Energy saving technologies of the decentralized ventilation of buildings

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Abstract. The growing aspiration to energy saving and efficiency of energy leads to necessity to build tight enough buildings. As a result of this the quantity of infiltration air appears insufficient for realization of necessary air exchange in. One of decisions of the given problem is development and application for ventilation of premises of the decentralized forced-air and exhaust systems (DFAES) with recuperative or regenerative heat-exchangers. For an estimation of efficiency of DFAES following basic parameters have been certain: factor of energy saving; factor of efficiency of energy; factor of a heat transfer; factor of an effective utilization of a surface of heat exchange. Were estimated temperature of forced air; actual speed of an air jet on an entrance in a served zone; actual noise level; the charge of external air. Tests of DFAES were spent in natural conditions at which DFAES influenced all set of factors both an external climate, and an internal microclimate of a premise, and also the arrangement on a wind side or behind wind side of a building, influence of surrounding building, fluctuation of temperature of external air is considered. Proceeding from results and the analysis of the lead researches recommendations have been developed for development and manufacture of new sample of DFAES.

1. Introduction
Quality of internal air substantially affects health of people. However, for last twenty years the quantity of infiltration air appears insufficient for realization of necessary air exchange in. Therefore, today there was especially actual a question on development of energy efficiency systems of forced-air and exhaust mechanical ventilation of buildings. One of decisions of the given problem is development and application for ventilation of premises of the decentralized forced-air and exhaust systems (DFAES) with recuperative or regenerative heat exchangers.

The purpose of work consists in test of the decentralized ventilating devices and development of recommendations for manufacture new energy saving installations in view of climatic conditions. Tests were spent for three samples of DFAES:
1) "UVRK-50" (Open Company NPO "EcoTherm", Omsk),
2) "Prana-150" (company "Prana", Lvov),
3) "TeFo" (Open Company "Heat exchange", Sevastopol).

2. The Principle of work of "UVRK-50"
"UVRK-50" - DFAES with regenerative heat exchanger (Figure 1). Work of "UVRK-50" shares on 4 basic phases:

In the first phase the fan of installation deletes air from a premise. Air, passing through regenerative heat exchanger, heats up it;

In the second phase the regenerator proper also occurs reverse work of the fan;

In the third and fourth phases cold external air, passing through a regenerator of installation, heats up almost to a room temperature, gradually cooling a regenerator.

**Figure 1.** The ventilating device with regenerative heat exchanger "UVRK-50".

3. The Principle of work of "Prana-150"

"Prana-150" - DFAES with recuperative heat exchanger (Figure 2). Ventilation of a premise occurs because "Prana-150" takes away warm fulfilled air from a premise and deletes it to street, simultaneously takes away from street cold fresh and dry air and submits it to a premise. Air streams are divided both inside of the working module, and on an input-output the special airdistributing device and do not mix up among themselves. Due to passage of air streams through copper recuperative heat exchanger, warm exhaust air gives the heat external cold fresh air.

**Figure 2.** The ventilating device with recuperative heat exchanger "Prana-150".

4. The Principle of work of "Tefo"

"Tefo" - DFAES with casing trumpet recuperative heat exchanger (Figure 3). Air gets through air branch pipe with a lattice and acts in recuperative heat exchanger. Passing inside pipes, external air heats up and moves the fan in a served premise. Exhaust air leaves the fan from a premise through a branch pipe. Passing through intertrumpet space of recuperative heat exchanger, air is thrown out outside through a branch pipe with a lattice.
Figure 3. The ventilating device with recuperative heat exchanger "TeFo".

