# International Conference on Compressors and their Systems

City University London, UK

7–9 September 2009

*Sponsored by:*

HOLROYD
PRECISION COMPONENTS
PRECISION TECHNOLOGIES GROUP

*Co-sponsored by:*

IOR ior.org.uk

bcas

pneurop

Institution of MECHANICAL ENGINEERS

CITY UNIVERSITY LONDON

CP

Chandos Publishing
TBAC Business Centre, Avenue 4, Station Lane
Witney, Oxford OX28 4BN, UK
Tel: +44 (0) 1993 848726
Email: info@chandospublishing.com

Chandos Publishing is an imprint of Woodhead Publishing Limited

Woodhead Publishing Limited
Abington Hall, Granta Park
Great Abington, Cambridge CB21 6AH, UK
www.woodheadpublishing.com

First published in 2009

ISBN: 978 1 84334 581 7



British Library Cataloguing-in-Publication Data.
A catalogue record for this book is available from the British Library.



Produced from electronic copy supplied by authors.
Printed in the UK and USA.

Cover photograph by courtesy of Visit London (www.visitlondon.com).

# The investigation and working out of drop- and dust catchers for compressor station

**A Yakuba, S Sabadash, M Savchenko**
Sumy National Agrarian University,
Department of Equipment for Food Production, Ukraine

**ABSTRACT**

The interaction of particles and gases in swirling flow units is analyzed in this paper. The equations for the calculation of the main swirling flow units' fractional effectiveness are obtained.

The calculations of the expected effectiveness for the experimental samples of created dust catchers are carried out. The theoretical dependencies of the calculation of the dust catchers' separation capacity and their resistance are proposed. The comparison of main dust catchers on their energy expenditure for gas cleaning is made. The research of the effectiveness of gas cleaning with the help of fabric filters is conducted. It is recommended to use knitted and woven sleeves manufactured by Kiev factory in bag filters for gas cleaning in the gas compressor units' engines and gas-mains.

**Key-words**
Gas, compressor stations, cleaning, swirling flows.

**NOTATION CONVENTIONS**

| | |
|---|---|
| $a_2$, $a_3$- | the functions of trigonometric values ($a_2=\cos\theta_*-\cos\theta_o$); $a_3=(1-\cos\theta_*)^2+\sin^2\theta_*$ |
| A- | the complex quantity, which takes into account input process-dependent and geometric parameters |
| $A_1$- | the complex parameter ($A \sin\theta_* \cdot 2n$) |
| B- | the complex quantity for the calculation of the fractional effectiveness in the internal layer |
| Co- | the rate of gas rotation in the output gas tube, 1/sec |
| D- | the dust catcher diameter, m |
| d- | the diameter of the particles, being caught by dust catchers, (micrometer) |
| f(H), f($H_1$)- | the functions of height and consumed indices of dust catchers |
| h- | the inlet height, m |
| H- | the separation zone height, m |
| k- | the flow mixing coefficient |
| $k_1$- | the relative flow mixing coefficient, (k/Rmax) |
| $k_\varepsilon$- | the flow bifurcation coefficient |
| l- | the inlet width, m |

| | |
|---|---|
| L- | the dusted gas consumption, $m^3/s$ |
| $L_1$- | the gas consumption through the bottom swirler |
| $L_2$- | the gas consumption through the top swirler |
| $L_3=L_1+L_2$- | the total dusted gas consumption |
| $L_{10}=L_3(1-k_\varepsilon)$- | the consumption of gas, running in the cyclone up to the bottom part without any branching off |
| $L_{20}=L_3K\varepsilon$- | the consumption of gas, getting to the inner layer |
| m- | the particle mass, kg |
| M- | the input angular momentum, N·m |
| Re- | the Reynolds number ($\frac{VD\rho_g}{\mu}$ -pipes, $\frac{Vd\rho_p}{\mu}$ -particle) |
| r- | the current radius |
| $r_0,r_1,r_3,r_4,r_5$- | the dust catcher radius at the distinguished point |
| t- | the time, sec |
| V- | the gas velocity, m/sec |
| $V_r$, $V_\varphi$, $V_r$ - | the radial, tangential and axial gas velocity, m/sec |
| x- | the complex quantity, dependent on process-dependent and geometric parameters |
| y- | the complex quantity ( $y=\sqrt{x}$ ) |
| z- | the distance in height up to the section under consideration |
| $\varepsilon=L_2/L_1$- | the flow relation |
| $\acute{\eta}_{av1}$, $\acute{\eta}_{av2}$- | the average value of the fractional effectiveness of the particles catching in the internal and external gas layers |
| θ- | the surface inclination angle in the conic dust catcher |
| $\theta_0$, $\theta_2$, $\theta_3$, $\theta^*$- | the surface inclination angles of the cone wall, surfaces of inlet, outlet and separation of the flows |
| μ- | the gas viscosity, Pa·sec |
| $\rho_g$- | the gas density, $kg/m^3$ |
| $\rho_p$- | the particle number density, $kg/m^3$ |
| ω- | the gas rotation angular velocity, 1/sec |
| π- | the circular constant |
| md- | middle |
| en- | entry |
| $_*$,0,e- | the flow parameters at the flow separation interface, at the unit wall and in the outlet fitting |

