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ABSORPTION CAPACITY OF DUST-AIR FLOW. (U)

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ABSORPTION CAPACITY OF DUST-AIR FLOW

By

A. G. Blokh and A. I. Nosovitskiy

EDITED TRANSLATION

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А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere. When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

1353

ABSORPTION CAPACITY OF DUST-AIR FLOW

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Results of the experimental research of the absorption capacity of flow, carrying coal dust, are presented. The calculation dependences for determining the beam attenuation factor in a dusty volume are proposed.

In many heat-engineering problems there often appears the necessity of the calculation determination of the amount of heat, absorbed by a flow of dispersed substance, from the emission of foreign substances. So, for example, problems about heat exchange in the root of a coal-dust flame, drying, warming up and gasification of coal dust in suspended state and others require knowledge of the absorption characteristics of flows, filled with dust of coal particles.

Analytical methods of calculation of the absorption capacity of a flow of coal dust, proposed by Wohlenberg [1], Haslam and Hottel [2], Malcor [3], were based on very rough assumptions and could not be used in practice.

A significant step forward in this region was the work of K. S. Shifrin [4], in which is given a deep, physical basis of the account of the theory of scattering and absorption of electromagnetic waves by suspended particles. Although this work does not contain experimental data on the characteristics of absorption properties of particles of coal dust, the general theoretical considerations developed in it can be used for analysis of the question of interest to us.

From experimental investigations of radiation-absorbing properties of coal-dust flows there is known only the work, accomplished in All-Union Institute of Heat Engineering (VTI) under the leadership of V. N. Timofeyev. The results of this work, however, cannot be used for the establishment of qualitative dependences, since the experiments were conducted at one temperature of radiator 2000°C. Furthermore, in these experiments took place separation of the dust particles on the turn before the measuring section, and also considerable dust-coating of the protective glasses, installed in front of the radiometer, makes the experimental data quite unreliable.

The investigation of the radiating capacity of flows, dust-coated with ash particles, conducted by the authors, and the quantitative characteristics established in this article [5] could not be distributed to coal dust, differing from ash dust both by structural composition and by physical characteristics.

Thus, the setting of special experimental investigations was required, which would permit giving recommendations for the quantitative evaluation of radiant heat exchange in volumes, filled with coal particles.

In this article are discussed the main results of the conducted investigation, carried out under the guidance of A. M. Gurvich.

The measurement of absorption was conducted under conditions of filling of airflow with coal dust. The experimental installation was made with closed scheme with respect to dust and air. The measuring section consisted of a vertical cylindrical tube 180 mm in diameter and 1500 mm long, placed in a rectangular box. Through the dusty flow passed radiation from foreign absolutely black sources with known temperature and spectral composition of radiation. The amount of passage was measured depending on the temperature of sources, concentration, fraction composition and type of dust. The small flow of air between the box installation and the tube of the working section eliminated the dust coating of the radiators and receivers.

The energy of radiation was measured by a radiometer specially constructed and manufactured for this purpose. The description of the experimental installation and the radiation instrument is provided in [5].

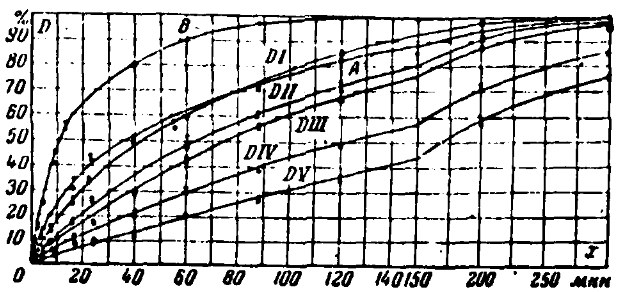
The flow rate of air was determined by the average planimetric speed of the nondust-filled flow in the working section of the cylindrical tube. The velocity distribution in the tube was measured with the aid of a pneumatic-type meter tube. The average speed of airflow in the working section of the cylindrical tube in all experiments was 11.6 m/s.