5. Parameters of an estimation of effective work of DFAES and a technique of carrying out of tests

For an estimation of overall performance of DFAES following criteria [1, 3] have been certain:

5.1. Basic power parameters of an estimation of effective work of DFAES

5.1.1. Factor of energy saving:

\[ \eta_{es} = \frac{Q_{ret}}{Q_{dem}} \cdot 100 \]

where \( Q_{ret} \) - the thermal capacity, returned by DFAES, Watt, is determined as quantity of heat, bringing with inflow air in a premise:

\[ Q_{ret} = G_{inf} \cdot c \cdot (t_{inf} - t_{ext}) \]

where \( G_{inf} \) - the mass charge of inflow air, kg·sec\(^{-1}\);
\( c \) - thermal capacity of air, \( c = 1005 \) Joule·(kg·h·K)\(^{-1}\);
\( t_{ext} \) - temperature of external air, K;
\( t_{inf} \) - actual temperature of inflow air, K;
\( Q_{dem} \) - thermal capacity which is necessary (demanded) for heating of inflow air from external temperature up to temperature of air of a premise, Watt, is determined under the formula:

\[ Q_{dem} = G_{inf} \cdot c \cdot (t_{prem} - t_{ext}) \]

where \( t_{prem} \) - temperature of air of a premise, K.

5.1.2. Factor of power efficiency:

\[ \eta_{pe} = \frac{Q_{ret}}{N} \]

where \( N \) - the electric capacity consumed at work of DFAES, Watt.

5.1.3. Factor of a heat transfer, \( W (m^2 \cdot h \cdot K)^{-1} \):

\[ k = \frac{Q_{ret}}{F \cdot \Delta t} \]

where \( F \) - the area of a surface of heat exchange, m\(^2\).
\[ \Delta t \] - an average temperature difference between inflow and external air, K.

The major factors, factor of a heat transfer, speeds of streams of external and internal air are influencing. Low values \( k \) corresponds to insufficient speed of air streams and specify that there is a potential opportunity of increase in productivity of DFAES.

5.1.4. Factor of an effective utilization of a surface of heat exchange, \((m^3 \cdot h^{-1}) \cdot m^{-2}\):

\[ m_1 = \frac{L_{\text{inf}}}{F}, \]

where \( L_{\text{inf}} \) - the charge of inflow air, m\(^3\)\cdot h\(^{-1}\).

The parameter \( m_1 \) characterizes efficiency of use of a surface of heat transfer of DFAES.

5.2. Basic sanitary-and-hygienic parameters of an estimation of effective work of DFAES

5.2.1. Actual temperature of inflow air - is compared to minimally admissible value of temperature of inflow air which is accepted on 2 degree above temperature of a dew-point of air of a premise.

5.2.2. Actual speed of an air jet on an entrance in a served zone, m\( \cdot \)s\(^{-1}\), is compared to normative value of mobility of air in the served zone \( v_{\text{norm}} \), counted under the formula:

\[ V \leq n \cdot v_{\text{norm}}, \]

where \( n \) - factor of transition from normalized speed of movement of air to the maximal speed of movement of air in inflow jet.

5.2.3. Actual noise level at work of DFAES.

5.2.4. Actual charge of external air.

5.3. Basic weight dimensional parameters of DFAES

5.3.1. Factor of an effective utilization of weight of DFAES, \((m^3 \cdot h^{-1}) \cdot \text{kg}^{-1}\):

\[ m_2 = \frac{L_{\text{inf}}}{M}, \]

where \( M \) - weight of a recuperator, kg.

The parameter \( m_2 \) characterizes efficiency of use of weight of the spent material on manufacturing of DFAES.

5.3.2. Factor of an effective utilization of the occupied area, \((m^3 \cdot h^{-1}) \cdot m^{-2}\):

\[ m_3 = \frac{L_{\text{inf}}}{F_{\text{occup}}}, \]

where \( F_{\text{occup}} \) - the occupied area on a surface of the wall, necessary for installation of DFAES, m\(^2\).

The parameter \( m_3 \) characterizes efficiency of use of the surface area of a protecting design for installation of DFAES.
5.4. Basic resource parameters of DFAES

5.4.1. Warranty period of operation. The more for a long time a warranty period of accident-free operation, the above reliability of DFAES.

5.4.2. Maintainability - is determined as complexity of repair of a product.

5.5. Basic operational parameters of DFAES

5.5.1. Periodicity of maintenance service. Maintenance service includes clearing or replacement of air filters, check of a condition of fans, washing of heat exchanger surfaces of DFAES. Absence of air filters in design of DFAES conducts to pollution of heat exchanger surfaces and, hence, to reduction in the basic power and sanitary-and-hygienic parameters.