**1.** The line of investigations and working out was chosen as a result of investigations of scientific and technical and literary sources of gas cleaning in compressor stations. It is expedient to use centrifugal dust catchers – counterflow cyclones for natural gas cleaning from solid particles. The maximum gas cleaning effectiveness by cylinder cyclones reaches 75-90%. The usage of conic cyclones may raise the cleaning effectiveness to 92-95%.

**1.1.** The units whose diagrams are shown in Figure1 were chosen as the subjects of theoretical inquiry. Cylinder cyclone (Fig.1a) possesses little resistance and average effectiveness parameters. Conic cyclones (Fig.1b) possess increased resistance and effectiveness. Cylinder Counter Swirling Flow unit (Fig.1c) possesses high productivity on dusted gas with lower indices of resistance. Its difference to cylinder cyclones lies in the additional dusted gas feeding through the axial swirler, arranged in the bottom part of the unit case.

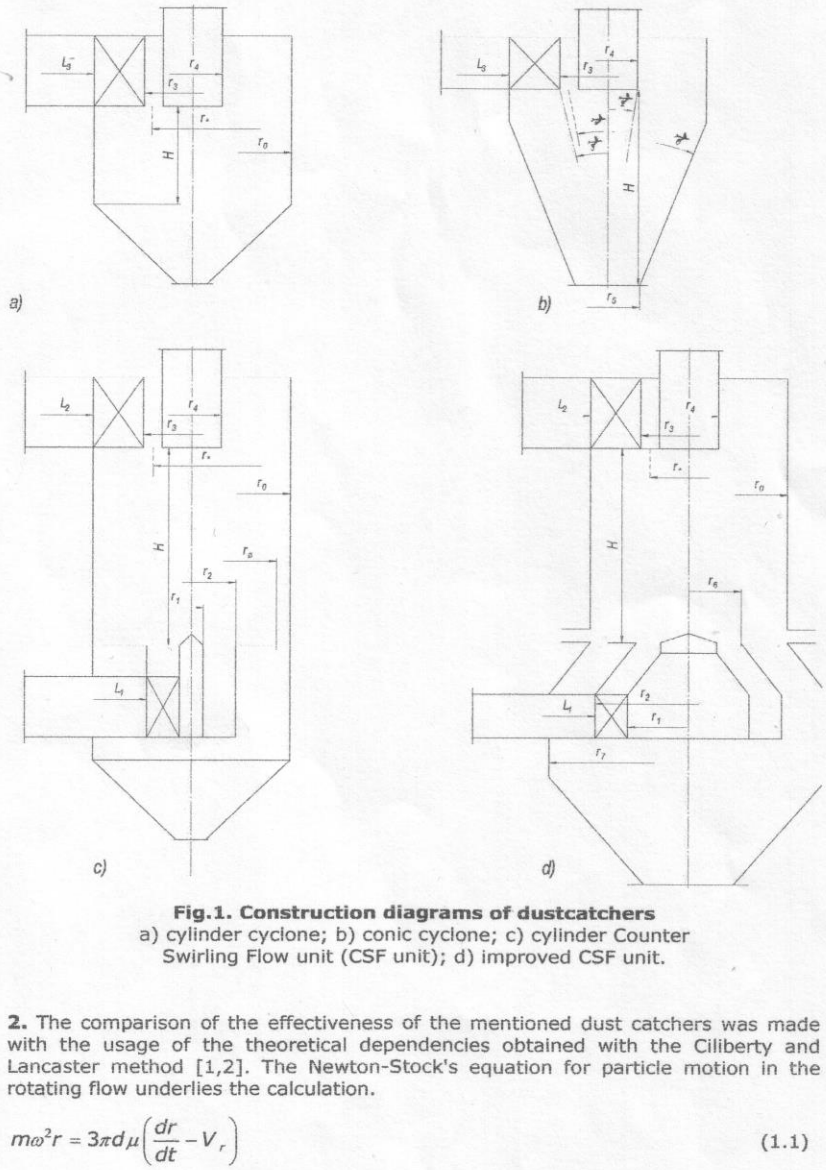


**Fig.1. Construction diagrams of dustcatchers**
a) cylinder cyclone; b) conic cyclone; c) cylinder Counter Swirling Flow unit (CSF unit); d) improved CSF unit.

**2.** The comparison of the effectiveness of the mentioned dust catchers was made with the usage of the theoretical dependencies obtained with the Ciliberty and Lancaster method [1,2]. The Newton-Stock's equation for particle motion in the rotating flow underlies the calculation.

$$m\omega^2 r = 3\pi d\mu\left(\frac{dr}{dt} - V_r\right) \tag{1.1}$$

