ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 7, Issue 9 , September 2020

# Analysis of the Possibility of Using Vortex Pipes When Drilling Wells with Air Purging

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**ABSTRACT:** Some of the urgent problems of prospecting drilling are the complications at drifting of chinks and mining developments (manufactures) in unstable, loosely coupled and strong lead breeds. The opportunity of application of Rank's effect is shown at drilling prospecting chinks for cooling volatile species of the tool, drifting of chinks or mining developments (manufactures) in breeds unstable, loosely coupled and strong lead, at drifting of chinks in permafrost breeds for maintenance of stability of walls and increase of an output (exit) core. The complete description of a design, opportunities and classification of a vortical pipe, and also principle and its work is resulted on the basis of the approached accounts the diagram of dependence of efficiency of a vortical pipe and its constructed parameters.

**KEY WORDS:** a vortical pipe, effect of Rank, charge of air, temperature of a flow, pressure, hot and cold air flow, air purge, drilling, well.

## I. INTRODUCTION

Improvement of mining equipment is associated with the search for new approaches to creating systems that ensure high-quality and reliable operation of equipment, while reducing production and operation costs. One of the most pressing problems of exploration drilling is the complication when drilling wells and mine workings in unstable, loosely bound and heavily watered rocks. To date, there are various ways to maintain the stability of well walls, one of which is to freeze unstable sections of the well using refrigeration units. The installations used are quite expensive and energy-intensive. In order to create more efficient, at the same time cost-effective equipment, we suggest using a vortex tube, in which the Wound effect occurs, as a cooling and heating system.

The vortex effect, or the Rank effect, is that if a tangentially swirling gas flow is fed into the pipe, then under certain conditions a temperature separation of the gas will occur in it. A colder flow is formed in the center than at the periphery, and through the Central opening of one of the ends of the pipe, gas will escape, the temperature of which will be much lower than at the entrance. Peripheral layers of gas that have a higher temperature will exit through the throttle opening at the other end of the pipe. This scheme of the vortex tube was called countercurrent. As the throttle is closed, the overall pressure level in the vortex tube increases, and the flow rate through the diaphragm opening increases with a corresponding decrease in the hot flow rate.

The discovered phenomenon was explained by J. Rank by the fact that the compressed outer layers have an insignificant angular velocity, on the contrary, the expanded Central layers have energy mainly in the kinetic form, since they rotate with a very high angular velocity. Moreover, the angular velocities of the gas layers are inversely proportional to the squares of their diameters. This distribution of speeds is bound to cause friction between neighbouring layers. As a result, with a sufficient length of layers, an equilibrium state is established, in which all layers rotate with the same angular velocity. Thus, there is a centrifugal transfer of energy, in which the Central layers communicate their speed to the outer layers.

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## II. ANALYTICAL STUDY OF VORTEX TUBE PARAMETERS

The most common classical type is a countercurrent vortex tube (Fig. 1) [4], which selects hot and cold flows from opposite ends of the pipe, called hot and cold, respectively.

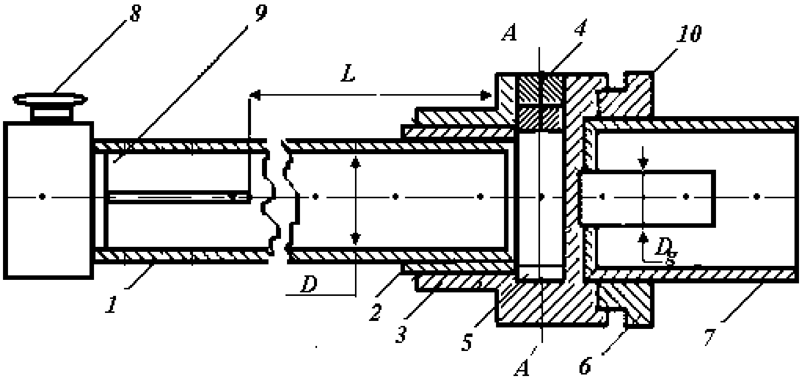


**Fig.1. The design of the vortex tube.**
**1-tube, 2-nut, 3-body, 4-snail, 5-diaphragm, 6-nut, 7 - tube, 8-throttle, 9-cross, 10-gasket.**

In General, the structure of the vortex tube consists of a body 3, in the annular cavity of which a tangential rectangular channel with width b and height h is propylene. A fitting for compressed air supply is soldered to the body from the outside of the rectangular channel. In the annular cavity of the housing is mounted the flanged tube 1 with a cylindrical polished inner surface with a diameter D, and then snail 4 that it propyl (dimensions similar to the rectangular channel case) coincides with the channel forming the nozzle entrance. In the same cavity of the housing, a diaphragm 5 with a hole Dg and a sealing gasket 10, pressed by a nut 6, are inserted. at the opposite end of the tube 1, at a distance L from the snail, a four-bladed cross 9 and a throttle 8 are tightly installed.