The flow rate of dust was gravimetrically determined by the time of passage of a known weighed amount of dust through the feeder. The vibration-type dust feeder provided feed of dust, uniform in a rather wide range of change of flow rates and stable in time.

The experiments were conducted with dust of Pechora coal of brand PZh and Donets anthracite, obtained in drum-ball mill, and also with dust of Donets gas coal, obtained in a medium-travel mill. From the Donets coal dust were separated five fractions with different fineness of grinding.

The fraction composition of all the investigated types of dust are presented in Fig. 1.

Fig. 1. Fraction composition of coal dust. See designations in the table.



The main characteristics of these dusts are presented in the table.

Table. Main characteristics of dust.

a) Обозначения	b) Топливо	(c) γ, г/см³	(d) F, м²/г	(e) d, мкм
A	Печорский уголь ПЖ	1,46	0,713	5,8
B	Донецкий антрацит	1,80	0,068	3,5
DI	Донецкий газовый уголь	1,52	0,657	6,0
DII	Донецкий газовый уголь	1,46	0,336	12,2
DIII	Донецкий газовый уголь	1,47	0,291	14,0
DIV	Донецкий газовый уголь	1,45	0,206	20,2
DV	Донецкий газовый уголь	1,44	0,130	30,6

Key: (a) Designation. (b) Fuel. (c) g/cm^3. (d) m^2/g. (e) μN. (f) Pechora coal PZh. (g) Donets anthracite. (h) Donets gas coal.

The average specific surface of dust F and the average diameter of particles d were computed on the basis of distribution curves presented in Fig. 1, obtained by sieve analysis and sedimentation, according to relationships

$$F=\frac{600}{\gamma}\int_{x_{мин}}^{x_{макс}}\frac{dD}{x};\quad d=\frac{6\cdot 10^4}{\gamma F}\ \mu N$$

where D = D(x) - percentage content of particles with dimensions less than x;

$x_{мин}$ and $x_{макс}$ - dimensions of smallest and largest particles;

γ - specific weight of dust.

Experiments encompassed the following region of change of main variables: temperature of radiation sources t changed from 400 to

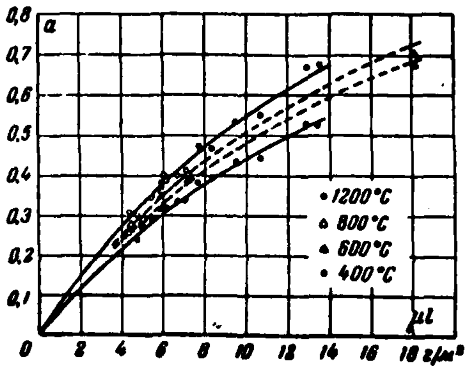
1200°C; dust concentration in flow μ - from 15 to 250 g/m³ and average diameter of dust particles d - from 3.5 to 30.6 μM.

TEST RESULTS AND THEIR ANALYSIS

The conducted tests made it possible to reveal the effect of the temperature source of radiation, the fraction composition and the type of coal dust on the absorption properties of dust-filled flow.

As an example in Fig. 2 are provided the experimental values of the coefficients of absorption a for dust of Pechora coal, obtained at different temperatures of the radiator.

Fig. 2. Dependence of the coefficient of absorption of dust-filled flow on μl and temperature for Pechora coal dust PZh.

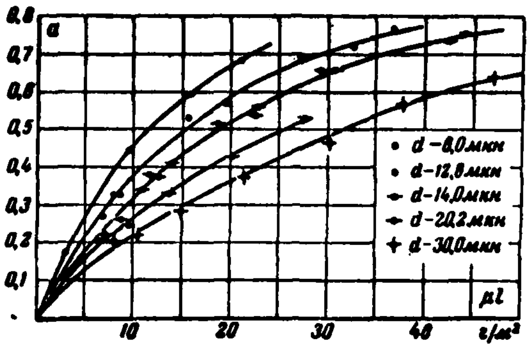


From this graph is clearly visible the effect of the temperature of radiation source on the absorption capacity of the dust-filled flow.