The equations for the calculation of the cylinder cyclones' and CSF units' fractional effectiveness were obtained in the cylinder coordinate system, for the conic cyclones' and CSF units' one - in the spherical coordinate system.

The following equations were obtained after the transformation and integration of the equation (1).

### 2.1. Conic cyclone

The equation of the fractional effectiveness in the external layer

$$\eta_{md2}=\frac{d^2\cdot\rho_p\cdot C_o^2\cdot S_3^2\left(\cos\theta_{md2}-\cos\theta_o\right)\left(\frac{x}{y\cdot K_1}\right)\left[\frac{\exp-K_1R_{min}}{R_{min}}-\frac{\exp-K_1R_{max}}{R_{max}}\right]}{18\mu\cdot L_2^2\cdot\pi^2\cdot a_2^2\cdot\mu\left(\sin\theta_0+\sin\theta_{md2}\right)\left(\sin\theta_0-\sin\theta_*\right)}-\frac{8\sin^2\theta_{md2}\cdot\sin^2\frac{\theta_{md2}}{2}\left(\ln R_{min}-\ln R_{max}\right)}{\left(\sin\theta_0+\sin\theta_{md2}\right)\left(\sin\theta_0-\sin\theta_{md2}\right)}-\frac{2\cdot\left(\cos^3\theta_{md2}-\cos^3\theta_0\right)}{3\cdot\left(\sin\theta_0+\sin\theta_{md2}\right)\left(\sin\theta_0-\sin\theta_{md2}\right)} \quad (1.2)$$

In the internal layer

$$\eta_{md1}=\frac{d^2\cdot\rho_p\cdot C_o^2\cdot S_3^2\left(1-\cos\theta_{md1}\right)\frac{y}{K_1}\left[\frac{\exp-K_1R_{min}}{R_{min}}-\frac{\exp\left(-K_1R_{max}\right)}{R_{max}}\right]}{18\mu\cdot L_2^3\cdot\pi\cdot\mu\cdot a_3\cdot\sin\theta_*\left(\sin\theta_*+\sin\theta_{md1}\right)}-\frac{8\sin^2\theta_{md1}\cdot\sin^2\frac{\theta_{md1}}{2}\left(\ln R_{max}-\ln R_{min}\right)}{\sin\theta_*\left(\sin\theta_*+\sin\theta_{md1}\right)}-\frac{2\cdot\left(\cos^3\theta_{md1}-\cos^3\theta_0\right)}{3\cdot\sin\theta_*\left(\sin\theta_0+\sin\theta_{md1}\right)} \quad (1.3)$$