Improved eddy tube designs have also been developed, such as uncooled eddy tubes that allow both low and high temperature flows to be produced simultaneously. The design of the pipe provides for the supply of part of the high-pressure air flow, which is introduced through a narrowing nozzle tangentially to the vortex chamber. This flow returns along the auxiliary circuit to the vortex formation zone. As a result, this design allows you to expand the temperature range and get a cold flow with a temperature from -60 to-1000℃ when working in optimal mode, as well as increase the temperature of the hot flow from 130 to 2000℃.

Studies [3] of vortex tubes of various geometric sizes with different parameters of compressed air at the inlet and the pressure of the cold flow behind the diaphragm allow us to draw the following conclusions.

The vortex effect of energy separation of gases depends on three main conditions:

the degree of gas expansion in the vortex tube ($\pi$) is the ratio of the absolute gas pressure in front of the nozzle $P_1$ to the pressure in the cold flow$P_x$.

$$\pi = \frac{P_1}{P_x}$$

the cooling effect of the cold stream increases with increasing p;

the total temperature $T_1$ of the gas entering the vortex tube; with increasing $T_1$, the cooling effect of the cold flow increases;

the degree of gas throttling at the hot end of the vortex tube, i.e. from the value of the cold component (μ). With increasing μ from 0, the cooling effect of the flow increases sharply and reaches a maximum at $0.2 \leq \mu \leq 0.3$. With a further increase in μ, the cooling effect gradually decreases.

The overall pressure level (before the nozzle $P_1$ and in the cold flower $P_x$ does not play a significant role for cooling. When the pressure level is lowered, but the degree of expansion is maintained, the cooling effect is slightly reduced.

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Increasing the total gas flow through the vortex tube (increasing the nozzle cross-section area) to some limits increases the cooling effect.

To obtain the maximum value of the cooling effect at this value of μ, it is necessary to have a strictly defined diameter of the aperture of the diaphragm Dg . For stationary operation of the vortex tube in the range of $0.2 \leq \mu \leq 0.8$ the following dependence can be used:

$$D_g = D \cdot (0{,}35 + 0{,}313\mu). [2]$$

The optimal length of the vortex zone is L = 9 ·D [2].

## III. ANALYSIS OF RESULTS

As the scale (pipe diameter) increases, so does the efficiency of the vortex tube. The dependence of the vortex tube efficiency on the listed values is shown in table 1 and figure 2. (the results of calculations performed on the basis of the above formulas).

Technical capabilities of vortex tubes:
- inlet pressure 0.05-10 MPa,
- minimum cold flow temperature-120 ℃,
- the maximum temperature of the hot stream + 300 ℃,
- Efficiency - 40-60 % [1].

Table 1.
Parameters of vortex tubes of various diameters

| Pipe diameter D, mm | Cold flow temperature tx , ℃ | The air flow rate G, kg/s | Pipe diameter D, mm | Cold flow temperature tx ,℃ | The air flow rate G, kg/s | Pipe diameter D, mm | Cold flow temperature tx , ℃ | The air flow rate G, kg/s |
|---|---|---|---|---|---|---|---|---|
| 20 mm | -20 | 0,00719 | 30 mm | -20 | 0,015 | 50 mm | -20 | 0,068 |
| | -40 | 0,009 | | -40 | 0,024 | | -40 | 0,079 |
| | -60 | 0,019 | | -60 | 0,043 | | -60 | 0,12 |
| | -70 | 0,022 | | -70 | 0,0513 | | -70 | 0,1436 |
| | -80 | 0,028 | | -80 | 0,0623 | | -80 | 0,176 |
| | -90 | 0,035 | | -90 | 0,0847 | | -90 | 0,237 |
| | -100 | 0,05 | | -100 | 0,1218 | | -100 | 0,34 |

