td>2005/2006 y.</td>
<td>7.9</td>
<td>3.1</td>
<td>-2.1</td>
<td>-5.9</td>
<td>-6.6</td>
<td>-2.9</td>
<td>6.4</td>
<td>44</td>
<td>37.4</td>
</tr>
<tr>
<td>2006/2007 y.</td>
<td>9.7</td>
<td>4.3</td>
<td>4.3</td>
<td>0.7</td>
<td>-7.4</td>
<td>5</td>
<td>5.3</td>
<td>44</td>
<td>40.6</td>
</tr>
<tr>
<td>2007/2008 y.</td>
<td>6.8</td>
<td>0.8</td>
<td>0.8</td>
<td>-1.1</td>
<td>2.7</td>
<td>2.4</td>
<td>8.6</td>
<td>44</td>
<td>41.7</td>
</tr>
<tr>
<td>2008/2009 y.</td>
<td>9.3</td>
<td>3.6</td>
<td>0.8</td>
<td>-1.6</td>
<td>-2.8</td>
<td>0.9</td>
<td>5.3</td>
<td>44</td>
<td>42.4</td>
</tr>
<tr>
<td>At normative</td>
<td>7.2</td>
<td>2.1</td>
<td>-2.3</td>
<td>-4.7</td>
<td>-4.3</td>
<td>-0.6</td>
<td>5.1</td>
<td>44</td>
<td>40</td>
</tr>
<tr>
<td>Average statistic</td>
<td>8.3</td>
<td>2.5</td>
<td>1.0</td>
<td>1.6</td>
<td>3.8</td>
<td>0.3</td>
<td>6.4</td>
<td>44</td>
<td>38.4</td>
</tr>
</tbody>
</table>

Table No. 2 Statistical data on standard and heating season outdoor and return from customers water temperatures.

In Table No. 2 perfect conditions for the operation of a passive condensing type economiser are presented. Climate conditions during the time period from January 1 to February 1, 2010 should be singled out as a special exception when the monthly average temperature was -10.56°C, $T_2$ increased up to 48.3°C, and the average capacity of the economiser was equal to 5.25 MW. Capacities of the economiser, which were certified by tests, are presented in Figure No. 8. The graph summarises data on the capacity of the condensing type economiser at stable boiler load of 90 MW. It shows that at outdoor temperature of -20°C the return of latent heat is completely stopped. Reading of the metering device of condensate indicate that the volume of condensate at Tout 0°C amounts to 0.5 t/h compared to volume of condensate of 5.9 t/h. Studies indicate that at very low temperatures, at operation with stable heat load low return of heat can be observed on certain instances, which certifies that the productivity modes of the boiler are changing.
Intermediate results of the project

Average monthly temperatures of the current heating season have been extremely cold, and this has permitted to assure quality of boiler equipment under high capacity conditions and also to test condensation of flue gas under rough climate conditions. Figure No. 10 reflects average outdoor temperatures during the three months, when the project was implemented, and their correspondence to the climatic standard.

Weather conditions have been extremely rough during January, 2010 when the monthly average temperature was 5.86°C below the climate standard. The temperature during January of this year has been by 8.96°C lower than during the previous heating season.
Although such climate conditions reduce production of condensing type economisers, still considerable savings of gas have been achieved and totally they amount to 1.685 mil m³ natural gas, (see Figure No. 11) and 3084 tons CO₂ (see Figure No. 12), which will permit to ensure better environment quality for the city residents.

From the data presented in the graphs it can be seen that the project goal is being achieved successfully. Considerable improvements of the environmental conditions and decrease of the volume of imported natural gas, which is provided by increase of efficiency of heat sources due to application of condensing type economisers, should be mentioned among the major results.
Main conclusions

1. The results of the performed tests and research indicate that in situations where natural gas is used in water heating boiler it is very important to select equipment with especially high efficiency.

2. Within heat supply systems with quantitative – qualitative control method it is possible to replace active condensing type economisers by passive condensing type economisers with considerably lower costs of equipment and maintenance.

3. The gained experience can be shared in the East European countries, where high capacity water heating boilers are widely used.

4. The best practice example should be used as a standard solution for increasing efficiency of high capacity water heating boilers.

Operational modes of a condensing type economisers have to be as efficient as possible for ensuring attraction of latent heat during the heating season. During a season condensing type economisers can cause problems in relation to maximum loading of boilers. It is not always that equipping of boilers, which are not loaded by the basic load, with condensing type economisers yields the expected result.

It is important to take into consideration construction climate information on average monthly temperatures, hourly load schedule of the particular heat source, as well as information on the actual average T2 at the set outdoor temperature during the heating season. Often it is not considered that during maximum loading of boilers T2 is not always suitable for attracting latent heat without additional water spraying. The amount of condensate and its utilisation possibilities are encumbered by fluctuating volumes, which are impacted considerably by T_out and thus also changes of T2.

Bibliography

3. Д.А. Кочугов, ИСПОЛЬЗОВАНИЕ ВТОРИЧНЫХ ЭНЕРГОРЕСУРСОВ НА ТЕПЛОВЫХ ЭЛЕКТРОСТАНЦИЯХ УДК 662.994
7. Рубина М.А., Ильин И.Н., Попов П.Я. и др. Об эффективности контактных теплообменников с активной насадкой // Промышленная энергетика Nr.8, 1986.