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TRANSACTIONS OF THE VIII ALL-UNION CONFERENCE ON CLOUD PHYSICS --ETC(U)
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FOREIGN TECHNOLOGY DIVISION

TRANSACTIONS OF THE VIII ALL-UNION CONFERENCE ON CLOUD PHYSICS AND ACTIVE MODIFICATIONS
(Selected Articles)

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Table of Contents

U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
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 ë in Russian, transliterate as yë or ë. The use of diacritical marks is preferred, but such marks may be omitted when expediency dictates.

GREEK ALPHABET

Alpha	A	α	𝛂	Nu	N	ν	
Beta	B	β		Xi	Ξ	ξ	
Gamma	Γ	γ		Omicron	O	o	
Delta	Δ	δ		Pi	Π	π	
Epsilon	E	ε	𝛜	Rho	P	ρ	𝛒
Zeta	Z	ζ		Sigma	Σ	σ	ς
Eta	H	η		Tau	T	τ	
Theta	Θ	θ	𝛝	Upsilon	T	υ	
Iota	I	ι		Phi	Φ	φ	ϕ
Kappa	K	𝛋	ϰ	Chi	X	χ	
Lambda	Λ	λ		Psi	Ψ	ψ	
Mu	M	μ		Omega	Ω	ω	

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

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

GRAPHICS DISCLAIMER

All figures, graphics, tables, equations, etc. merged into this translation were extracted from the best quality copy available.

CLOUD CONDENSATION NUCLEI.

A. G. Laktionov.

Institute of applied geophysics.

Page 48.

In the process of their development of cloud passes a series of stages. During the first stage of the development of all cloud species (including of fog) as a result of the condensation of water vapors on the most active condensation nuclei occurs the formation of the cloud spectrum with the determined concentration of drops.

The determination of concentration and spectrum of cloud condensation nuclei was conducted by us by the flow photoelectric meter of cloud nuclei [5].

Near the ground of investigation were conducted near Moscow in region g. Obninsk during September 1965, in region g. Zvenigorod during April 1969 and in summer near Kiev in region of Borispole during July - August 1966 and 1967. In all cases of measurement are

carried out with following supersaturation 0.1; 0.16; 0.25; 0.4; 0.63; 1; 1.6o/o.

The numerous measurements in different season and in different regions showed that majority of the obtained integrated spectrums of nucleus concentration of supersaturation in the range of supersaturation from 0.1 to 1.6o/o it is not possible to describe by the simple power dependency, proposed by Twomey.

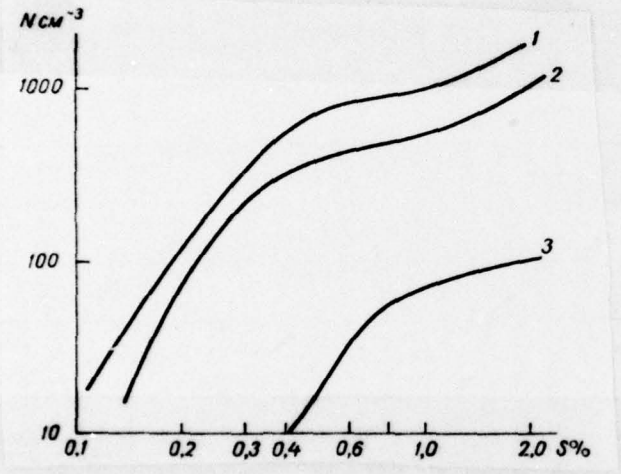

Fig. 1. Spectra of the integral concentrations of condensation nuclei of supersaturation. 1 - near the ground, 2 - at height 200 m, 3 - at height 4000 m.

Page 49.

Figure 1 gives an example of the characteristic integral distribution

of nucleus concentration of supersaturation, obtained near the ground of atmosphere.

In integrated spectrum it is possible to isolate three characteristic sections, divided by the regions of curve knee. The initial region of the spectrum of nuclei in the region of low supersaturation can be approximated by exponential function with the exponent, which varies from 0.7 to 2.0. The initial region of the spectrum of nuclei is arranged in the region of supersaturation to 0.2-0.6o/o. The second region of the spectrum can be approximated by power dependency with exponent K < 0.7. This course of a change in nucleus concentration from supersaturation is observed in the range of supersaturation from 0.2-0.6 to 1-1.6o/o.

In the half of the obtained near the ground of air spectra of condensation nuclei is exhibited the third section with more rapid than in the second section, by an increase in nucleus concentration, that occurs with an increase in the supersaturation. This section begins from the values of supersaturation 1.0o/c. Given in Fig. 2 calculated on the basis of the measured integrated spectrum differential spectrum has clearly expressed maximum, which lies at the region of supersaturation 0.2-0.5o/o, and second maximum, arrange/located in the region of supersaturation more than 1.6o/o.

The integral distribution function of nuclei according to supersaturation in the region of the first maximum can be approximated incomplete γ-function with the parameter α, which varies from 1 to 10.

By the method, described above, produced the study of cloud condensation nuclei in free-air conditions from aircraft. Concentration measurements of nuclei are carried out in the same range of supersaturation (0.1-1.6o/o) during June - July 1966, during July - August 1967 and during July - August 1968. The spectra of condensation nuclei were measured at levels 200, 1000, 2000, 3000 and 5000 m above the surface of the Earth.

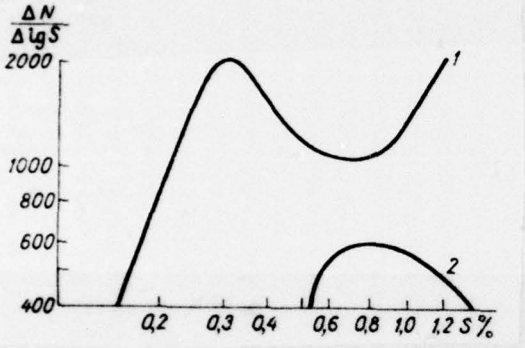

Fig. 2. Differential spectra of condensation nuclei on supersaturation. 1 - at height 200 m, 2 - at height 4000 m.

Page 50.

All 32 soundings of atmosphere conducted. Most of all soundings it is carried out in center section ETS [ETC - European Territory of the Union] in the region of Kiev - Kursk, part of the soundings of atmosphere is made in the region of righi, Murmansk, Arkhangelsk.

The analysis of the obtained materials showed that in summer

above the central regions of ETS in layer 200-1000 m of concentration and the spectra of nuclei virtually do not change on height and coinciding with concentrations and spectra of nuclei near the ground (Fig. 1). In layer from 4000 to 5000 m the integrated spectrums of cloud condensation nuclei can be broken into two sections. the original region of the spectrum to 0.6-1.0o/o is approximated by power dependency with the exponent, which varies from 1 to 2. On the second section after the region of curve knee spectrum also can be approximated by power dependency with exponent less than 1.

The differential spectrum of condensation nuclei (Fig. 2), arrange/located in layer 4000-5000 m, has one maximum, arrange/located in the region of supersaturation 0.6-1.0o/o. The comparison of the spectra at heights 200-1000 and 4000-5000 m it shows that with an increase in altitude faster (30-100 times) decreases the concentration of the most active condensation nuclei, which are exhibited with supersaturaticn from 0.1 to 0.3-0.6o/o. Concentration least active from the measured nuclei (S $\approx$ 1.6o/o) decreases 10-20 times during transition from height from 100 to 4000 m. Most slowly (in all 2-3 times) occurs decrease with height in layer 100-4000 m of nucleus concentration, active in region supersaturation 0.7-1o/o. This behavior in the atmosphere of the different fractions of cloud condensation nuclei to us is presented by extremely interesting.

In spite of the quantitatively different rate of the decrease of nucleus concentration with height, in nine cases of sounding, made in daytime hours in summer 1966, was recorded the qualitatively identical character of their change. Simultaneously with the measurement of nuclei were carried out concentration measurements of aerosol particles 20 μm in diameter.

Figure 3 shows the simultaneously measured changes in the height of the concentration of the cloud nuclei, active with supersaturation S ≈ 0.3o/o (curve 1), and particles of aerosol d ≈ 20 μm (curve 2).

From shape of the curve in this figure, it is evident that the decrease of the concentration both of particles of the aerosol and cloud nuclei occurs in the atmosphere not monotonically.

Of the rate of the decrease of particle concentration with height above land in summer in daytime hours distinctly separate/liberated three layers. In lower layer, to 1.5 km, which occurs powerful convective mixing, particle concentrations slowly decrease with height. In the second layer, from 1.5 to 3 km, the intensity of vertical turbulent mixing is small and, furthermore, in this layer are developed the clouds, which lead to the washout of

cloud condensation nuclei. Both these reasons contribute to the rapid decrease of the concentration of particles of the aerosol both of giant ($d \approx 20$ μm) and cloud condensation nuclei.

Page 51.

In the third layer, above 3.5 km, the concentration of cloud nuclei it is little affected with height. In this figure is shown the course of change with the height of the concentration of Aitken's nuclei (curve 3), of Ye. S. Seleznevoy's data [4]. The comparison of the shape of the curve 1-2 and of curve 3 in lower layer shows that the concentration of Aitken's nuclei in this same layer changes with height considerably faster in comparison with the concentrations of cloud nuclei and giant aerosol particles.

In work [4] it was shown, that the decrease with the height of the concentration of Aitken's nuclei ($N_0 \approx 10^3$-10^4 cm^{-3}) in essence is explained by the coagulation of particles. The velocity of coagulation is proportional to the square of concentration; therefore a coagulating decrease in the concentration of the cloud nuclei, active with supersaturation 0.3o/o ($N \approx 300$ cm^{-3}), little. After examining the reasons, which lead to a change in the concentration of particles of the aerosol with height, it is possible to be returned to the explanation of a change in the spectrum of cloud nuclei during

transition from 100 to 4000 m (Fig. 2). Considerable decrease at height 4000 m in comparison with an increase at height 200 m of the concentration of low-activity nuclei, $S \approx 1.6o/c$ (concentration of these nuclei at height 200 m is equal approximately $1 \cdot 10^3$ cm^{-3}), occurs analogous with decrease with the height of the concentration of Aitken's nuclei in essence because of the coagulation of particles.

The slowest change with the height of nucleus concentration, active in region supersaturation 0.7-1.0o/o, apparently, is connected with the fact that with a decrease in the initial concentration sharply falls the velocity of the coagulation of such particles, and, on the other hand, a quantity of such nuclei is increased because of the coagulation of smaller particles; furthermore, these low-activity nuclei slowly are eluated from atmosphere. By the most important factor, which leads to a sharp decrease in the most active condensation nuclei ($S \approx 0.3$-$0.6o/o$), is their rapid washout from atmosphere clouds and precipitation.