5.5.2. Convenience of installation and dismantle. The simplest decision of installation of one of DFAES is drilling in a wall of one round aperture which is not demanding additional strengthening of building designs and high accuracy.

5.5.3. Complexity of a design. The parameter considers complexity of a control system, manufacturing of heat exchanger and its repair. At application of the microprocessor electronics, special gauges, the control system is considered as complex since for its manufacturing and adjustment competent experts and special adjustment equipment be required.

5.5.4. Simplicity and convenience of management. A parameter considering presence of a remote control, an opportunity of automatic or manual adjustment of productivity of DFAES.

5.6. Layout in an interior of premises
A parameter specifying an opportunity simple or difficult install in an interior of a premise of DFAES elements.

Tests of DFAES were spent in natural conditions at which DFAES influenced factors both an external climate, and an internal microclimate of a premise, and also the arrangement on winding or outside winding side of a building, influence of surrounding building, fluctuation of temperature of external air is considered. The photo of installations of DFAES samples with measuring devices are resulted on Figures 4-7.

![Figure 4](image1.png) "UVRK-50", installed for carrying out of tests (from a premise).

![Figure 5](image2.png) "UVRK-50", installed for carrying out of tests (from a street).
Natural tests of DFAES have been lead in December, 2012 on achievement of daily average temperatures of external air of steady negative values below -6.3 °C (Orenburg) - average temperature for the heating period.

Results of natural tests are resulted in Table 1.

### Table 1. Results of natural tests of samples of DFAES.

| Parameters of an estimation | Designation | Units of measure | Value of a parameter for DFAES |
|-----------------------------|-------------|-----------------|--------------------------------|
|                            |             |                 | "UVRK-50" | "Prana-150" | "TeFo" |
| 1. Parameters of power efficiency |             |                 |          |              |        |
| Factor of energy saving $\eta_{es}$ | %          | 70…83           | 29…36   | 52…61        |
| Factor of power efficiency $\eta_{pe}$ | %          | 13…31           | 5…11    | 38…70        |
| Factor of a heat transfer $k$ | W·(m²·h·K)$^{-1}$ | Not determined | 33…51   | 13…17        |
| Factor of an effective utilization of a surface of heat exchange $m_1$ | (m³·h$^{-1}$)·m² | Not determined | 172      | 20           |
| 2. Sanitary-and-hygienic parameters |             |                 |          |              |        |
| Actual temperature of inflow air $t_{inf}^{act}$ | K          | 14…20           | 1.2…1.7 | 15…19        |
| Actual speed of an air jet on an entrance in a served zone $v$ | m·sec$^{-1}$ | 0.2             | 0.1     | 0.1          |
| Actual noise level at work | -           | Decibel         | 47…55   | 30…44        | 35.5…41 |
| Actual charge of external air $L$ | m³·h$^{-1}$ | 56              | 33…54   | 22…34        |
| 3. Weight dimensional parameters |             |                 |          |              |        |
| Factor of an effective utilization of weight $m_2$ | (m³·h$^{-1}$)·kg$^{-1}$ | 8.6         | 9.4…15.4 | 4.3…6.7    |
| Factor of an effective utilization of the occupied area $m_3$ | (m³·h$^{-1}$)·m² | 1270         | 1050…1720 | 220…340 |
| 4. Resource characteristics |             |                 |          |              |        |
| Warranty period of operation | -           | Month           | 12       | 24           | No data |
| Maintainability | -           | -               | High complexity of repair | Repair not difficult | Repair easy |
| 5. Operational characteristics |             |                 |          |              |        |
| Periodicity of | -           | -               | 2 times a year | Thicket 2 | Thicket 2 |
| Maintenance Service                                      | Yearly        | Yearly |
|----------------------------------------------------------|---------------|--------|
| Convenience of installation and dismantle                | -             | -      |
| Complexity of a design                                    | High complexity| High complexity| Low complexity          |
| Simplicity and convenience of management                  | Simple management| Difficult management| Difficult management |