Similar data were obtained for dust of Donets anthracite and Donets gas coal.

Fig. 3 contains test data, characterizing the effect of the fraction composition of dust on the absorption capacity of the dust-filled flow, pertaining to dust of Donets gas coal at temperature 1200°C.

Fig. 3. Dependence of the absorption coefficient of dust-filled flow on μl for dust of Donets gas coal of various fraction compositions at temperature of radiator 1200°C.



From the graph is seen a very considerable lowering of the absorption capacity of coal dust in proportion to coarsening of the fraction composition of the latter. Similar dependences are obtained at temperatures 400 and 1000°C.

As the processing of experimental material on ash and coal dust showed, the absorption coefficient of the dust-filled flow can be calculated by a formula of the type:

$$a = 1 - e^{-kF\mu l},$$

where k - attenuation factor of beam;

l - length of path of beam in turbid medium.

The beam attenuation factor k determines the dependence of the absorption coefficient of the dust-filled flow on the temperature of the radiation source, size and physical properties of dust particles. The theoretical determination of k for actual ash and coal particles at present is not possible. However, from general consideration of the problem about attenuation of monochromatic bundle of beams in turbid medium [4] it is possible to establish the main parameters, determining the spectral absorption capacity of any dust-filled flow.

For this purpose we used the results of investigations of K. S. Shifrin on the diffraction of electromagnetic waves on a sphere, which were spread to the case of attenuation of radiation from an absolute black body [5].

The beam attenuation factor in this case is uniquely determined by two main parameters: d/λ_0 and A. The first of them characterizes the relationship between the sizes of particles d and the wave length λ_0, at which the radiation of absolute black body reaches its maximum value. The second considers the effect of the physical properties of the substance of dust and the complexity of the shape of the surface of dust particles on the absorption capacity of the dust-filled flow.

Thus, the formula for the attenuation factor of the beam in dusty volume can be written in the form:

$$k = A\left(\frac{d}{\lambda_0}\right)^p.$$

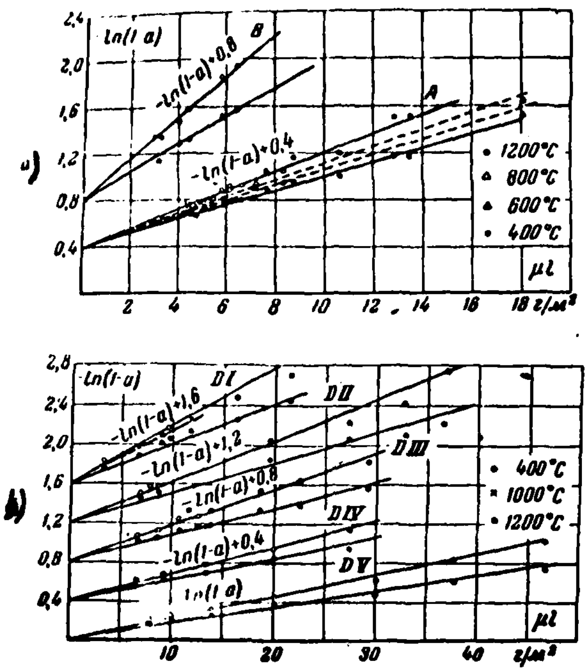
The final task of the experiment was the determination of index p and the numerical value of parameter A for dust of the investigated fuels.

Fig. 4 shows the dependence of the optical density of dusty volume τ=ln(1-a) on the force of absorption μl for dust of all fuels investigated in the work *.

FOOTNOTE: * In Fig. 4 the curves, pertaining to different series of experiments, for convenience are shifted with respect to each other along the axis of ordinates by addition of constants, indicated near the corresponding curve. END FOOTNOTE.