Here:
k- the flow mixing coefficient; K=0 - the external flow is uniformly mixed with the internal one; K>0 – mixing rises downwards, K<0- mixing slows down downwards, $L_3=L_{10}+L_{20}$

$$x=\left\{\frac{L_3+\frac{A_1}{K_1}\left(R_{max}+\frac{1}{K_1}\right)\exp\left(-K_1R_{max}\right)}{\left(R_{md2}+\frac{1}{K_1}\right)\exp\left(-K_1R_{md2}\right)}-\frac{A_1}{K_1}\right\}^2 \quad (1.4)$$

$$y=\sqrt{x};A=\frac{-L_2K_1}{2\pi\cos\theta_*\cdot\left[\left(R_{max}+\frac{1}{K_1}\right)\exp\left(-K_1R_{max}\right)-\left(R_{min}+\frac{1}{K_1}\right)\left(\exp-K_1R_{min}\right)\right]} \quad (1.5)$$

The value K is dependent on the unit diameter ($D_0$) and is chosen from Table 1. It has been found experimentally.

**Table 1. Dependence of k on $D_0$**

| D(m) | 0,12 | 0,2 | 0,4 | 0,6 | 0,8 | 1,0 | 1,2 | 1,6 | 1,8 |
|---|---|---|---|---|---|---|---|---|---|
| K | 14 | 13,2 | 11,5 | 10,2 | 9,3 | 8,5 | 8,0 | 7,3 | 7,1 |

### 2.2. Cylinder Counter Swirling Flow unit (CSF unit)

The equations for the average fractional effectiveness calculation.
External layer.

$$\eta_{md2}=\frac{d^2 2\pi\rho_p C_o^2 r_*^4\left(r_o+r_*\right)f(H)}{9\mu L_3^2\left(r_o+r_{md2}\right)\left(r_o^2+r_{md2}^2\right)}+\frac{\left(r_{md2}^2-r_o^2\right)r_{md2}^2 f(H_1)}{2\left(r_o+r_{md2}\right)\left(r_o^2+r_{md2}^2\right)\left(r_o-r_*\right)} \quad (1.6)$$

$$f(H) = 2L_1H + \frac{L_2H}{2} + \frac{L_1^2H}{L_2} f(H_1) \tag{1.7}$$

$$f(H_1) = \left[(H-1) - \frac{(H-1)^2}{2} + \frac{(H-1)^3}{3} - \frac{(H-1)^4}{4} + \frac{(H-1)^5}{5} + 2.83\right] \tag{1.8}$$

Internal layer.

$$\eta_{md1} = \frac{\exp B - 1}{\exp B}$$
$$B = d^2 \frac{\pi \rho_p r_*^2 C_o^2 H}{18 \mu L_3^2}\left(L_1 + \frac{L_2}{2}\right) - \frac{1}{2}\ln\frac{L_1+L_2}{L_1} \tag{1.9}$$

$$M_{in} = \frac{2}{3}\rho_g L V_{gin2} \cdot \frac{r_{ex}^2 - r_{in}^3}{r_{ex}^2 - r_{in}^2} \tag{1.10}$$
$$L_3 = L_1 + L_2$$

$$r_{md1} = \frac{r_*}{2}; r_{md2} = \frac{r_3 + r_4}{2}; \theta_{md1} = \frac{\theta_*}{2}; V_{en1} = \frac{L_1}{h_1 \cdot l_1}; V_{en2} = \frac{L_2}{h_2 \cdot l_2}; \tag{1.11}$$

**2.3. Cylinder cyclone**
The equation for the fractional effectiveness calculation.

External layer.

$$\eta_{md2} = \frac{d^2 \cdot 2 \cdot \pi \cdot \rho_p \cdot C_o^2 \cdot r_*^4 (r_o + r_*) H\left(L_{10} + \frac{L_{20}}{2}\right)}{9 \cdot \mu \cdot L_3^2 (r_o + r_{md2})(r_o^2 + r_{md2}^2)} + \frac{2(r_{md2}^2 - r_0^2) r_{md2}^2 \cdot \ln\frac{L_{10}+L_{20}}{L_{10}}}{(r_o + r_{md2})(r_o^2 + r_{md2}^2)(r_o + r_x)} \tag{1.12}$$

