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An investigation of the process of producing the snow carbon dioxide

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An investigation of the process of producing the snow carbon dioxide

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Abstract. Currently, the Russian and foreign scientists are actively involved in the development of technologies for the processing and utilization of carbon dioxide. At the Kemerovo State University, the technologies for processing and application of carbon dioxide in the food industry have been developed. One of them is based on throttling the CO_2 coater in the generator. In order to determine the optimal operating modes of the generator, throttling is performed through washers with different throttle holes and their configuration. Also, throttling is performed with different angles of cones of snow formers at different temperatures of liquid carbon dioxide, which allows to reveal the influence of the above factors on the process of carbon dioxide snow formation. Based on the analysis of the obtained dependencies, we can conclude that the largest volume of snow weighing 0.25 kg was obtained using a cone with an angle of 12° and a temperature of minus 10°C. In percentage terms, 31.25% of the CO_2 consumed liquid phase was reworked into snow. The additional lowering of the temperature of the liquid carbon dioxide, as well as the choice of the optimum, for a given temperature, the angle of the bell, have a significant impact on the volume of the snow carbon dioxide produced. However, in the process of choosing the temperature control parameters, possible additional economic costs of creating conditions for lowering the temperature of liquid carbon dioxide should be considered.

1. Introduction

In recent years, the Russian and foreign scientists have been actively involved in the development of technologies for the processing and utilization of carbon dioxide. This corresponds to the agreement beginning to operate from 2020, the purpose of which is to limit the growth of the average temperature on the planet by 2°C.

The Ministry of Natural Resources and the Ministry of Economic Development are developing a methodology for reporting greenhouse gas emissions for enterprises. Until the end of 2019, those companies and enterprises whose emissions exceed 150,000 tons of carbon dioxide, an equivalent for the year, will have to ensure the transfer of emissions reporting to the Rosprirodnadzor agency. By the beginning of 2020, such information will already provide all production with annual emissions of more than 50,000 tons. After that, a data verification and reporting system will be created and financial impact instruments introduced (such as tax charges).

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Thus, in the future, the demand of industrial enterprises for the methods used for utilizing greenhouse gases, including carbon dioxide produced by alcohol processing enterprises, is expected. The promising areas for the use of waste carbon dioxide: chemical and petrochemical industries; pharmaceutical and biotech; food industry and agriculture; medicine; metallurgy and engineering; laboratory research; pulp and paper industry; electronics and ecology [3].

2. Materials and Methods

At the Kemerovo State University, a technology for the carbon dioxide processing in the food industry has been developed. To study the process of obtaining snow-like carbon dioxide, a generator-snowmaker was developed. A simplified diagram of which is presented in Figure 1. Its principle of operation is based on throttling the liquid CO_2 phase and achieving a pressure lower than at the triple point, since the snow produced in such conditions is not to be wet and loose [2].

The process of throttling the snow-like CO_2 in the generator-snow skimmer occurs through throttle washers having different diameters of the bore. In addition, the angle of the snow former cone and the temperature, at which the throttling is performed, change.

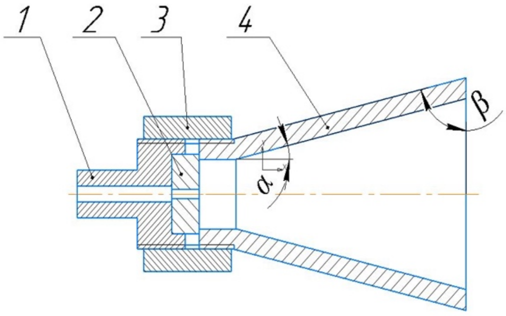

Figure 1. The working drawing of the generator – a snow former.

All elements of the generator "snow former" are made of stainless steel. The fitting (1) on the one hand joins the pipeline supplying liquid carbon dioxide. On the other hand, it has a guide recess for centering the throttle washer (2). Along the nozzle axis, the through hole is located, while the connecting nut (3) is made with a turnkey outer profile. A throttle washer with an outside diameter of 20 mm is made with a through hole. The diameter of the hole and its type were chosen experimentally to ensure maximum snow output with a minimum consumption of the CO_2 liquid phase [1].

In the manufacture of the cone "snow former" (4), the design of generating elements used in carbon dioxide fire extinguishers were considered. The cone angle was selected experimentally to ensure maximum snow yield with a minimum consumption of the liquid carbon dioxide phase.

The CO_2 throttling was carried out through the washers with a choke hole having a diameter of 1 mm. The process of snow formation occurred in cones with angles (α) from 3^o to 16^o, which made it possible to reveal the effect of a cone angle on the process of carbon dioxide production in the solid phase. Geometric data cones are presented in Table 1.

Table 1. Cone geometry.

No	d, mm	D, mm	l, mm	α,°	β,°
1	42	50	80	3	87
2		60		6	84
3		65		8	82
4		70		10	80
5		75		12	78
6		85		16	74

The first series of experiments was carried out at a temperature of liquid carbon dioxide of 20±1 °C. The results of the dependence of the amount of the snow-shaped CO_2 obtained on the angles of the cone 3÷16° are presented in Figure 2.