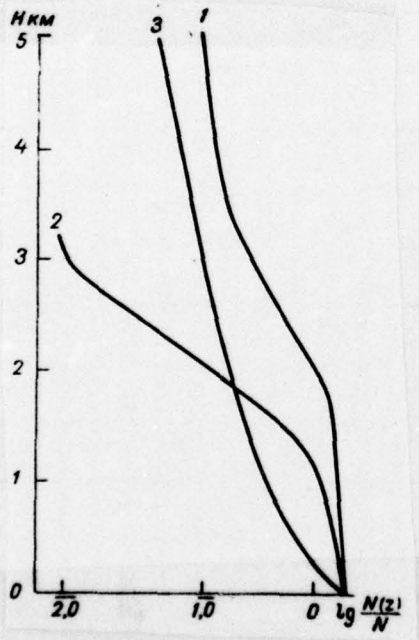

Fig. 3. Change in the height of the concentrations of cloud condensation nuclei, active with supersaturation S ≤ 0.3o/o (1),

aerosol particles 20 μm in diameter (2) and Aitken's nuclei (3).

Page 52.

To evaluate the values of the supersaturation, which appear in clouds, were conducted during July - August 1968 measurement of concentration and spectra of nuclei under clouds and of the concentration and spectrum of drops in the lower part of the generating cumulus clouds the method, described in [6]. As an example are given the measured during the same days spectra according to the supersaturation of the cloud condensation nuclei, which are contained in subcloud layer (Fig. 4), and the spectra of the size/dimensions of drops, which are located in the lower half of the cumulus clouds (Fig. 5), measured in two essentially different regions: in the city distric of Arkhangelsk, arrange/located on the coast of white sea, and in the center section of the European territory of the USSR in the city distric of Kiev. Lower boundary of the cumulus clouds, measured in the region of Arkhangelsk on 11 July 1968, was arrange/located on height 200 m. Power/thickness of clouds from 400 to 700 m. Lower boundary of the cumulus clouds, measured on 18 July in the region of Kiev, was arrange/located on height 900 m. The cloud layer is 300-500 m.

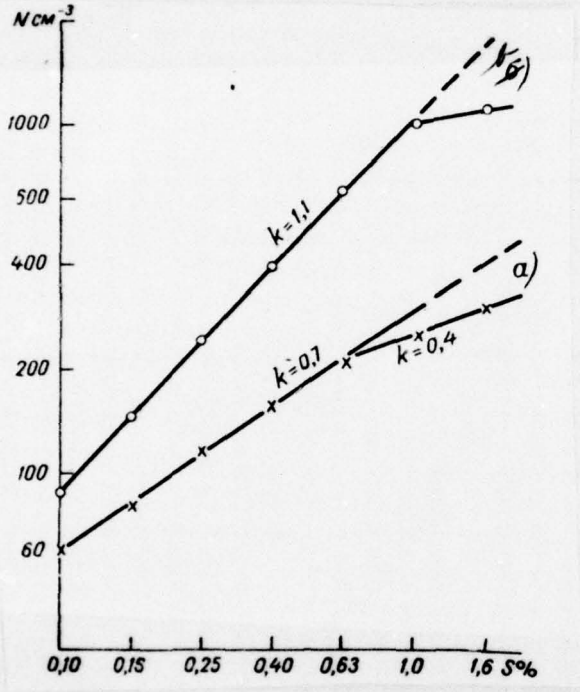
N cm⁻³
1000
500
400
200
100
60
k=1,1
k=0,7
k=0,4
b)
a)
0,10
0,15
0,25
0,40
0,63
1,0
1,6 S%

Fig. 4.

Fig. 4. Spectra of the integral concentrations of condensation nuclei of supersaturation in the subcloud layer on 11 July 1968 in the region of Arkhangelsk (a) and on 18 July 1968 in the region of Kiev (b).

Page 53.

As already mentioned earlier [6], the concentrations of drops at just one level in cloud were distributed substantially unevenly, the maximum concentrations of drops are observed in the zones, the temperature in which is somewhat higher than in the surrounding parts of the cloud at the given height. These zones are interpreted [3] by convective jets or upflows in cloud.

The measured spectra of the size/dimensions of drops in streams and outside streams in clouds are shown in Fig. 5. As can be seen from this figure, the total integral concentration of drops whose diameter is is more than 5 μm in streams 3-4 times higher than the concentration of the drops, arrange/located in cloud outside streams, which will agree with obtained previously data [6]. From the comparison of data given in Figs. 4 and 5, we find that the maximum supersaturation, which act in the lower parts of the cloud in the ascending streams, are 1-1.2o/o, and of supersaturation outside

streams in the clouds, investigated in the region of Arkhangelsk, are equal approximately 0.1o/o, also, in the region of Kiev of approximately 0.5o/o.

The findings on the spectra of nuclei and concentration of drops in clouds make it possible to evaluate the values of the vertical velocities of airflow in the lower parts of the clouds.

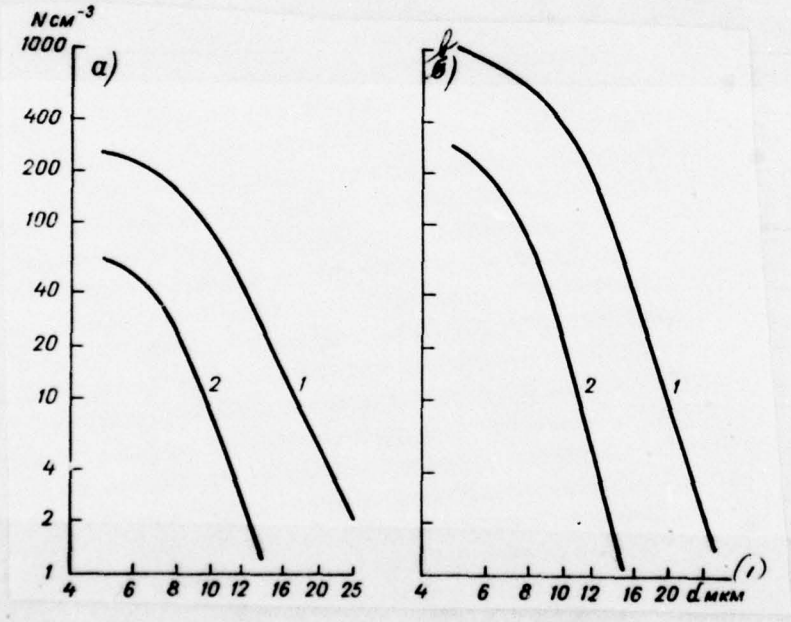

Fig. 5. Spectra of the integral concentrations of drops of size/dimensions in cumulus clouds, measured on 11 July 1968 in the region of Arkhangelsk (a) and on 18 July 1968 region of Kiev (b). 1 -

in streams, 2 - outside streams.

Key: (1). μm.

Page 54.

For the first time communication/connection of the concentration of drops in clouds with the velocities of vertical airflow in cloud and with the spectra of nuclei of supersaturation was given in the work of Twomey [8]. More precise relationship/ratios taking into account the psychrometric temperature of drop, initial nuclear sizes of condensation and jumps of the elasticity of the water vapors and temperature near the surface of drop are found in the work of Volkovitskiy and Sedunov. On the comparison of data given in work [2], calculated on formula of Twomey and the formulas of Volkovitskiy and Sedunov, communication/connection between these formulas can be written in the following form:

$$N_{\text{Волк. Сед}} \approx N_{\text{Тумн}} u_z^{0,14}, \qquad (1)$$

where u is the vertical velocity, expressed in m/s.

Empirically obtained dependence (1) takes the following form:

$$N_{эмп} \approx N_{Тумн} 0,16 u_z^{0,6}. \qquad (2)$$

Formulas are derived when the spectrum of nuclei on supersaturation is described by exponential function. As it was shown above, this requirement over a wide range of supersaturation is not fulfilled. But with the supersaturation, which do not emerge beyond the limits of the initial region of the spectrum of cloud condensation nuclei, vertical velocities can be calculated by the formulas indicated.

Table 1 gives the estimations of the upwash velocities of air, obtained on the basis of formulas of Twomey, Volkovitskiy and Sedunov, also, from the empirical obtained formula. The velocities, indicated in table in brackets, are determined with the supersaturation, which emerges beyond the limits of the initial region of the spectrum. As can be seen from table, the value of vertical velocities, calculated by formulas (1) and (2), they turned out to be more close between themselves as compared with the velocities, calculated by formula of Twomey. The velocities in streams, found by formula of Twomey, exceed the velocities, determined in formulas (1) and (2), 4-6 times.

Table 1. Upwash velocities (cm/s.), July 1968.

(1) Число и район	(2) В кучевых облаках	(3) По формуле		
		(4) Туми	(1)	(2)
(6) 11 Архангельск	(5) В струях	(360)	(60)	(57)
	Вне струй (7)	10	5	13
(8) 18 Киев	(5) В струях	680	160	110
	Вне струй (7)	80	40	40

Key: (1). Number and region. (2). In cumulus clouds. (3). By formula. (4). per Twomey. (5). In streams. (6). Arkhangelsk. (7). Outside streams. (8). Kiev.

Page 55.

The absolute values of the vertical velocities in clouds in streams (0.5-1.2 m/s), calculated in formulas (1) and (2), will agree with [3, 7] of the magnitude estimates of the vertical upwash velocities in the lower parts of the cumulus clouds. In clouds outside the streams of the velocity of vertical motions it is considerably less (4-15 times) the upwash velocities in streams.

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PROPERTIES OF ACTIVE CONDENSATION NUCLEI.

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One of the most effective methods of number determination of active cloud nuclei is the determination of the concentration of cloud drops in the lower layer of the recently formed clouds. In this case with large probability it is assumed that the effect of the coagulation of drops can be disregarded. For this reason were carried out microstructural measurements in the lower layer of the recently formed summer cumulus clouds above Hungary [3].

Simultaneously was determined the concentration of large and giant aerosol particles with the aid of aircraft with the utilization of plates and membrane filters. Independent of these measurements the physical and chemical properties of atmospheric aerosol were studied also at one mining station (Kekes, 1014 m), approximately under lower boundary of cumulus clouds. It should be noted that the

membrane filters were held with low relative humidity before preparation for a microscopic analysis; thus, from accidentally the grasped drops of solution on filter remained the only "dry" soluble particles. Concentration measurement of large and giant particles is necessary in order according to these data to estimate the role of these particles in the process of condensation. The necessary (however insufficient) yield condition of active condensation nuclei from this region of size/dimensions is that that the concentration of these particles minimally would be equal to the concentration of cloud drops.