Internal layer

$$\eta_{md1} = \frac{\exp B - 1}{\exp B}; B = d^2 \frac{\pi \rho_p C_o^2 r_*^2 \cdot \left(L_{10} + \frac{L_{20}}{2}\right)}{18 \mu L_3^2} - \frac{1}{2}\ln\frac{L_{10}+L_{20}}{L_{10}} \tag{1.13}$$
$$L_{20} = L_3 \cdot K_\varepsilon; L_{10} = (1 - K_\varepsilon) L_3; L_3 = L_{10} + L_{20}$$

$$C_o = \frac{2M_{en} \cdot r_*^2}{\rho_g L_3 \cdot r_4^2} \tag{1.14}$$

**2.4. CSF units' effectiveness increase**
By the study of the equations for the cylinder CSF units' effectiveness (6,9) one can determine their following peculiarity. The proportion of the consumption of the flow fed from the top $L_2$ to the consumption of the flow fed from the bottom $L_1$ usually makes $L_2 : L_1 = 2:1$. The calculation of the angular momentums (10) input through the top swirlers ($M_2$) and through the bottom ones ($M_1$) makes in this case $M_2:M_1 = 4:1$. Such difference between the consumptions and the input angular momentums results in particles and gas angular motion deceleration, especially in the internal layer, which results in the dust catchers' fractional effectiveness reduction.

In one of the technologies (Fig. 1c) the proportion equality of the consumptions ($L_2$: $L_1$=2) and the input angular momentums ($M_2:M_1$ = 2) is achieved at the expense of the extension of the axial swirler diameters. The effectiveness calculation of the CSF units both before and after the improvement is carried out by the similar equations (6-14). For the comparative analysis we have worked out the draft designs of the cylinder cyclone, conic cyclone, cylinder CSF units with the parameters $D_0$ = 100mm, H = 200mm, $D_2$ = 50mm. In the improved CSF unit the quantity $D_2$ was increased up to 100 mm. At present time the models are at the stage of manufacturing. Before the experimental research, included to the program of the post-graduate students' training, the theoretical comparisons of the expected effectivenesses had been made.

## 3. THE COMPARISON OF THE FRACTIONAL EFFECTIVENESS OF THE DUST CATCHERS' LABORATORY MODELS

Process-dependent and geometric parameters of the laboratory models.

### 3.1. Conic cyclone

$R_{max}$=0,335m; $R_{min}$=0,132m; H=0,203m; $h_2 \times l_2$=90x20;

$r_0$=50mm; $r_3$=30mm; $r_4$=28mm; $\theta_0$=9,47°;

$\theta_2$=6,66°; $\theta_3$=5,71°; $\theta_*$=6,2°; $\theta_{md2}=\frac{\theta_o+\theta_*}{2}$

$\mu=0,018\cdot10^{-3}$ Pa·s

$L_2=L_3$=130 m$^3$/per hour. $K_\varepsilon$=0,35. K=12. $\rho_t$=1500 kg/m$^3$; ρg=1,21 kg/m$^3$

### 3.2. Cylinder cyclone

$L_3$=134m$^3$/ per hour; $L_{20}=K_\varepsilon\cdot L_3$; $K_\varepsilon$=0,35

$L_{10}=(1-K_\varepsilon)L_3$; $r_o$=50mm; $r_3$=30mm;$r_4$=28mm

$h_2xl_2$=90x20mm; $r_{md2}=\frac{r_0+r_*}{2}$ ; $r_*=\frac{r_3+r_4}{2}$ ; $V_{en2}=\frac{L_2}{h_2 l_2}$

### 3.3. Cylinder CSF unit before the improvement

$L_3$=201m$^3$/ per hour; $L_2$=134m$^3$/ per hour; $L_1$=67m$^3$/ per hour;

$r_o$=50mm; $r_1$=5mm; $r_2$=25mm; $r_3$=30mm; $r_4$=28mm; $r_*=\frac{r_3+r_4}{2}$ ;

$h_2xl_2$=90x20mm;$a_1xb_1$=45x20mm; H=20mm; $r_{md1}=\frac{r_*}{2}$ ; $r_{md2}=\frac{r_3 \cdot r_4}{2}$ ;

$\theta_{md1}=\frac{\theta_*}{2}$ ; $V_{en1}=\frac{L_1}{h_1 l_1}$ ; $V_{en2}=\frac{L_2}{h_2 l_2}$ ; $\rho_p$=1500kg/m$^3$; $\rho_g$=1,21 kg/m$^3$;

$\mu_g=0,018\cdot10^{-3}$ $P_a$·s

### 3.4. Cylinder CSF unit after reconstruction

All the parameters are identical to the original one with the exception of $r_2$=50mm; $r_1$=30mm.

