# Heat transfer enhancement of the open-type heat recovery unit

*Stanislav* Davydov[1], *Rafail* Apakashev[1], and *Konstantin* Kokarev[1*]

[1]Ural State Mining University, 620044, Kuibysheva St., 30, Yekaterinburg, Russia

**Abstract.** An increase in the heat transfer efficiency of the open-type heat recovery unit due to the sequential heat and mass transfer enhancement is considered. The graphs of variances in the water temperature, gas temperature, gas enthalpy and gas specific humidity at the end of each site are presented. The proposed designs of the open-type heat recovery unit can be used for the flue gas disposal, including the disposal of natural gas combustion products in the greenhouse facility.

## 1 Introduction

The studies conducted during the recent decades both in Russia and abroad have shown that the use of highly efficient condensation heat exchangers (CHEs), including the open-type CHEs (direct liquid and gas contact for deep cooling of the exhaust gases below the dew point), allows to make comprehensive solutions in relation to the energy preservation tasks and reduce the amount of harmful emissions into the atmosphere. Water heated in the CHE can be used in the construction industry to produce foamed concrete. It is also possible to heat water for the external consumers of the hot water supply systems and underground heating of greenhouses, recycling air heating systems.

The development objective is to increase the used design efficiency for the Donetsk Chemical and Metallurgical Plant and the Ministry of Industry, Energy and Science of the Sverdlovsk region due to the consistent heat and mass transfer enhancement. The graphs of variances in the water temperature, gas temperature, gas enthalpy and gas specific humidity at the end of each site are presented. The proposed designs of the open-type heat recovery unit can be used for the flue gas disposal, use of the natural gas combustion products in the greenhouse facility.

The efficient open-type recovery unit was designed for the Donetsk Chemical and Metallurgical Plant [1-3]. The equipment used is extremely easy to maintain, it uses the flue gas previously released into the atmosphere.

By order of the Ministry of Industry, Energy and Science of the Sverdlovsk region [4], the effective open-type recovery unit was developed [5-7].

The modified design of the efficient open-type recovery unit is shown in Figure 1, including the mounted additional driving drip eliminator 5 and contact tip 4 (Fig. 1). The drip eliminator is filled with the ceramic annular or saddle-shaped temperature- and

* Corresponding author: konstantin.kokarev@m.ursmu.ru

corrosion-resistant nozzles. In this case, the heat-exchange nozzle "IRG" 3 is made in the form of a package of corrugated metal plates made of steel sheets. In these nozzle designs, the liquid washing the elements comes off in the form of a film. The comparative analysis of the fluid mechanical specifications (Table) of the IRG and Inzhekhim-2004 nozzle with the pall rings used in this device showed that at a vapor velocity of above 3 m/s, the Inzhekhim-2004 nozzle is operated consistently with a relatively low flow resistance.

**Table 1.** Technical specifications of the nozzles

| Parameter | Inzhekhim-2002 | Inzhekhim-2004 | IRG |
|---|---|---|---|
| Element dimensions, mm | 50x40x35 | 45x27x25 | - |
| Corrugation height, mm | - | - | 12;15;20 |
| Specific surface area, $m^2/m^3$ | 200 | 149 | 255;156;120 |
| Specific volume, $m^3/m^3$ | 0.95 | 0.96 | 0,97;0,98; 0,98 |