In summer 1967 were made five aircraft measurements in midday [3]. During these measurements it was assembled 33 sample/tests of cloud drops and was determined also the concentration of large and giant aerosol particles. The obtained results are given in Table 1. For a comparison is indicated also the mean concentration of aerosol, measured at the mentioned mining station.

Table 1. Concentration of cloud drops, and also of large and giant atmospheric particles.

(1) Концентрация капель, $см^{-3}$	(2) Концентрация аэрозолей ($r \geqslant 0{,}15$ мкм), $см^{-3}$	
	(3) самолет	(4) горная станция
1770	340	77

Key: (1). Concentration of drops, cm^{-3}. (2). Concentration of aerosols ($r \geqslant 0.15$ μm), of cm^{-3}. (3). aircraft. (4). mining station.

Page 78.

According to data of table it is easy to ascertain that the concentration of cloud drops considerably exceeds the concentration of large and giant particles. Comparatively high concentration of cloud drops is explained themes that the sample/tests collected in cumulus clouds immediately after their formation and directly above their lower boundary. Similar results obtained Juan me1-yuan in the USSR [1]. In connection with data given in table, it should be noted that comparatively small particle concentrations at mining station are caused themes that they were measured not only in cloud weather, but also in cases when cloud formations did not occur, i.e., upflows

they were absent.

Data Table 1 clearly show that the concentration of large and giant aerosol particles amounts on the average to only 20o/o of total number of cloud drops. This fact obvious it derives that the certain fraction of Aitken's particles plays the considerable role in the process of cloud formation.

It is well known that the soluble (or mixed) particles are much more active nuclei, than insoluble. Consequently, if such particles are encountered in the region of Aitken's particles in a sufficient quantity, then, obviously, they serve as cloud nuclei. However, data, relating to the chemical composition of Aitken's particles, in the literature are not for that reason, that the researchers (specifically, Young [4]) studied first of all large and giant particles. It was assumed that the predominant part of the mass of solutes is located in this region of size/dimensions.

For experimental research on this problem were fulfilled the measurements with the aid of the four-stage impactor, equipped with supplementary convenient filter. Impactor seized large and giant particles in four step/stages, while filter accumulated Aitken's particles [5, 6]. After the collection of sample/tests, which was being continued several days, the sample/tests at separate

step/stages were subjected to chemical analysis. Table 2 gives the given data of the ion concentrations ($\mu g/m^3$) of different size/dimensions, obtained during summer periods of 1967-1968. From table it is evident that the giant particles contain relatively a little solutes. On the other hand, the majority of solutes is encountered in the region of Aitken's particles, where predominate sulfate ions of ammonium.

The measurements pointed out above were made near the surface of the Earth (main aerological observatory, Budapest, 139 m); however, data on a change in the chemical composition of aerosol to the height of the formation of clouds are not. Therefore were produced the measurements by summer 1968 for the comparison of concentration and distribution of sulfate ions at mining station and in observatory. It is assumed that the findings are characteristic for vertical distribution, since the investigations showed [7] that into flight half-year horizontal changes of sulfate concentration in Hungary were negligible. Table 3 gives the obtained results for sulfate as the most important ion.

Page 79.

In the last/latter row of this table is given general concentration in $\mu g/m^3$, and other data show its percentage according to sizes.

From the analysis of the given data first of all it becomes obvious, that the lapse of common/general/total concentration in the lower 1000- metric layer of atmosphere is very insignificant. This fact will agree well with the results of aircraft measurements Georgiy and its coworkers [8].

However, are expressed some differences in according to the sizes of the sulfate particles between two stations: a relative quantity of large and giant particles at mining station more than b of observatory. Taking into account the hygroscopicity of particles, and also the condition that the average relative humidity was equal during measurements 71o/o in observatory even 83o/o in Kekes, these differences are explained well. For the substantiation of the aforesaid it serves as Fig. 1, which shows average communication/connection of a relative quantity of sulfate in the region of Aitken's particles with relative humidity. The curve of the figure was conducted in accordance with the measurements, carried out in aerological observatory. From the figure one can see that from the value of the relative humidity, equal approximately 75o/o, a relative quantity of sulfate in the region of Aitken's particles decreases first rapidly, and then is slower.

Table 2. Different ion concentration (μg/m³) in the different regions of particle sizes.

(1) Ядра	SO_4^{--}	NH_4^+	NO_3^-	Cl^-	Ca^{++}	(2) Сумма
(3) Гигантские	0,6	0,2	0,3	0,3	0,2	1,6
Большие (4)	2,2	1,6	0,5	0,4	0,2	4,9
Айткена (5)	3,0	1,8	0,3	0,2	0,4	5,7
Сумма (2)	5,8	3,6	1,1	0,9	0,8	12,2

Key: (1). Nuclei. (2). Total. (3). Giant. (4). Large. (5). Aitken.

Table 3. Weight concentration and according to the sizes of sulfate particles at two different heights above sea level.

(1) Ядра	(2) Обсерватория (132 м), %	(3) Кекеш (1014 м), %
(4) Гигантские	12	14
Большие (5)	34	47
Айткена (6)	54	39
(7) Сумма (мкг/м³)	4,5	3,8

Key: (1). Nuclei. (2). Observatory (132 m), o/o. (3). Kekes (1014 m), o/o. (4). Giant. (5). large. (6). Aitken. (7). Sum (μg/m³).

Hence it follows that hygroscopic particles "grew" from this region of size/dimensions. From an abrupt/steep decrease in the curve with relative humidity 80o/o it is evident that the phase transition of sulfate particles occurs at this value of humidity, and also, as in observatory with relative humidity 83o/o in the region of Aitken's particles also is located approximately 39o/o of sulfate. After relating this value to 71o/o of relative humidity (with which particles are located, probably in "dry" state), we will obtain the same distribution in Kekes as and in observatory.

From foregoing it is possible to establish that the concentration of sulfate particles (at the heights of the formation of clouds) will agree actually with the values, obtained in the surface layer of air without considering changes of relative humidity. Hence it follows that the active condensation nuclei are sulfate particles (probably sulfates of ammonium), which are found in dry state in the region of Aitken's particles.

On the basis of the results of the investigations, presented above, were solved the thermodynamic problems of the condensation

water pair on soluble and mixed nuclei [9]. Was derived formula for determining the dependence between the radius of the drop of solution and supersaturation, and is also developed equation for the calculation of free energy of nucleation. During the removal of formulas it was assumed that the nucleus completely is not wetted by drop (Fig. 2), i.e., the angle of wetting θ is more than zero. From the brought out equations escape/ensue all other simpler cases.

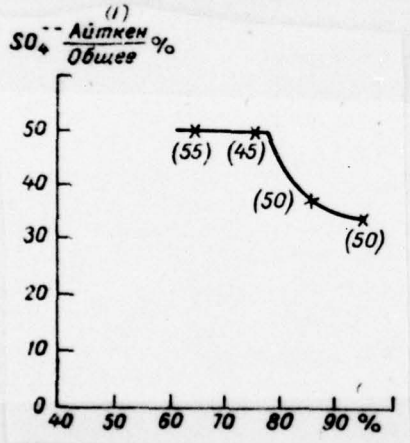

Fig. 1. Dependence of a relative quantity of sulfate in the region of Aitken's size/dimensions on relative humidity. Numerals in brackets designate the number of days of the collection of sample/tests.

Key: (1). Aitken/Total, o/o.

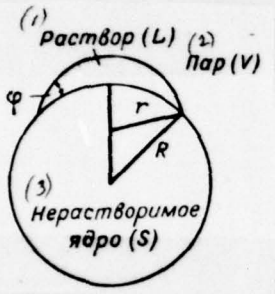

Fig. 2. The diagrammatic representation of the studied thermodynamic system.

Key: (1). Solution (L). (2). Pairs (V). (3). Insoluble nucleus (S).

Page 81.

These theoretical studies make it possible to characterize the condensation activity of the nuclei of different types. For this purpose most approaching is the comparison of the critical supersaturation, with which these condensation nuclei are promote/activated. For determining critical supersaturation was applied the following formula:

$$\ln \frac{P_V}{P_\infty} = \frac{2\sigma_{LV} V_L}{KTr} + g_W \ln X_W,$$

where P_V/P_∞ — supersaturation; σ_{LV} — surface tension between solution and water vapor; K - Boltzmann's constant; T - the absolute temperature; r - the radius of the drop of the solution; g_W — the osmotic coefficient of water in solution; V_L — the recurrent value of the number of water molecules in 1 cm³ of the solution; X_W — the concentration of water in the drop of solution. In the case of the presence of this quantity of determined solute $V_L X_W$ it is the complex function of size/dimension of R and surface properties ф insoluble nucleus. Without being occupied here in detail by the determination of this complex functional dependence, let us examine the results of the calculations, made in electronic computer "Minsk-22". During calculations were assumed the values of temperature T = 273° and the masses of sulfate of ammonium $m_M = 5 \cdot 10^{-17}$ g (radius of dry nucleus was equal to $1.86 \cdot 10^{-6}$ cm.). Sulfate of ammonium is the mixed nuclei with the insoluble particles of different size/dimensions and surface properties. Let us note that the necessary for the calculations physicochemical parameters were taken from corresponding tables [9]. The obtained results are represented

in Fig. 3. Along the axis of ordinates are plotted/applied critical supersaturation, along the axis of abscissas - the critical radii R*. For a comparison figure gives also curve, that relates to the insoluble, completely hydrophilic nuclei (Thomscn's formula).

On data, presented in the figure, it is possible to establish/install following: the mixed nuclei, which contain the soluble and insoluble components, are always more active, than the soluble nuclei of the same mass (R* = 0 in the figure), with the exception of the case, with which the angle of the wetting of insoluble nucleus is equal to 180°. From the figure one can see that with increase in R* the critical supersaturation rapidly decreases with datum ϕ. On the other hand, an increase in the angle of wetting ϕ decreases the condensation activity of mixed nucleus. It should be noted that to the insoluble nuclei of these size/dimensions and surface properties in the absence of solutes correspond the critical supersaturation of such large values, which are not encountered under atmospheric conditions [10, 11]. Thus, the coagulation of the soluble and insoluble particles has large value in the formation of cloud nuclei. The figure shows further that with certain value R* (precise value of which it is function ϕ) the completely hydrophilic insoluble nuclei will become the more active mixed nuclei, which contain insoluble substance with the wide angle of wetting.

Page 82.

It is known that for determining concentration and distribution according to the supersaturation of active condensation nuclei are applied the diffusion cloud chambers. Our conclusions, obtained from the measurements of the physical and chemical properties of atmospheric aerosol, must be in accordance with the results of the measurements, carried out in diffusion cloud chamber.