### 3.5. The comparison of the dustcathers' effectiveness

**Table 2. Effectiveness indices, %**

| d, mkn | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Conic cyclones | | | | | | | | | | |
| External layer | -33,1 | +6,8 | +73,3 | +166,4 | | | | | | |
| Internal layer | -73,8 | +116,6 | | | | | | | | |
| Cylinder CSF | | | | | | | | | | |
| External layer | +33,0 | +174,9 | | | | | | | | |
| Internal layer | -56,4 | -15,3 | +34,8 | +66 | +86,4 | +98,8 | | | | |
| CSF after the improvement | | | | | | | | | | |
| External layer | +52,4 | +252 | | | | | | | | |
| Internal layer | -59,1 | +5,1 | +77,8 | +82,7 | +95,2 | | | | | |
| Cylinder cyclones | | | | | | | | | | |
| External layer | +0,77 | +52,6 | +139 | | | | | | | |
| Internal layer | -19,4 | +2,3 | | | +34,4 | | | | | +89 |

The given theoretical calculations as a whole correspond to the experimental data and field experience (cylinder cyclone and CSF unit). They also forecast increase in the CSF units' effectiveness in case of the improvement of the axial swirler design. But when one compares cylinder and conic units, certain reduction of the effectiveness indices in the external layer of the conic cyclones as compared to the cylinder cyclones takes place. But the theory forecasts high indices in the internal layer of the conic cyclone. This makes a disagreement with the field experience of the conic cyclones, which possess the highest operation indices. This disagreement was obviously caused by the consideration of the comparison question in the different coordinate systems. Unfortunately it doesn't seem possible to receive the dependencies of the conic units' fractional effectiveness in the cylinder coordinate system through the complexity and unhandiness of the obtained equations.

## 4. THE REFINEMENT OF THE THEORETICAL EQUATIONS FOR THE EFFECTIVENESS ON BASIS OF EXPERIMENTAL DATA

An important matter of dust catchers' designing is the check of the correspondence of the obtained equations for effectiveness calculation to the data of experimental research and to the operation of production prototypes. At the first stage of investigations the comparison of the theoretical dependencies for cylinder cyclone and indices of the commercial operation of the dust catchers used in CIS countries was made. The correlation coefficients $K_1$ and $K_2$ which correspond to the first and the second items of the theoretical equation were obtained.

**Table 3. Correlation coefficients of the equation for the cylinder cyclone effectiveness.**

| Cyclone model | $K_1$ | $K_2$ |
|---|---|---|
| 1 | 2 | 3 |
| External layer | | |
| Цн-11 | 0,045 | 5 |
| Цн-15 | 0,061 | 5,5 |
| Цн-15у | 0,107 | 7 |
| 1 | 2 | 3 |
| Цн-24 | 0,39 | 4,98 |
| Internal layer | | |
| Цн-11 | 0,0861 | 1,29 |
| Цн-15 | 0,117 | 1,47 |
| Цн-15у | 0,277 | 2,2 |
| Цн-24 | 0,58 | 1,74 |

Similar correlation coefficients will be obtained after carrying out of the experimental research of the models given above.

## 5. DUST CATCHERS' RESISTANCE

It is usually determined with the usage of experimental coefficients. The resistance of series-produced units can be determined by this method. At present time it is practically impossible to determine the resistance of newly-created units.