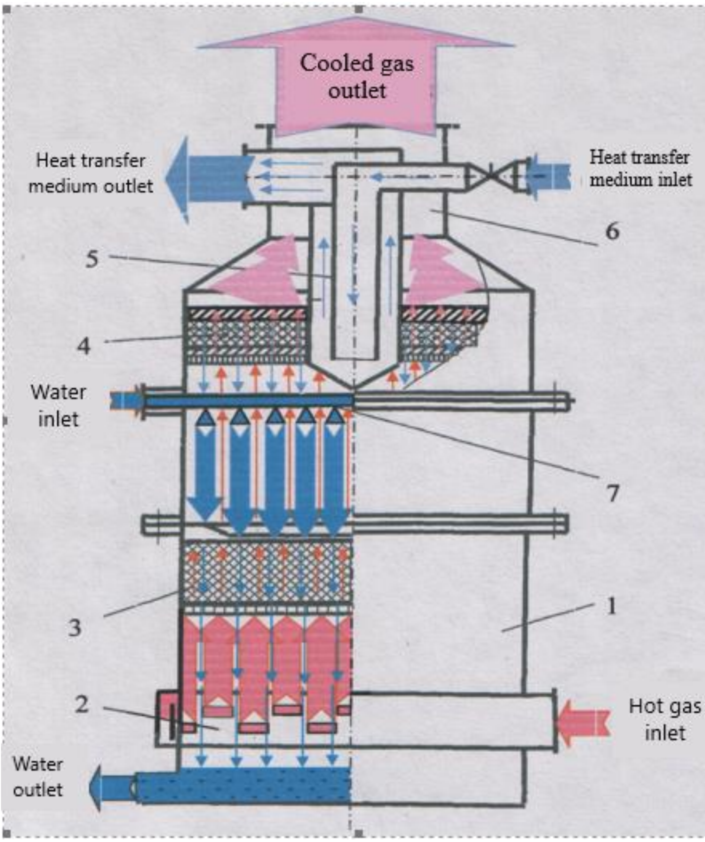


**Fig.1.** Open-type heat recovery unit with drip eliminator for the Ministry of Industry, Energy and Science of the Sverdlovsk region: 1 - body; 2 - supply of the used hot gases of metallurgical enterprises; 3 - heat transfer nozzle; 4 - drip eliminator; 5 - cooler; 6 - gas outlet; 7 - sprinkler

## 2 Materials and methods

According to the calculation results of the final temperature [1, 4, 8] in 14 sites N with an interval of 10°C, the graphs of changes in the water temperature Θ (Fig. 2), gas temperature *t*

(Fig. 3), gas enthalpy *J* (Fig. 4) gas specific humidity *d* (Fig. 5) at the end of each site are presented.

During the calculations, the following initial data were used [1, 4, 8]: flue gas volume flow rate $V_1$ = 10580 nm³/h; gas temperature: before the economizer $t_1$ = 165°C, after the economizer $t_2$ = 35°C (with the moisture content $d_2$ = 0.032 kg/kg); air excess factor in the flue gases □= 1.3; water temperature: at the inlet of the economizer $\theta_1$ = 5°C, at the outlet - $\theta_2$ = 55°C.

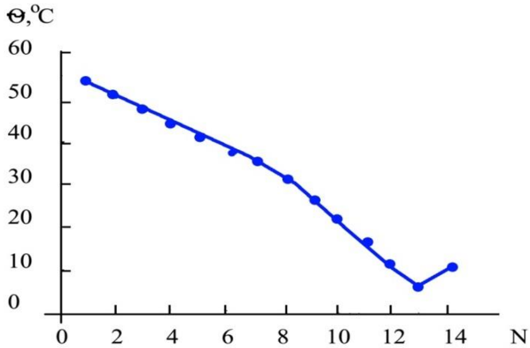


**Fig.2.** Water temperature changes by sites

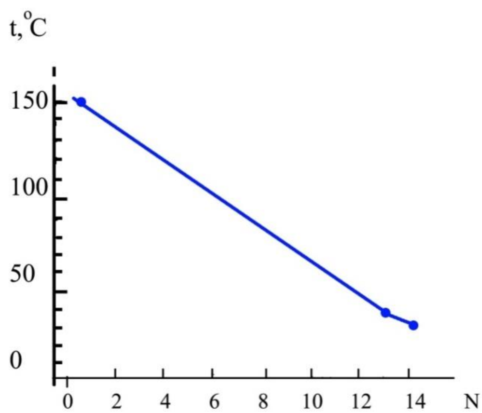


**Fig.3.** Gas temperature t changes by sites

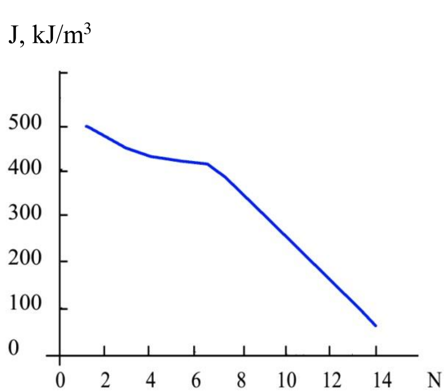


**Fig.4.** Gas enthalpy J changes by sites

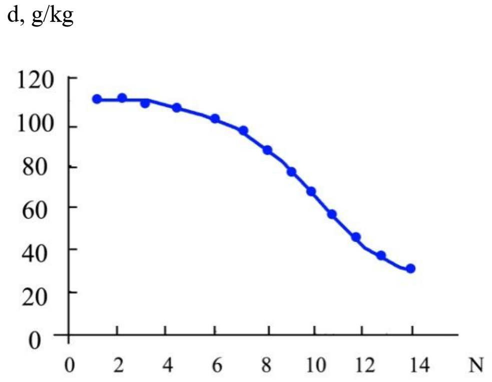


**Fig.5.** Gas specific humidity d changes by sites

An additional driving drip eliminator 5 (Fig. 1) includes an outlet connection 8 (Fig. 6) in the form of a bowl [9] for the heat-exchange medium discharge.