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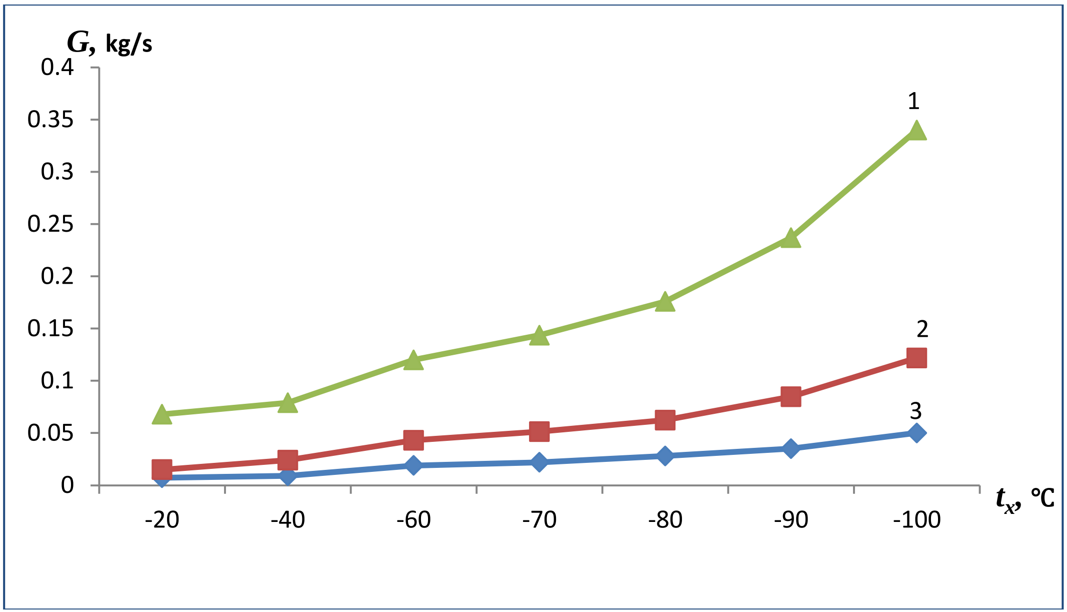


**Fig. 2 dependence of the temperature of the cold flow of the vortex tube on the total air flow.**
1 - with a pipe diameter of 50 mm, 2-with a pipe diameter of 30 mm, 3 - with a pipe diameter of 20 mm.

Depending on the specific technological tasks and possibilities of the vortex effect, vortex tubes are classified according to the main priority feature or a combination of technological and structural features [3].

Vortex tubes are distinguished depending on the following conditions:

the directions of the initial incoming flow and the separated outgoing flows (cold and hot) of gas are direct – flow and counter-flow;

purpose of the main technological process of the pipe for cooling, heating, vacuuming, throttling, pressure control, etc.;

methods of heat supply and removal – uncooled (adiabatic) and cooled (non-adiabatic).

The advantage of the vortex tube is the simplicity of the device, the absence of moving elements, low weight and reliability in operation.

The seemingly simple effect involves a complex gas-dynamic process that occurs in a spatial vortex flow of a viscous compressible gas. A significant contribution to the study of the vortex effect was made by Soviet scientists, who analytically justified the causes of its occurrence, obtained the main calculation dependencies, and created various vortex installations that are successfully used in production. In table. 2 shows the main design characteristics of vortex tubes.

Table 2.
**Geometric dimensions of the investigated vortex tubes [1]**

| Vortex tube | The diameter of the pipe, mm | Aperture, mm | Nozzle, mm | Length of the vortex zone, calibers |
|---|---|---|---|---|
| R.Hilsh №1 | 4,6 | 2,2 | 1,1 | 50 |
| №2 | 9,6 | 4,3 | 2,3 | 50 |
| №3 | 17,6 | 6,5 | 4,1 | 50 |
| D. Vtbster | 8,7 | 2,4 | 1,6 | 35 |
| G. Sheper | 38,1 | 12,7 | 6,35 | 24 |
| V. Martinskiy №1 | 4,5 | 1,5 | 1,0 | 67 |

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| | | | | |
|---|---|---|---|---|
| №2 | 9,0 | 4,5 | 2,3 (2) | 50 |
| L. Melser №3 | 16,0 | 7,5 | 3,9 (2≤) | 50 |
| V. Alekseev №4 | 28,0 | 12,0 | 6,0(2≤) | 50 |
| M. Dubinsky | 32,0 | 25,0 | | 5 |
| A. Merkulov | 33,0 | 16,0 | 6x14) | 9 |

## IV. CONCLUSION

The vortex tube, having universal qualities, especially the ability to obtain energy flows of various parameters, is increasingly used in many industries.

When drilling geological exploration wells, it is possible to use vortex pipes for cooling rock-breaking tools, sinking wells or mine workings in unstable, loosely bound and heavily watered rocks. It is also relevant when drilling wells in permafrost to ensure the stability of the walls and increase the core yield.

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