One of the first attempts of the theoretical forecasting of dust catchers' resistance was made by W. Barth [3,4]. We used these equations for the cyclones' resistance calculation.

$$\Delta p_1 = \frac{\rho_g}{2}\left[\frac{V_{\varphi o}^2 \cdot r_o}{r_*} - \frac{V_{\varphi *}^2 \cdot r_*}{r_o} + V_{\varphi *}^2\right] \tag{1.15}$$

$$\Delta p_2 = \frac{\rho_g V_{\varphi *}^2}{2}\left[K \cdot \left(\frac{V_{\varphi *}}{V_{z*}}\right)^{3/4} + \left(\frac{V_{\varphi *}}{V_{z*}}\right)^2\right] \tag{1.16}$$

The calculation of velocity constituents was carried out with the dependencies [5]. Design values of resistance were compared with the empirical methods of calculation [6]. The comparison made it possible to calculate the coefficients of conversion of the theoretical indices into real ones, which are introduced in Table 4.

**Table 4. The coefficients of conversion of the theoretical indices into real ones.**

| Units' diameter $D_0$, mm | 500 | 1000 | 2000 |
|---|---|---|---|
| Coefficient of conversion | 0,4 | 0,54 | 0,58 |

## 6. ENERGY EXPENDITURE FOR GAS CLEANING

For the comparison of the introduced dust catchers` variants (conic cyclone, cylinder cyclone; - conic and cylinder CSF units) graphic dependencies of the energy expenditure for gas cleaning [7] needed for providing of the specified separation capacity were made. By separation capacity the minimal critical diameter of the particles able to be caught in the given dust catcher ($d_{cr}$) is taken.

The equations of the separation capacity were obtained by one of the authors in the paper [7]:

1) cylinder CSF unit

$$d_{cr} \geq \frac{6(L_1+L_2)\sqrt{\dfrac{L_2 \cdot \mu}{\pi \rho_p H}}}{\pi C_o r_* \left[\dfrac{L_1+L_2}{2\pi} + \dfrac{L_2(Z-H)}{2\pi H}\right]} \tag{1.17}$$

2) cylinder cyclones

$$d_{cr} \geq \frac{6L_2\sqrt{\dfrac{L_2 \cdot \mu}{\pi \rho_p H}}}{\pi C_o r_* \left[\dfrac{L_2}{2\pi} + \dfrac{L_2(Z-H)}{2\pi H}\right]} \tag{1.18}$$

3) conic CSF units and cyclones

$$d_{cr} \geq \frac{6(L_1+L_2)R\sin\dfrac{\theta_*}{2}\sqrt{\dfrac{2\mu R\sin\theta_* a_2}{\pi a_3^2 \rho_p(\cos\theta_* - \cos\theta_o)}}}{C_0 R_{max}^2\left\{(L_1+L_2) + \dfrac{A_1}{K_1}\left[f(R_{max}) - f(R)\right]\right\}} \cdot \frac{\sqrt{\dfrac{\cos\theta_*}{\sin\theta_*}A_1\exp(-K_1R) + \dfrac{L_2}{R^2}(\cos\theta_* - \sin\theta_0)}}{1} \tag{1.19}$$

$$f(R) = \left(R + \frac{1}{K_1}\right)\exp(-K_1R) \tag{1.20}$$

$$f = R_{max} = \left(R_{max} + \frac{1}{K_1}\right)\exp(-K_1R_{max}) \tag{1.21}$$

K=0÷15 -coefficient dependent on diameter (Table 2).

Energy expenditure indices in different dust catchers are presented for the units with the diameters = 200 mm, on which experimental researches were carried out at the same time with the theoretical ones with the usage of lime dust with $\rho_p$ = 2700 kg/m$^3$.

The data on Fig. 2 indicate the preference of the used cylinder cyclones for the catching of the particles with the size larger than 16 micrometer. It is more rationally to catch particles with the size 5-10 micrometer with the conic cyclones.

Cylinder CSF units possess increased productivity with low expenditure for the cleaning as compared to cylinder cyclones. Conic CSF units don't have any evident advantages over the conic cyclones. It is advisable that cylinder cyclones have a bin. For conic units it is not necessary to have a bin.