Similar investigations in the USSR conducted by Laktionov [2]. The completed by it aircraft measurements showed that the concentration of cloud nuclei in the lower 1.5- layer of atmosphere per kilometer changes with height very insignificantly. This fact will agree well with our results, on which it was obtained equal almost to zero. On the other hand, Twomey in the USA on simultaneous measurements with the utilization of a diffusion cloud chamber and diffusion tube it arrived at the conclusion that the cloud nuclei are the water-soluble particles, which according to their size/dimensions belong to the region of Aitken's particles [12]. Volatility of these particles attests to the fact that their substance consists of sulfate of ammonium or chloride of ammonium [13]. From the given data it is possible to ascertain that our conclusions do not contradict the results, obtained by other authors with the aid of diffusion cloud chambers.

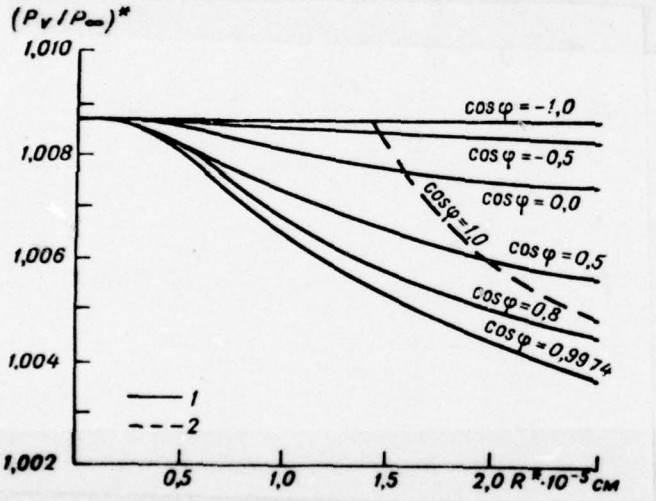

Fig. 3. Critical supersaturation of the mixed particles depending on the properties of the insoluble nucleus; $m_H = 5 \cdot 10^{-17}$, **T = 273°K. 1 - the mixed nuclei, 2 - insoluble nuclei.**

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THE TOTAL SPECTRUM OF PARTICLES OF NATURAL AEROSOLS AND ESTIMATE OF THE FRACTION OF ACTIVE CONDENSATION NUCLEI.

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In view of the available difficulties, caused by the considerable width of the range of size/dimensions and concentrations of natural aerosols,, until now, it is made very few the measurements of the full/total/complete spectrum of particle-size distribution. It is possible to indicate only the works by Junge [5, 6] in which, on the basis of 25 combined measurements of particle sizes by the impactor and of the spectrum of ions it is given the representation of the full/total/complete spectrum of the distribution of solid particles under terrestrial conditions. For a free atmosphere there are no such data generally.

On the other hand, the numerous measurements of the sizes of particles and their concentrations in the individual sections of the

overall spectrum although are of doubtless interest for the solution of the different problems, bonded with aerosols, all the same they have the limited value, since often the region of measurement is not clearly determined. Furthermore, the absence of the information about other regions of the spectrum can lead to erroneous conclusion/derivations from the obtained results.

For determining an entire region of particle sizes it is necessary to utilize simultaneously several methods, since not one of the existing at present instruments does not make it possible to measure the aerosols in this broad band of size/dimensions.

The greatest difficulty appears during the investigation of highly dispersed aerosols with sizes of particles less than 1 μm in radius. Direct methods here turn out to be hardly suitable due to the incompleteness of the coverage/scope of the region indicated; therefore for research on the size/dimensions of small particles increasingly more frequently are drawn indirect methods. One of such methods, base on communication/connection between the electric characteristics of particles and their size/dimensions, was applied also in the present work. More precise saying, were used two modifications of this method. The idea of the first, proposed by Junge [6], consists in the conversion of the spectrum of ions into the spectrum of particles, for which necessary to know the number of

charged and neutral particles, and also their full/total/complete concentration in the given air volume. These information were obtained with the aid of the specially re-equipped Scholtz counter, for which inside the chamber instrument it was introduced radial deflection terminal whose diameter is 1 mm and whose length is 40 mm it was created electric stress field 300 V.

In the second case was considered as a whole the effect of the sizes of particles and their concentrations on the electric characteristics of atmosphere.

Page 94.

According to [4], in lower atmosphere in the absence of clouds and fog between electric intensity E, concentration N and particle sizes there is communication/connection, which with the utilization of known relationship/ratios between the mobility of current carriers and the coefficient of their diffusion can be presented in the final form:

$$r = \frac{qe^2}{4\pi iK} \frac{E}{NT}. \qquad (1)$$

Here r - the average effective radius of particles in sample/test, q

- the rate of formation of ion pairs in 1 cm^3/s, e - elementary charge, i - the air-earth current, K - the is constant of Boltzmann, T - the temperature of the medium.

When evaluating particle sizes according tc formula (1) for q and i are accepted their average values, values E, N and T were recorded.

Both methods gave the matching between themselves results. Let us note also that the average values of the radii of particles coincide with data, obtained by A. G. Laktionov [3] with the aid of the nephelometer KOL-90, justifying thereby the accepted by us methods of the estimation of the size/dimensions of small particles.

Besides the methods indicated, for determining size/dimensions and calculating particle concentration were used the methods of filtration the abusive filters whose effectiveness is virtually equal to 100o/o for particles with $r \geqslant 0.1$ μm. In the second - the one-stage impactor trap, in which completely were caught the solid particles with $r \geqslant 1$ μm and specific gravity/weight 2 g/cm^3. Recording particles in both cases conducted under optical microscope.

Thus, the utilized in work methods supplemented each other and were covered the boundaries between the small, large and giant

particles of aerosols. The detailed analysis of the conditions of the taking of the samples of aerosols and estimation of error in the measurements for each method they made it possible to obtain the overall spectrum of particle-size distribution. Figure 1 gives the averaged from several hundreds of measurements in Central Asia picture of the full/total/complete spectra of the size/dimensions of the natural aerosols, for the first time obtained for a free atmosphere. For the facilitation of work with curve/graphs on the figure are used the coordinates ($dN/d \lg r$, $\lg r$). In order to determine the number of particles in 1 cm^3 in this interval of size/dimensions, it is necessary to multiply the average value of ordinate in this interval for an absolute difference in the logarithms of the corresponding radii.

From Fig. 1 it follows that the atmospheric aerosols are included within the limits of an interval of approximately four orders of size/dimensions on the average from 0.005 to 20 μm. In this case the extreme values of the radii of particles, recorded in sample/tests, were 0.003 and 45 μm. The range of the concentrations of natural aerosols is wider and includes approximately 7 orders of magnitude N from 10^3 in 1 cm^3 for particles 0.05-0.1 μm in radius to 10^{-4} cm^{-3} for giant particles.

The concentrations, in which are encountered the aerosols under

natural conditions, are subjected to considerable variations, especially in the region of particles of the small size/dimensions.

Page 95.

Greatest a representation according to number at height 250 m have particles 0.05 μm in radius, at height 2000 m the maximum of distribution is displaced to particles with r = 0.2 μm, which is caused, obviously, by the action/effect of the process of the coagulation of aerosols.

On opposite region of the spectrum, where predominates the sedimentation of particles, also are observed ccnsiderable changes in their concentration. So, at height 250 m in an interval of size/dimensions r = 15-20 μm the number of giant particles on the average comprises $3 \cdot 10^{-3}$ per 1 cm^3 of air, and at height 2000 m - in all $5 \cdot 10^{-5}$.

The smallest changes with height in the common/general/total spectrum of size/dimensions test/undergoes particle concentration from 0.2 to 0.5 μm in radius, as a result of which these particles are the most stable component of atmospheric aerosol.

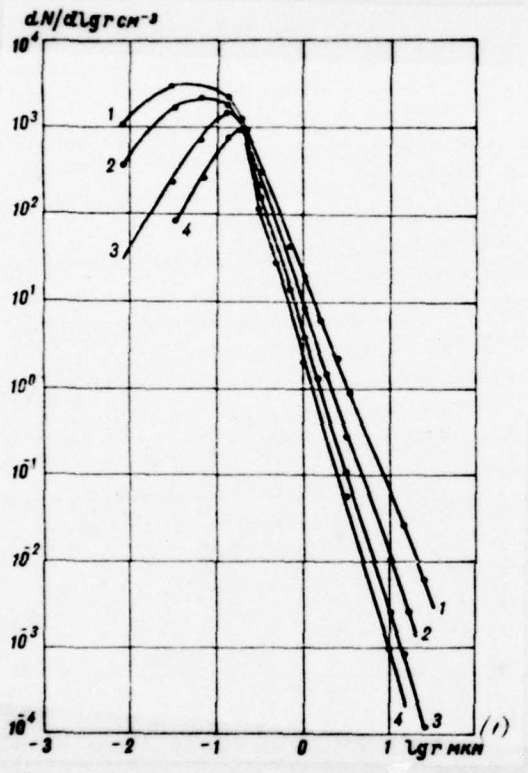
dN/dlgr см⁻³
10⁴
10³
10²
10¹
10⁰
10⁻¹
10⁻²
10⁻³
10⁻⁴
1
2
3
4
-3
-2
-1
0
1
lgr мкм
(1)

Fig. 1.

Fig. 1. Full/total/complete spectra of the sizes of particles of natural aerosols according to observations in free-air conditions. 1) 250 m, 2) 500 m, 3) 1000 m, 4) 2000 m.

Key: (1). μm.

Page 96.

During the study of the curves of particle-size distribution logically arises the question concerning their approximation by one function or the other. In view of the considerable oscillation/vibrations of particle concentration virtually there is no relationship/ratios, which satisfactorily described the character of entire spectrum. At the same time its separate sections with sufficient accuracy can be represented analytically. Author [1] was found that for highly dispersed aerosols in a sufficiently large interval of size/dimensions (0.02-1 μm) let us use normal logarithmic law. The further analysis showed that virtually for an entire region highly-dispersed aerosols (from 0.003 to 1 μm) the average particle-size distribution with error, not exceeding 12o/o, can be approximated by the simpler gamma function of the form

$$f(r) = Are^{-\beta r}. \qquad (2)$$

The presented in Fig. 2 rectified diagrams of density of distribution according to the size/dimensions of aerosol particles testify to the feasibility of formula (2), just as the different slope/inclination of curves it confirms previously expressed thought about the considerable strain of the spectrum at heights, which one can see well in Fig. 1.