### 6. Layout in an interior of premises

| Layout in an interior of premises                        | Simple install in an interior | Simple install in an interior | Difficult install in an interior |
|----------------------------------------------------------|------------------------------|------------------------------|---------------------------------|

### 6. Conclusions by results of tests

1. The Basic lack for all 3 presented samples of DFAES is the insufficient pressure developed by axial fans that is distinctly shown during presence of a wind in the street. The wind creates on windy side of a building superfluous pressure that leads to reduction in volume of an exhaust air from a premise, that, in turn leads to reduction of factors of energy saving, power efficiency, temperatures of inflow air. At outside winding side the wind creates underpressure that leads to reduction in volumes of inflow air that conducts to reduction of air exchange, to increase of air humidity and concentration of CO₂. To exclude the given lack, it is necessary to replace axial fans on centrifugal, creating a pressure essentially exceeding wind loadings.

2. Essential lack is the acoustic noise created by the axial fan. Decrease in noise probably at installation of fans with smaller number of turns, but with the greater diameter of the driving wheel that entails increase in length and aerodynamic resistance of DFAES and accordingly, decline of productivity.

3. At carrying out of tests essential non-uniform distribution of speeds of an air stream on section of inflow and exhaust channels at DFAES "Prana-150" and "TeFo" has been revealed. It is characteristic for axial fans from "exhaust". To level non-uniform distribution of speeds of an air stream on section of the channel it is possible installation of stabilizing devices, for example, the filter of thin clearing.

4. Application of reversive fans in design of DFAES "UVRK-50" initially leads to decrease in the charge of air in a mode of a reverser on 10-20 %. To eliminate this lack, it is possible installation of the second fan, however lack of such decision is the increased noise level, created by two fans.

5. Low values of parameters of energy saving, power efficiency, temperatures of inflow air at DFAES "Prana-150" are caused by the small area of a surface of heat exchange. To increase these parameters, it is possible: having increased length of heat exchanger; having narrowed width of channels and having increased their quantity; having made a design of multirunning heat exchanger.

6. At DFAES "TeFo" it is possible to explain Low values of a heat transfer factor in the low speed of movement of inflow streams and exhaust air inside of heat exchanger. For an intensification of process of a heat transfer it is necessary to increase speed of air inside of a recuperator by installation of more productive fans on inflow and an exhaust.

7. DFAES "UVRK-50" and "Prana-150" create high noise level at work. Are necessary: installation chamber of noisier suppresser, pasting of internal surfaces of DFAES by sound-proof materials, replacement of the fan with smaller noise level.

8. In DFAES "Prana-150" and "TeFo" there are no air filters of thin clearing from a premise and streets that leads to pollution of a surface of heat exchange and worsens power and sanitary-and-hygienic parameters.

### 7. Recommendations for development of manufacture of new sample of DFAES

Proceeding from results and the analysis of the lead researches recommendations have been developed for development and manufacture of new sample of DFAES [3-6].
1. In a design of new sample of DFAES the centrifugal fan should be applied instead of axial fan. This measure will provide steady work of system irrespective of change of wind pressure outside of a building and will prevent overturning circulation.

2. For decrease in noise level in design of DFAES it is recommended to apply chamber of noisier suppresser, and also to consider an opportunity of development of design of DFAES in which centrifugal fans are installed outside of a building.

3. At selection of the centrifugal fan it is necessary to provide productivity by air within the limits of 90-120 m$^3$h$^{-1}$ since as a result of the lead tests the low efficiency of heat exchange caused in the small speed of movement of air in heat exchanger has been revealed. The increase in productivity by air will allow to improve such parameters as: factor of a heat transfer; effectiveness ratio of use of a surface of heat exchange; the actual charge of external air, factor of an effective utilization of weight; factor of an effective utilization of the occupied area.

4. For clearing external air and prevention of pollution of a surface of heat exchange it is necessary to install filters.

5. For reduction of heat exchanger weight and increases of efficiency of heat exchange it is necessary to reduce thickness of heat exchange pipes walls up to the minimal size providing rigidity of a design that will allow to improve such parameters as: factor of a heat transfer; factor of an effective utilization of weight.

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