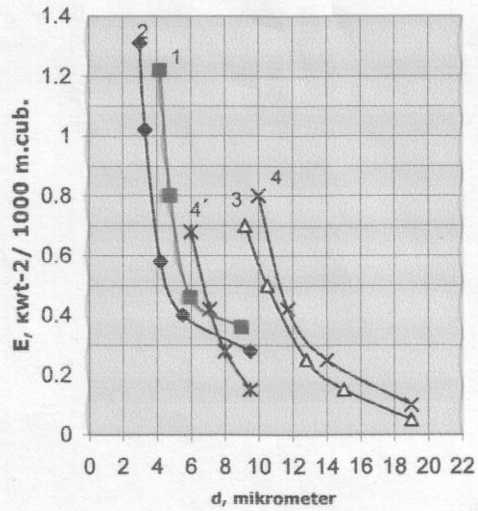


**Fig.2 Expenditures for dust catching in the units of different design.**
1- conic CSF unit; 2 – conic cyclone; 3 – cylinder CSF unit;
4 – cylinder cyclone without a bin, 4` - with a bin.

### 7. FILTERING UNITS

For the catching of fine-dispersed dust (1-10 micrometer) the testing of different filter fabrics was conducted [8]. Glass-fabric filters possess little resistance and increased rate of filtration (0,7-1 m/sec), but they let fine-dispersed particles (1-2 micrometer) pass. Filters with kapron partitions possess the resistance which is 2 - 3 times higher than glass-fabric ones do. They let micro-fractions of particles (0,5-1 micrometer) pass at the beginning of the filtering process. Filter with lavsan knitted and woven sleeves manufactured by Kiev technical factory possessed initial resistance which was 5 and 6 times higher than glass-fabric ones did (1000-1400 Pascal). Lavsan fabric is impassable for the particles of any fractions. Dust accumulation results in resistance increase and filtering rate reduction. Resistance reduction of lavsan fabric and filtering rate increase are achieved by the usage of kapron lining nets. The main advantages of lavsan knitted and woven sleeves are:

- increased mechanical strength;
- absolute impassability for the particles with the size of 1-3 mm;
- the possibility of the filtering layer regeneration by the way of cleaning.

Using the results of the researches, experimental-industrial filter was worked out; the filter has passed industrial tests. As a whole, the tests indicate the principal possibility to use knitted and woven sleeve filters in gascompressor units and the possibility of their application for the filters of gas-mains.

## CONCLUSION

The interaction of dust particles and swirling gas flow was analyzed.

The theoretical equations for the fractional effectiveness of cyclones and Counter Swirling Flow units were obtained. The comparisons of the expected effectiveness were made. Unbalance between input gas consumptions and angular momentums was determined through the analyzing of the Counter Swirling Flow units (CSF units). The methods of improvement were proposed. The comparison between the theoretical and experimental effectiveness indices made it possible to increase calculation accuracy through the introduction of the correlation coefficients.

The energy expenditures in the units of different design were analyzed.

The testing of filter fabrics for natural gas cleaning was conducted. It is recommended to use knitted and woven lavsan fabrics.

## REFERENCE LIST


1. Ciliberti D. F., Lancaster B.W. Perfomance of rotary from Cyclones//Alche Journal, Vol. 22, №2, 1976.-P.394-399.
2. Ciliberti D.F., Lancaster B.W. An Improvement of the Simple Model of rotary from Cyclones//Alche Journal, Vol. 22, №6, 1976.-P.1150-1182.
3. Barth, W., Design and Layout of the Cyclone Separator on the Basis of New Investigations, Brennstoff-Warme-Kraft, Vol. 8, № 4, 1956, P. 1-10
4. Barth W., Leinweber L. Evaluation of design of cyclone separators// Staub, Vol. 24, № 2, 1964 – P. 41-84.
5. Yakuba O.R., Kalashnikov O.M., The structure of the flow in the counterflow cylinder cyclone//// SSAU bulletin, №.5. 2000- P. 184-188.
6. Birger M.I., Viltsberg A.J., Myagkov B.I. and others. Reference book in dust- and ash-catchers// Moscow.: Energoizdat, 1983.- P.312
7. Yakuba A.R Hydrodynamics and effectiveness of the swirling flow dustcatchers// Thesis for a degree of Doctor of technical Science.- Sumy.: Sumy State University, 1996. – P.378.
8. Yakuba O.R., Vasilenko O.O., Cherednichenko A.V., Maslennikov J.I., Savchenko M.J., Improvement of gas cleaning filters in the gas compressor units` engines // Sumy State University bulletin №12 (96), 2006. Sumy.- P.91-96.