Parameter A it is easy to find from the condition of standardization. By standardizing (2) to unity, we will obtain $A = \beta^2$. In turn, the parameter β is bonded with arithmetic mean radius by relationship/ratio $\beta = 2/r_1$, that it is not difficult to show from the determination arithmetic mean radius:

$$r_1 = \frac{\int_0^\infty r f(r)\,dr}{\int_0^\infty f(r)\,dr} = \frac{A\int_0^\infty r^2 e^{-\beta r}\,dr}{A\int_0^\infty r e^{-\beta r}\,dr} = \frac{2}{\beta}. \qquad (3)$$

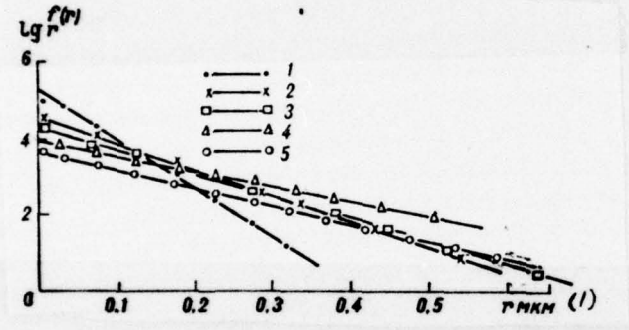

Fig. 2. Diagrams of the density of distribution of aerosol particles according to size/dimensions at different heights. 1) 250 m, 2) 500 m, 3) 750 m, 4) 1000 m, 5) 2000 m.

Key: (1). μm.

Page 97.

The integral distribution function for density (2) takes the form

$$F_b(r)=\int_0^r f(r)\,dr=A\left(\frac{1}{\beta^2}-\frac{1}{\beta^2}\,e^{-\beta r}-\frac{r}{\beta}e^{-\beta r}\right). \qquad (4)$$

According to the sizes of the aerosol particles, measured directly under microscope, on the average is described by the power law

$$\frac{dN}{d\lg r}=Cr^{-\varkappa}. \qquad (5)$$

Moreover exponent $\varkappa$ is sufficiently close to the value, proposed Young and equal to 3. However, during more careful analysis it is explained, which $\varkappa$ has different values for large and giant particles. Of the surface of earth in the average conclusion/derivations $\varkappa_1=3{,}6$ for particles with r < 1 μm, and for particles with r > 1 μm $\varkappa_2=2{,}0$. Values $\varkappa_1$ in separate sample/tests varied from 2.0 to 5.0, and $\varkappa_2$ — from 1.5 to 3.7. Characteristic fracture in distribution curves was observed in the region of size/dimensions from 0.5 to 1 μm.

The values of the parameter $\varkappa$ do not remain constants, also,

with height, which is evident in Fig. 1 and more visually in Table 1.

From table it follows that the spectrum of large particles with height virtually is not changed, i.e., taking into account errors of measurement the sizes of particles and their concentrations the parameter $x_1 \approx \text{const}$, although is planned certain tendency toward its increase. At the same time of change with the height of values x_2 are are more essential, what, obviously, is the consequence of subsidence of giant particles in gravitational field. In Fig. 1 this was reflected in a difference in the slope/inclination of distribution curve.

The knowledge of the full/total/complete spectrum of the sizes of particles of the natural aerosols makes it possible to evaluate the portion/fraction of particles, which can become active condensation nuclei under atmospheric conditions. In order that the particles with $r < 0.1$ μm would act as continucus condensation nuclei, they are required, as is known, the rarely being encountered under natural conditions considerable supersaturation.

Table 1. Values of the parameter x in the spectra of large and gigantic particles at heights.

(1) Высота, м	x_1	x_2	(2) Высота, м	x_1	x_2
0	3,6	2,0	500	3,9	2,9
100	3,7	2,5	1000	4,0	3,4
250	3,9	2,6	2000	4,0	3,6

Key: (1). Height, m.

Page 98.

Moreover these particles must consist of the substance, readily soluble in water. Consequently, in the overall mass of particle with $r < 0.1$ μm cannot be active condensation nuclei. Their content in the atmosphere although is great, is subjected to considerable changes, and that decrease in the concentration of aerosols, which usually is observed during the measurements in clouds by the counters of Aitken and Scholtz is explained, obviously, themes by the fact that these instruments catch the sufficiently considerable portion/fraction of particles, which have size/dimensions more than 0.1 μm.

On the other hand, with the appropriate supersaturation all particles with $r > 2$ μm, which possess the hydrophilic surface, act

as continuous condensation nuclei. However, the concentration of these particles in the atmosphere is extremely low. Even above the regions, subjected to intense natural becoming dusty, the such include, for example, Central Asia, the concentration of aerosols with $r > 2$ μm at heights 250-500 m it comprises less than 1 particle in 1 cm^3 of air, and at height 1000 m - about 0.1 cm^{-3}, while the calculating concentration of drops by different cloud forms usually exceeds 100 cm^{-3}.

Thus, for particles, which can play the role of active condensation nuclei under atmospheric conditions, remains the region of size/dimensions $0.1 < r < 2$ μm. These particles are most stable in the atmosphere and are observed in the concentrations, commensurable with the concentrations of cloud drops. Measurements in the atmosphere of Central Asia show that the common/general/total content of particles in this range of size/dimensions on the average comprises: at height 250 m of the order of 1500 particles in 1 cm^3 of air, at height 1000 m 900 and at height 2000 m it is more than 400. It is understandable that not all these particles under atmospheric conditions can become real condensation nuclei; for this it is necessary that they be partially or completely water-soluble. At the same time made by us chemical analyses [2] make it possible to conclude that the portion/fraction of solutes in them is sufficiently great and on the average in mass exceeds 20o/o. In essence these are

compounds NaCl, $MgCl_2$, $MgSO_4$, $CaSO_4$ and $(NH_4)_2SO_4$; in larger particles is encountered also $CaCO_3$. Let us note that in giant particles this compound predominates.

The supplementary proofs of the fact that active condensation nuclei in the atmosphere are the particles of the region of size/dimensions indicated, were obtained from the following considerations. In Central Asia high frequency they have such atmospheric phenomena as mist and haze. Haze is the totality of the suspended in the atmosphere solid aerosols with very low air humidity. Critical for mist are the smallest droplets of water. Since meteorological mist usually is observed with relative air humidity above 50, but is below 100o/o, in condensation processes must participate the particles, soluble or hygroscopic. The particles, which do not possess these properties, form the passive impurity/admixture, analogous by that, that is observed with haze.

Page 99.

Active condensation nuclei, absorbing water pairs from atmosphere, are increased in size/dimensions, after which by the Scholtz counter are not caught. Consequently, the general concentration of "free" particles in the atmosphere with haze must be higher than in mist. This indicate the results of the systematic measurements of aerosols

by the Scholtz counter realized in Central Asia in period with 1961 on 1965. The concentration difference in this case is the approximate estimation of the portion/fraction of the active condensation nuclei, which are present in the atmosphere. Evaluated thus on different heights the concentration of active condensation nuclei changed from 830 particles in 1 cm^3 at height 250 m to 115 at height 2000 m. In this case in the calculations were utilized only observations within morning periods in order to exclude the possibility of the nonuniform effect of convection.

Comparison with the spectrum of sizes of particles, measured by the Scholtz counter, it showed that the estimated values of the concentrations of active condensation nuclei amazingly will agree well with the independently obtained values of particle concentrations with $r > 0.2\,\mu m$. Here the upper limit of particle dimensions was $1.5\,\mu m$. As can be seen from Table 2, disagreement do not exceed 35%.

Thus, the range of the sizes of particles of the natural aerosols, which under the atmospheric conditions, close to saturation state, can become the stable nuclei of drops, is estimated at the range of radius from 0.2 to 1.5 μm. Under favorable conditions this range somewhat is expanded. However, on the basis of the overall spectrum of the sizes of particles of the deviation to one side or the other they cannot be considerable.

Table 2. Estimated concentrations of active condensation nuclei (cm^{-3}).

(1) Высота, м	(2) Разность, мгла — дымка	(3) Число частиц с $r > 0,2$ мкм	(4) Отклонения, %
250	830	1030	24
500	590	540	8
750	420	340	19
1000	170	230	35
1500	135	150	11
2000	115	105	9

Key: (1). Height, m. (2). Haze-smoke difference. (3). Number of particles with $r > 0.2\,\mu m$. (4). Deviations, %.

Page 100.

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SOME RESULTS OF STUDIES OF THE REACTION OF WATER AEROSOL WITH PARTICLES OF A SOLID REAGENT.

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The processes of the inertia and inertia-free capture of the drops of water aerosol by the collector/receptacles of various forms have vital importance in the theoretical examination of natural processes in clouds and fog.

Eden effects by different reagents on clouds and fog lean not only on condensation, but also on the coagulating mechanism of the reaction of water aerosol with the particles of hygroscopic and hydrophilic reagent.

We carried out the number of experiments in the reaction of water aerosol with obstructions - collectors of different geometric

form, namely:

1. Flat/plane obstructions (model of snow crystals) are disks, rectangular plates, film/strip, six-ray asterisks.

2. Fiberlike obstructions.

3. Grains of the grinding of bentonite.

As the basis of investigation was placed the determination of the coefficient of the capture of the obstructions, introduced into the flow of the coarsely dispersed water aerosol (diameter of drops 5-28 μm) of the assigned liquid-water content and velocity.

1. The precipitation of a water aerosol on flat/plane obstructions.

As the fixer of the drops, deposited to flat/plane particles, served the plotted on them layer of gelatin. The deposited during obstruction drops leave the replicas, size/dimension and number of which they were determined under microscope. The coefficient of capture is calculated as ratio of the mass of the deposited during obstruction aerosol to the mass of the aerosol, which leaks in with

flow.

The developed by us procedure of study makes it possible to present the flow of polydisperse aerosol as totality of monodisperse flows with the completely determined liquid-water content. Procedure makes it possible to experimentally define the coefficients of the capture both entire obstruction as a whole and any local point during obstruction, the so-called local coefficient of capture [1].

It should be noted that the measurements were conducted in the region between the viscous and potential flow (Re = 50-300), which was caused by the solution of the problems of applied character.

Page 309.

In the region of flows indicated the coefficient of the capture of the obstructions of flat/plane forms theoretically cannot be calculated in view of the absence of data on velocity field.

As a result of investigations [2] are obtained the local and full/total/complete coefficients of capture for disks (with Reynolds number 50-300), for a film/strip and a plate (Re = 120) and for a six-ray asterisk (Re = 220).

Were establish/installed the dependences of the local coefficients of capture on relative coordinates (R_L/R) for all forms of flat/plane barrier with Stokes' numbers, equal to 0.08-1.3.