Fig. 4. Dependence of ln(1-a) on μl and the temperature of flow.

a - dust of Donets anthracite and Pechora coal; b - dust of Donets gas coal.



As the parameter is selected the temperature of the radiation source. From these graphs were established the experimental values of the effective section of attenuation

$$kF = \frac{1}{\mu l} \ln (1 - a)$$

for all fractional compositions of dust at prescribed temperatures of black radiator.

The effective section of attenuation in the temperature range from 400 to 1200°C for all fractional compositions of dust turned out to be independent of the force of absorption μl. The linearity of change of ln(1-a) depending on the force of absorption μl shows, furthermore, the uniformity of distribution of dust along the section of the measuring section, available in experiments.

Thus, values of μl can be taken constant outside the dependence of

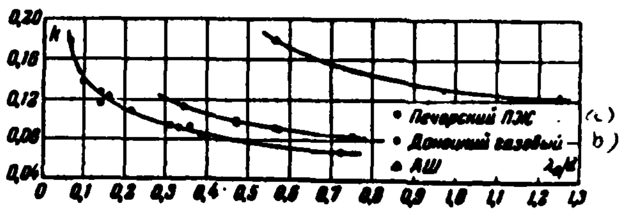
By changing to establishment of the dependence of the attenuation factor on the temperature of radiation source, it is necessary to bear in mind that the absorption properties of any turbid medium depend not only on its own characteristics, but also on the spectral composition and the intensity of incident radiation. In view of the fact that in our tests as radiation source there was used a physical model of absolutely black body, the spectral composition of incident radiation was clearly determined by the temperature of the radiation source.

As seen from the provided graphs, the effective section of attenuation kF is determined for all fractional compositions of dust of given fuel by assignment of the temperature of radiation source and the average diameter of dust particles.

In all the conducted tests the value of kF grew in proportion to increase of temperature of the radiation source and decrease of the size of dust particles.

Fig. 5 shows the dependence of attenuation factor of a beam, pertaining to average specific surface of dust, on value λ_0/d.

Fig. 5. Dependence of attenuation factor of beam on parameter $\frac{\lambda_0}{d}$.

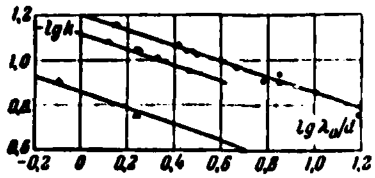


Key: (a) Pechora PZh. (b) Donets gas.

The absorption capacity of dusty flow substantially depends on the type of fuel (Fig. 5). The cause of this is not yet established, however, it can be assumed that the difference of the absorption capacity is basically connected with deviations in the value of effective specific surface of dust, actually participating in the attenuation of incident radiation.

In Fig. 6 dependence $k=f(\lambda_0 d)$ is represented in logarithmic anamorphism.

Fig. 6. Dependence of lg k on $\lg\frac{\lambda_0}{d}$ for different types of coal dust. Designations are the same as in Fig. 5.



From this graph was established the value of index p for all test fractions and types of dust.

This value turned out to be constant for all types of dust and equal to 1/3. This same value of p was obtained earlier in numerous tests with ash dust.

Thus, the attenuation factor of the beam in flow, filled with coal particles, can be determined from relationship

$$k = A\sqrt[3]{\frac{d}{\lambda_0}},$$

in which for dust of Donets gas coal A=0.06, for dust of Pechora coal A=0.08 and for dust of Donets anthracite A=0.14.

By changing to effective section of attenuation and by replacing λ_0 by the temperature, we can write

$$kF = \frac{0{,}42A}{\gamma}\sqrt[3]{\frac{T}{d^3}}.$$

The obtained formula establishes the dependence of the effective section of attenuation kF on the temperature of the radiation source and the average diameter of particles and can be recommended for estimation of the absorption capacity of dust-air flow.

Due to the fact that the tests were conducted on a limited quantity of types of fuel, the problem of further investigation is the accumulation of test data about the effect of the type of dust on the absorption capacity of the dust-filled flow.

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