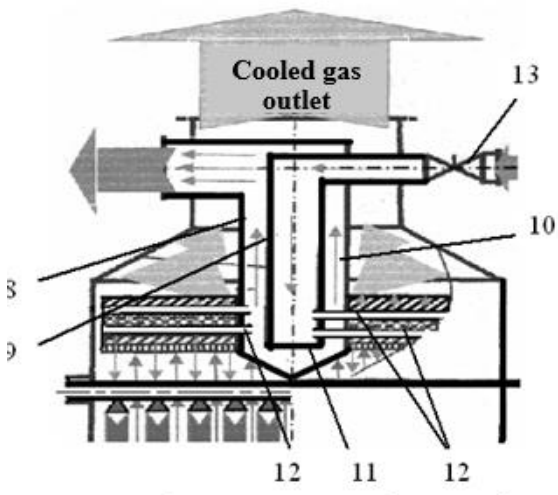


**Fig.6.** Drip eliminator of the open-type heat recovery unit: 8 - outlet connection; 9 - bypass pipe; 10 - annular clearance; 11 - plug; 12 - hollow heat-exchange elements; 13 - heat transfer agent input valve

The high efficiency of the proposed design is that on the bowl bottom, the connection 8 and bypass pipe 9 are equipped with a plug, and the heat exchange elements are hollow and filled with a flowing heat exchange medium. The cavities of the heat exchange elements interconnect with the bypass pipe and with the annular clearance of the outlet connection 8.

## 3 Results and discussion

The new proposed solution to improve the efficiency of water vapour recovery and reliability in the operation of the upgraded plant provides a device that is easy to manufacture and use [10] (Fig. 7). The cavities of the sprinkler 4 and the cooler 5 are connected by an overpass 1 through the connections 2 and 3.

The consistent efficiency improvement during the development of the open-type heat exchangers [2, 3, 7, 9, 10] makes it possible to enhance the heat transfer of the open-type heat recovery units. The treatment of finely-dispersed mists to the regulated residual concentration is provided. Cooling of the combustion products to a temperature allows to concentrate the maximum possible part of the water vapor contained in the gases and use the latent heat released during the concentration. Decrease in the flue gas temperature and elimination of the heated coolant medium release shall minimize the air hoar generation and icing at the outlet of connections 2 and 3, allowing to reduce the labor costs for cleaning and increase its service life.

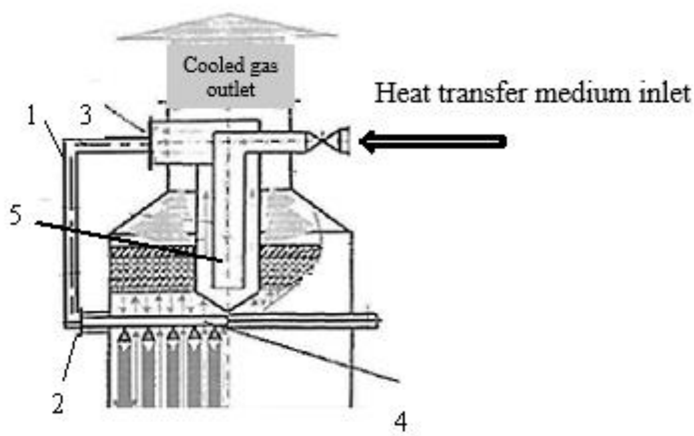


**Fig.7.** Heat recovery unit with the cooler cavities combined with the sprinkler: 1 - overpass; 2 and 3 - connections; 4 - sprinkler; 5 - cooler

## 4 Conclusions

The consistent efficiency increase during the development of the open-type heat exchangers makes it possible to enhance the heat transfer of the open-type heat recovery units. Cooling of the combustion products to a temperature allows to concentrate the maximum possible part of the water vapor contained in the gases and use the latent heat released during the concentration. Decrease in the flue gas temperature and elimination of the heated coolant medium release shall minimize the air hoar generation and icing at the outlet of connections, allowing to reduce the labor costs for cleaning and increase its service life.

The proposed designs of the open-type heat recovery unit can be used for the disposal of flue gases generated, for example, in the open-hearth furnaces, glass melting furnaces, cupola furnaces during calcination of bricks, ceramics, when the ingots are heated prior to rolling, and other thermal generating units [11]. The use of natural gas combustion products in the greenhouse facilities of the industrial enterprises shall simultaneously solve two issues related to the increase of yield capacity and increase of efficiency of the thermal generating units.

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