Figure 1 shows characteristic curves $\alpha_L = f(R_L/R)$ for disks with Reynolds number Stokes' 50-300 and some numbers. It should be noted that with Stokes' numbers $K \leqslant 0.255$ the coefficient of capture sharply grow/rises to the edge of obstruction. With $K > 0.260$, the difference in α_L in center and at the edge of collector/receptacle decreases. And finally, with certain K, named us K_0, the coefficient cf capture turns out to be constant during all cbstruction.

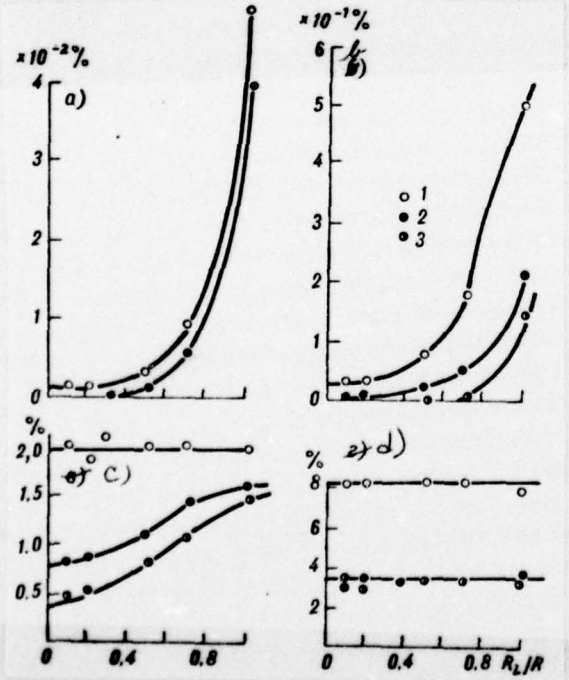

Fig. 1.

Fig. 1. Change in the local coefficient of capture along disk with Stokes' numbers: 0.130 (a); 0.200 (b); 0.400 (c); 0.600 (d). 1) Re = 280, 2) Re = 220, 3) Re = 73.

Page 310.

The analogous character of the dependence of the local coefficients of capture on the coordinates of local point was obtained for all by us flat/plane obstructions being investigated.

It is establish/installed that the value of the maximum number K_0 depends on Re, streamlined obstruction and its form. Figure 2 depicts dependence $K_0 = f(Re)$. With an increase ReK_0 it decreases.

For the various forms of collector/receptacle K_0 it has the following values:

(1) Форма	K_0	
	Re = 120	Re = 280
Звездочка (2)	—	0,320
Диск (3)	0,500	0,420
Пластина (4)	0,550	—
Лента (5)	0,630	—

Key: (1). Form. (2). Asterisk. (3). Disk. (4). Plate. (5). Film/strip.

The coefficient of the capture of disks, which corresponds to Stokes' maximum number K_0, is 2.0-3.5o/o, star-shaped disks - 20o/o.

Thus, obtained by us data about the local coefficients of the capture of disks, plates, film/strip and asterisks in the intermediate region of flow showed that the precipitation of water aerosol for flat/plane obstructions can be divided into two types:

I type of precipitation - the local coefficient of capture depends on the coordinates of local point and depends substantially on form (Fig. 3a);

II type of precipitation is a local coefficient of capture for Stokes' numbers, the equal or large K_o, is constant during all obstruction and the dependence on form is unessential (Fig. 3b).

The constancy of the coefficient of capture by obstructions we consider as proof of the fact that the distortion of flow as a result of the flow about the obstructions does not change the concentration of the flying with particle flux of the water aerosol. In this sense Stokes' maximum number in the intermediate number domain of Reynolds we identify with Stokes' critical number for a potential flow (obtained by the theoretical calculations).

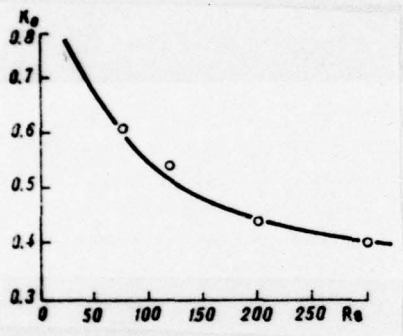

Fig. 2. Dependence K_0 local on Reynolds number (disk).

Page 311.

The dependence of the coefficient of capture on the coordinates of local point for the first type of precipitation, possibly, indicates an increase in the concentration of smaller particles of the edge of the streamlined obstruction during the distortion of flow, and also to the fact that we here observe the noninertia precipitation of particles.

Experimentally we establish/installed the dependences of the full/total/complete coefficients of capture on the number of Stokes and Reynolds number. It is establish/installed that the full/total/complete coefficient of capture increases with an increase of the number of Stokes and Reynolds number, it depends on form (Fig. 4). Disk has a coefficient of capture larger than plate and film/strip.

The analogous character of curves is obtained for the full/total/complete coefficients of capture by obstructions in the form of asterisks.

The studies of the precipitation of water aerosol for flat/plane collector/receptacles in the intermediate region of flow showed that for all studied forms occurs the precipitation of drops with the number of Stokes, considerably smaller than the critical number even for a potential flow.

It was establish/installed that the capture of collector/receptacle-asterisks considerably exceeds the capture of the flat/plane obstructions of other forms.

Figure 5 shows the capture of asterisks and disks with $S_д=S_э$ and $R_д=R_э$ other conditions being equal.

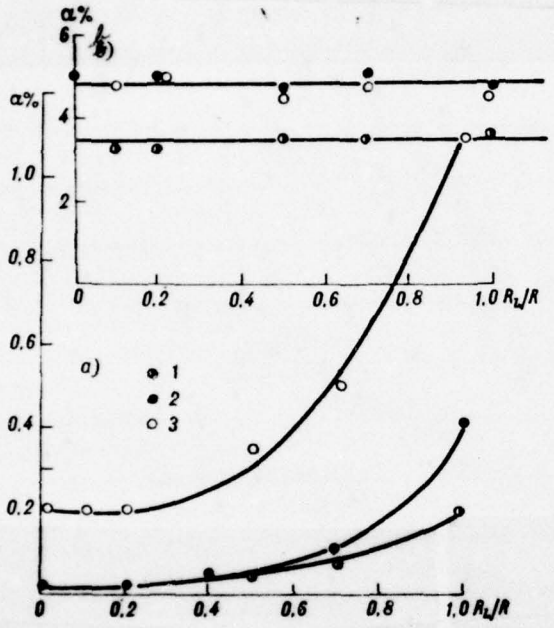

Fig. 3. Characteristic curved changes in the local coefficients of capture along the obstructions of various forms. a) I type of precipitation, b) II type of precipitation; 1 - for a film/strip, 2 - plate, 3 - disk.

Page 312.

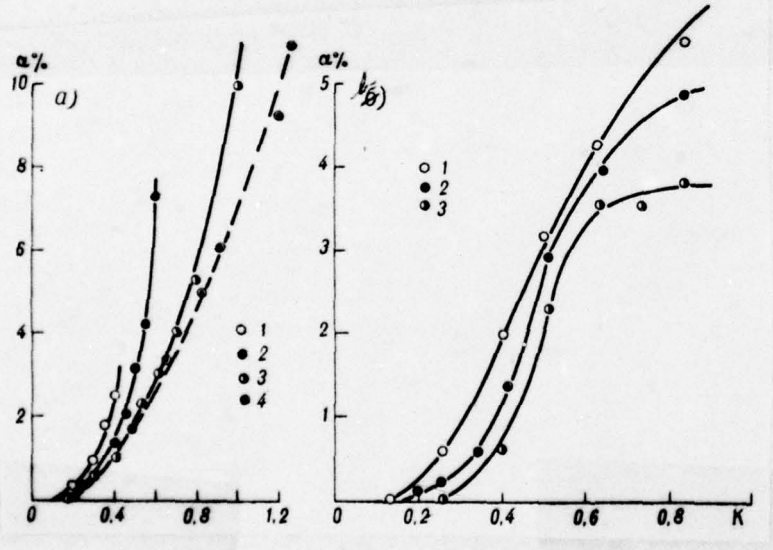

Fig. 4. Dependence of the full/total/complete coefficients of capture on the number of Stokes and form of collector/receptacle. a) dependence $\alpha = f(K)$ for disks with Reynolds number: 1) 280, 2) 220, 3) 120, 4) 73; b) dependence $\alpha = f(K)$ with Re = 120 for disk (1), plates (2) and film/strips (3).

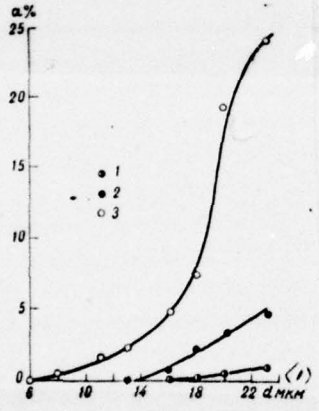

Fig. 5. Capture of asterisks and disks. 1 - for a disk with $R_д$-$R_з$; 2 - for the disk of identical area, $S_д$-$S_з$; 3 - for an asterisk.

Key: (1). μm.

Page 313.

Under our conditions star-shaped obstructions assure the capture of the smallest drops, namely: asterisk is drops 8 μm (diameter),

disk from $R_д = R_э$ — drop 16 μm, disk from $S_д = S_э$ — drop 12 μm.

One of the essential efficiency factors is a small mass of collector/receptacle relative to the mass of the assembled on it liquid. Consequently, interesting is the investigation of the collector/receptacles of various forms, which possess large specific surface area.

One of the sets of experiments is related to research on the reaction of fine/thin disk-shaped films with the flow of water aerosol. Films by radius $0.25 \cdot 10^{-2}$, $0.37 \cdot 10^{-2}$, $0.50 \cdot 10^{-2}$, $0.65 \cdot 10^{-2}$ m with thickness from 1 to 30 μm more were prepared from Black Sea agaroid and possessed hydrophilic behavior and hygroscopicity. They were suspended on three fine/thin caprone filaments in the vertical current of water aerosol and were maintained by flow in suspended state so that filaments would not be stretched. With an increase in the mass of film was increased the speed of the maintained flow, in value of which it was possible to judge the mass of film with moisture.

In the initial stage of an increase in the films occurs the bloating their, and then accumulation of the being precipitated out water on surface.