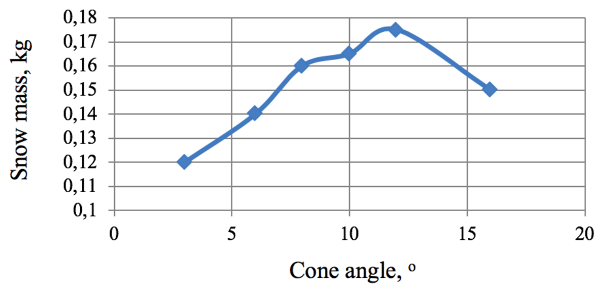

Figure 2. Characteristics of the release of snow at a temperature of liquid carbon dioxide of 20±1° C.

Analyzing the dependence presented in Figure 2, we note that the process of obtaining snow-like carbon dioxide in the socket - the snow former is divided into several stages. The first one is connected with the Bernoulli equation, since the CO_2 flow passes through a washer with a throttle orifice 1 mm in diameter, where the velocity of the gas or liquid increases (dynamic pressure increases – $\frac{pv^2}{2}$). But at the same moment, the static pressure decreases, it follows that with a decrease in the flow cross section due to an increase in velocity (a dynamic pressure), and a static pressure p drops.

Further, the stream enters the cone and with an increase in the angle of the cone, the snow former, an increase in the mass of the formed snow is observed to 0.175 kg, the angle of the cone being 12^0. Thus, an increase in pressure in front of the cone leads to an increase in speed along the entire cone - the snow former. The flow velocity in the expanding part decreases, and the pressure increases. The optimum angle of the cone is 12^0. At this angle, the maximum pressure occurs, allowing one to convert the maximum amount of carbon dioxide into a snow-like state.

The ratio of the fluid flow rate to the snow-shaped CO_2 output (Fig. 3) is 25% (0.175 / 0.7 kg / kg), while the optimum angle of the cone is 12^0.

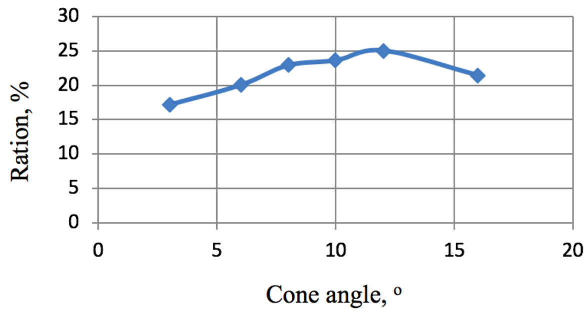

Figure 3. The ratio of liquid consumption to the output of the snow-shaped CO_2 in %, at a temperature of liquid carbon dioxide of 20±1°C.

The following experiments were carried out at a temperature of liquid carbon dioxide of 10±1 °C. With an increase in the angle of the cone-snow former, an increase in the mass of the resulting snow to 0.18 kg is observed, the optimum angle of the cone being 12^0.

The ratio of fluid flow to the snow-shaped CO_2 output is in this case 30% (0.18 / 0.6 kg / kg). Lowering the temperature of liquid CO_2 before throttling increases the output of snow-like carbon dioxide.

At a temperature of liquid carbon dioxide of 0±1°C, the ratio of liquid consumption to the output of snow-like CO_2 is 30.9% (0.17 / 0.55 kg / kg). The optimum angle of the cone was also 12°.

The following group of experiments was carried out at the temperature of liquid carbon dioxide minus 10±1 °C. The results of the dependence of the amount of the snow-shaped CO_2 obtained on the angles of the cone 3÷16° are presented in Figure 4. Optimal in this experiment is also a cone with an angle of 12°.

3. Conclusion
Characteristics of the output of snow-like carbon dioxide at different cone angles are presented in Figure 4.

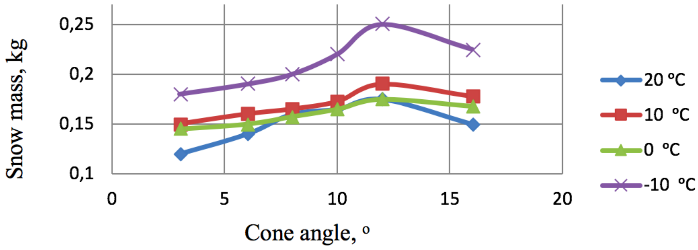

Figure 4. Characteristics of the snow emission of CO_2 at different cone angles.

Our analysis of dependences shows that the greatest amount of snow was obtained at a temperature of minus 10°C (0.25 kg), using a cone with an angle of 12°. The ratio of fluid flow to the snow-shaped CO_2 output is 31.25%.

Thus, lowering the temperature of liquid carbon dioxide before throttling allows one to increase the output of snow-like CO_2. And choosing an optimal angle leads to an additional increase in the yield of snow-like carbon dioxide. However, when choosing the conditions of temperature control, it is necessary to take into account the economic aspect of the issue associated with the cost of lowering the temperature of liquid carbon dioxide.

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