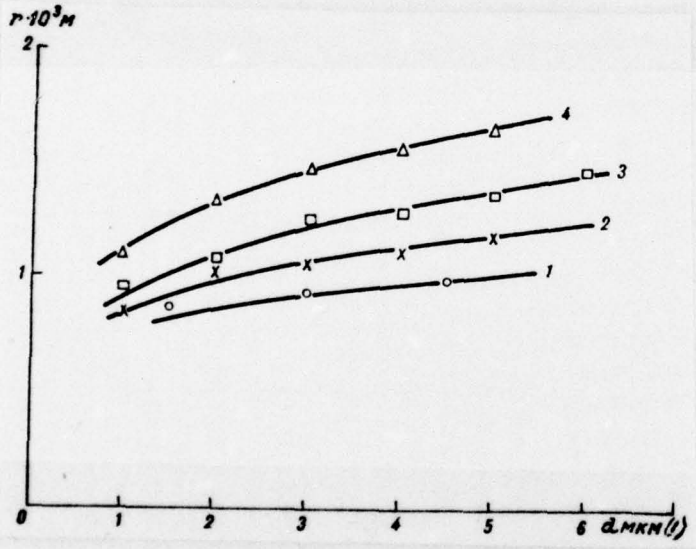

Fig. 6. Dependence of the size/dimensions of the drops, obtained on the being displaced films, on the thickness of films for their following size/dimensions: $0.25 \cdot 10^{-2}$ m (1); $0.37 \cdot 10^{-2}$ m (2); $0.50 \cdot 10^{-2}$ m (3); $0.65 \cdot 10^{-2}$ m (4).

Key: (1). Mm.

Page 314.

With thickness more than 25 μm of film they are not strained and are not displaced, but if the thickness of films less than 9 μm, is observed the turning of films and the formation of drops. In the intermediate region of thicknesses is observed the incomplete turning of films.

Upon reaching of certain mass of the untwisted films occurs the dropping of drops from them, after which the process of the precipitation of water aerosol to films begins first. The dependence of the size/dimensions of the expendable drops on the size/dimensions of films the is following:

(1)				
Радиус пленки	$0{,}65 \cdot 10^{-2}$	$0{,}50 \cdot 10^{-2}$	$0{,}37 \cdot 10^{-2}$	$0{,}25 \cdot 10^{-2}$
Радиус капли (2). . . .	$0{,}33 \cdot 10^{-2}$	$0{,}35 \cdot 10^{-2}$	$0{,}33 \cdot 10^{-2}$	$0{,}27 \cdot 10^{-2}$

Key: (1). Radius of film. (2). Radius of drop.

It is evident that for the different radii of the films, which exceed $0.37 \cdot 10^{-2}$ m, the expendable drops in the range of experimental

error are identical and only for the smallest size/dimension of film the expendable drops considerably less. Hygroscopic addition the film plays the role only in the initial stage of an increase in the untwisted films, subsequently occurs the washout of salt from the surface of film.

The dependence of the size/dimensions of the drops, which are obtained on the being displaced films, on the thickness of films is given in Fig. 6. From the figure one can see that with an increase in the geometric dimensions of films is increased the size/dimension of the generating on them drops. With the turning of the films, which have hygroscopic salts, are formed the drops whose increase in future occurs according to the laws of an increase in the hygroscopic drops.

In such a manner both the being displaced and untwisted polymer films they can be used for formation in the natural aerosol of large drops. Moreover during the utilization of the being displaced films the number of drops is equal to the number of films. The untwisted films in the presence of the corresponding upflows can repeatedly form large drops.

2. Precipitation of aerosol on fine/thin filaments.

As is known from the literature, the greatest coefficient of capture have the obstructions, significant dimension of which is less than the diameter of the leaking-in drops. So, for cylinders it is known that the coefficient of capture $\alpha = 1 + r/R$, where r is a radius of drops, R - the radius of cylinder [3].

Since with precipitation and merging/coalescence of drops on cylinders (filaments) appears the constantly changing in time configuration from the drops of different value, in consequence of which is changed the aerodynamic field of the flow about the system, it is of interest to study the laws governing the precipitation of water aerosol for fine/thin filaments [4, 5]. FP As a result of the fact that the filaments with incidence/drop through aerosol cloud can accept different orientations, necessary to study the laws governing precipitation, merging/coalescence and runoff of drops from filaments in different positions, in particular with their horizontal and vertical arrangement.

Page 315.

Since to merging/coalescence and runoff of drops from filaments can have an effect the chemical nature of their surface, for

investigation were taken filaments with hydrophobic and hydrophilic surfaces.

Investigations were conducted by flow method. Filament on special holder was inserted into the flow of aerosol with the following parameters: the speed of flow 0.5 m/s, liquid-water content 1.5 g/m^3, the diameter of the leaking-in drops of virtually monodisperse aerosol 8 μm. Conducted microcinematography of the process of precipitation with a velocity of 16, 24, 48 frame/ss. For investigation were applied the filaments from Plexiglas 1, 3 and thickness 6 μm. As hydrophobic filaments were applied the filaments without surface treatment, since the Plexiglas is the badly/poorly hydrophilic material. As hydrophilic were applied the same filaments, but with surface treatment OP-7.

The capture efficiency of filaments was calculated from the formula

$$\alpha = \frac{\Delta m_3}{\Delta m_p},$$

where Δm_3 — the mass of the water, precipitated for the filament for time Δt, determined on the basis of the experimental data; Δm_p — the mass of water, leaking in after Δt to the mid-section of system

filament - drop.

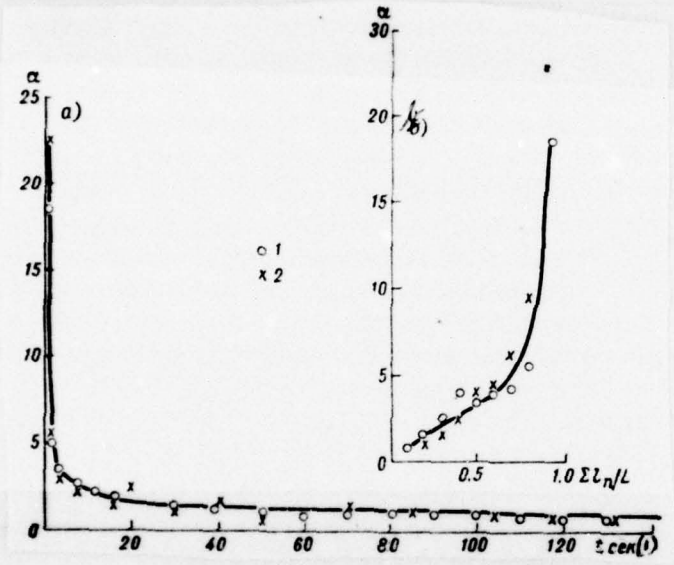

Fig. 7. Dependence of the capture efficiency of filament on time (thickness of filament 1 μm) (a) and of the relative length of the free from drops sections of filament (b). L is length of filament in sequence, Σl_n – the total length of the free from drops sections of filament, 1 - pure/clean filament, 2 - filament with surface covering.

Key: (1) S.

Page 316.

The investigations showed following.

1. The capture efficiency of filament has the greatest value at the first torque/moment of the process of precipitation, then its value decreases in the course of time (Fig. 7a). So for a filament 1 μm thickness α = 22.0; for 3 μm α = 8.5, for 6 μm α = 5.5.

2. The capture efficiency depends on the thickness of filament in the initial stage of the process of precipitation, and then it is determined by the degree of the filling of filament with drops it falls with the decrease of the free length of filament (Fig. 7b).

3. During the precipitation of drops for hydrophobic filament they virtually do not change their form, during precipitation for the hydrophilic (hydrophilic) filament of drop they acquire spindle-shaped form and their merging/coalescence during filament it is facilitated, to what contributes, apparently, formation between

the drops of water cross connection.

4. The chemical nature of the surface of filament (hydrophobic, hydrophilic) in effect does not affect the capture efficiency of horizontal filaments.

5. During the precipitation of drops from flow for vertical hydrophilic filaments is observed the intense motion of drops under the action/effect of the force, their merging/ccalescence and runoff from filament, which contributes to the cleansing of filament from drops and to an increase of the capture efficiency on the average 2 times.

6. The diameter of the drops of those flowing from vertical hydrophobic filaments, is 100 μm and more, whereas the diameter of the drops, which flow from vertical hydrophilic filaments, on the order of 70-80 μm.

3. Reaction of water aerosol with the grains of the grinding of bentonite.

For research on the reaction of water aerosol with the

hydrophilic and hygroscopic substance, which consists of particles of the incorrect geometric form, was used the grinding of bentonite of Ukrainian deposits.

Of 11 specimen/samples of bentonite of Gorbskoye, Kurtsovskoye, Dashukovskoye and Pyzhevskoye deposits were selected the specimen/samples, the most active in relation adsorption of water vapors made of air-steam mixture and possessing the maximum electric particle charge.

Adsorption of water vapors on bentonite was conducted under dynamic conditions from air flow. Was determined the curve of kinetics and the value of maximum adsorption.

The particle distribution of the bentonitic powders according to charges was studied by the method of the deviation of the trajectory of the freely falling/incident monodisperse particles in uniform electric field. All powders were characterized by the asymmetric distribution function with the preponderance of the negatively charged particles.

Were investigated natural bentonite and the specimen/samples, which subjected to heat and chemical (acid, alkaline, salt) treatment.

Page 317.

It was explained that the optimum adsorptive properties and the maximum portion/fraction of charged particles with the charges of both signs possesses kurtsovskiy bentonite, thoroughly heated at a temperature of 200°C.

The reaction of the bentonitic powder, which has the maximum of the particle-size distribution function 10-15 μm in diameter, with condensation fog was studied in the chamber of fog of GGO [ГГО - Main Geophysical Observatory] with respect to a change in the optical transmission of fog, which was record/written on recorder tape EPP-09. The powder of bentonite (60 g) was sputtered with the aid of the pulverizing device in the upper part of the chamber during 10 minutes. To two working experiments was conducted one control. For a comparison with bentonite in the chamber test/underwent the powders of cement and hydrophobic calcium stearate. The estimation of the kinetics of scattering fog under the influence by reagents was reveal/detected by the statistical interpretation of the large number of experiments. Each working experiment was compared with adjacent control.

The seeding of reagent began in all experiments upon reaching by the formed fog of the certain degree of transparency, through 5-7 minutes after fog formation. Time of observation for the scattering curve of fog was 35-40 minutes.

Typical scattering curve of fog during continuous trace for the working and control of experiments, transferred to one curve/graph, take the form, shown in Fig. 8a.

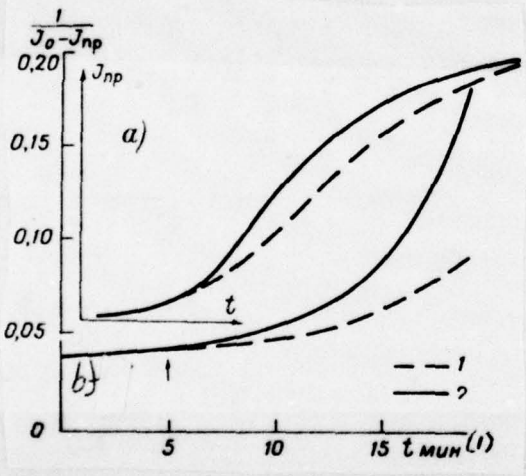

Fig. 8. Typical scattering curve of fog. a) change in time of the transparency of fog at its scattering, b) a change in value $\frac{1}{J_0 - J_{np}}$ in time during scattering fog; 1 - control experiment, 2 - working experiment. Arrow/pointer showed the beginning of the introduction of reagent.

Key: (1). min.

Page 318.

The estimation of reaction conducted on the processed curve, expressing the dependence

$$\frac{1}{J_0 - J_{\text{пр}}} = f(t),$$

where J_0 is intensity of luminous flux without fog, $J_{\text{пр}}$ — the intensity of the luminous flux, passed through fog. During this processing/treatment of the scattering curves of fog the effect of reagent appeared more clearly (Fig. 8b).

The experiments showed that the effectiveness of kurtsovskiy bentonite render/showed 2 times more than the effectiveness of cement. The hydrophobic calcium stearate, atomized under different conditions, effect did not give.

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Page 470.

INTEGRAL EQUATION OF THE KINETIC THEORY OF THE COAGULATION OF CLOUD PARTICLES.

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Investigations in the theory of transfer of cloud particles to a considerable degree are bonded with the development of the methods of the solution to kinetic equations. In this respect, very promising is the writing of the kinetic equation of coagulation in the form of integral equation. In particular this is exhibited during the solution to the boundary-value problems of the kinetics of coagulation. This integral equation, including boundary conditions, in very compact form contains entire physics of the process of the transfer of cloud particles and can render/show more convenient than integrodiff equation. Let us note that the integral kinetic equations successfully are utilized in the theory of transfer of neutrons [1], in the aerodynamics of rarefied gases [2, 3].

The transport problem of cloud particles - this the problem of many particles and during the investigation of the formation of the spectrum of cloud particles in space and in time must be considered their absolute motions, mutual collisions and merging/coalescences. Simultaneously with this the value of the distribution function of cloud particles in point with radius-vector r (x, y, z) they must be bonded not only with the values of distribution function in the points, close toward the end of vector r, but also with values in all points of cloud, including interfaces.

Let n (v, r, t) be the distribution function of cloud particles according to volumes v at the moment of time t about point in space with radius-vector r, so that value

$$dn = n(v, r, t)\,d\Omega\,dv \qquad (1)$$

is for the moment of time t the mathematical expectation of the number of clcud particles, which have radius-vector in the range r, r + dr and volume in the range v, v + dv; $d\Omega$ = dxdydz - the elementary three-dimensional/space volume, which adjoins toward the end of radius-vector r.

Distribution function n (v, r, t) in question makes sense of the density of the mathematical expectation of the number of cloud particles; however, together with this it simultaneously makes sense

of the density of distribution of the probability of the detection of one particle in the four-dimensional volume $dvd\Omega$.

Let us isolate in cloud the small volume element $d\Omega$ and let us determine in this volume about point with radius-vector r for the arbitrary moment of time t, the number of cloud particles with volume in the range v, v + dv, i.e., let us determine $dn = n(v, r, t)\, d\Omega dv$.

Page 471.

It is obvious, this number will be determined by the intensity of the emergence (generation) of cloud particles by the volume in the range v, v + dv in all cloud (including interfaces) at the different moments of time, which precede the moment of time t in question, and also by the probability of the admission of the emergent cloud particles into the volume $d\Omega$ in question without collision with other cloud particles.

Let $\Pi(v, r, t, \tau)$ be a probability of free motion in the time interval (τ, t) of this cloud particle, which at the moment of time τ is located in point with radius-vector $r - (t - \tau)c$ and at the moment of time t proves to be at the point of space with radius-vector r. Here c - velocity of the motion of the cloud particle, which has volume v, which depends on v, and also on the

velocity of the motion of air masses in cloud. The generalization of the physical derivation of the system of the integral equations of the kinetics of the coagulation of cloud particles in the case of the accelerated motion of cloud particles presents no difficulties [4]. Special examination requires the case of the mction of cloud particles in the turbulent flow of air masses.

Let us examine certain cloud particle at certain moment of time t. Let it is locate in point with radius-vector r and has volume v and velocity c. It is possible to assert that at certain moment of time $\tau < t$ it experienced the last/latter collision and that it as the cloud particle, possessing volume v and velccity c, was born in point with radius-vector $r - (t - \tau) c$ at the mcment of time τ.

Further, let Φ (v, r, t) be a function of generations, so that value

$$dn_1 = \Phi(v, r, t)\, d\Omega\, dv\, dt \qquad (2)$$

gives the mathematical expectation of the number of cloud particles, which were being born in the volume element of space $d\Omega$ about point with radius-vector r for a period of time dt and which have volume in the range v, v + dv.

Is expressed function n (v, r, t) through the function of

generations and the probability of free motion. At the moment of time $t > t_0$ (t_0 - the initial moment) the mathematical expectation of the number of cloud particles with a volume of v, v + dv in the volume element of space $d\Omega$ is composed of two parts.

$$n(v, \mathbf{r}, t)\,dv\,d\Omega = dn_0 + dn_2, \qquad (3)$$

where dn_0 is a mathematical expectation of the number of cloud particles with volume in the range v, v + dv, which reached in $d\Omega$ from the initial state without collisions; dn_2 is a mathematical expectation of the number of cloud particles with a volume of v, v + dv, which appear in cloud in time interval from t_0 to t at the different moments of time τ at the different points of space with radius-vector r - (t - τ) c and which without collisions reach $d\Omega$ up to the moment of time t.

It is obvious that

$$dn_0 = n\,|v, \mathbf{r} - (t - t_0)\mathbf{c}, t_0|\,\Pi(\mathbf{r}, v, t, t_0)\,dv\,d\Omega. \qquad (4)$$

Page 472.

Then, according to determination (2), value

$$\Phi\,[v, \mathbf{r} - (t - \tau)\mathbf{c}, \tau]\,d\Omega\,dv\,d\tau \qquad (5)$$

will be equal to the mathematical expectation of the number of cloud

particles, which are born within volume dΩ about point with radius-vector r - (t - τ) c for a pericd of time dτ and have a volume in the range v, v + dv. From this quantity of cloud particles to element of volume dΩ about point with radius-vector r will reach only the those, that for duration (τ, t) do not experience collisions. Therefore, if we expression (5) multiply by the probability of free motion Π (r, v, τ, t) and integrate alcng alternating/variable τ from t_0 to t we will obtain the total quantity of cloud particles with a volume of v, v + dv, which appear in cloud in time interval (t_0, t) and the moment of time t enter element of volume dΩ about point with radius-vector r. Thus,

$$dn_2 = d\Omega\, dv \int_{t_0}^{t} \Phi\,|v,\ \mathbf{r} - (t-\tau)\mathbf{c},\ \tau|\cdot \Pi(\mathbf{r},\ v,\ \tau,\ t)\,d\tau. \qquad (6)$$

Special examination requires the case, when occurs the emergence of cloud particles on interface, for example at the level of condensation. For those regions of the clouds, into which can enter cloud particles, which arose on interface in time interval (t_0, t), in relationship/ratio (3) one should write the additive term, which considers a quantity of cloud particles with volume in the range v, v + dv, which appear on interface at the appropriate moment of time and which without collision reach dΩ about point with radius-vector r up

to the moment of time t. In this case, it goes without saying, the boundary function of generations is assumed to be known.

Substituting (4) and (6) in (3), we obtain

$$n(v, \mathbf{r}, t) = n|v, \mathbf{r} - (t - t_0)\mathbf{c}, t_0|\,\Pi(\mathbf{r}, v, t, t_0) + \\ + \int_{t_0}^{t} \Phi|v, \mathbf{r} - (t - \tau)\mathbf{c}, \tau|\,\Pi(\mathbf{r}, v, \tau, t)\,d\tau. \qquad (7)$$

For obtaining the closed system of integral equations it is necessary to express the probability of free motion and the function of the generations by distribution function.

Let ΔQ_i — the probability of the random event, consisting in the fact that during time interval $\Delta\tau_i$ the cloud particle in question adjacent cloud particle. Then we have

$$\Delta Q_i = \Delta\tau_i \int_0^{\infty} n|u, \mathbf{r} + \tau_i\mathbf{c}, t + \tau_i|\,\sigma(v, u)\,du,$$

where

$$\sigma(v, u) = \pi E \left(\frac{3}{4\pi}\right)^{2/3} (v^{1/3} + u^{1/3})^2 \, |\mathbf{c}(v) - \mathbf{c}(u)|$$

- the effective volume of the collisions of the cloud particles, which have volumes v and u; E is a coefficient of capture.

Page 473.

With small $\Delta\tau_i$ the probability of free motion for the cloud particle in question during time interval $\Delta\tau_i$ will be equal to

$$P_i = 1 - \Delta Q_i = e^{-\Delta Q_i}.$$

Then the probability of the free motion of the cloud particle in question for a period of time $T = \sum_{i=1}^{n} \Delta\tau_i$ will be

$$P=\prod_{i=1}^{n} P_i=\exp\left\{-\sum_{i=1}^{n}\Delta Q_i\right\}=\exp\left\{-\sum_{i=1}^{n}\left[\int_0^{\infty} n(u,\ \mathbf{r}+\tau_i\mathbf{c},\ t+\right.\right.$$
$$\left.\left.+\tau_i)\sigma(v,\ u)\,du\right]\Delta\tau_i\right\}.$$

Hence, replacing addition by integration, we obtain

$$\Pi(v,\ \mathbf{r},\ \tau,\ t)=\exp\left\{-\int_{\tau}^{t}\left[\int_0^{\infty}\sigma(v,\ u)n(u,\ \mathbf{r}-(t-q)\mathbf{c},\ q)\,du\right]dq\right\}. \tag{8}$$

The last/latter relationship/ratio gives communication/connection between the probability of free motion and the distribution function of cloud particles.

To the generation of cloud particles with a volume of v in the volume of space dΩ for time dt are brought the collisions of cloud particles with volumes of v-u, u, with this u it can take values from 0 to v. Therefore the collision frequency, summed up in terms of all possible values of u, gives interesting us the mathematical expectation of the number of generations of cloud particles with a

volume of v, thus

$$\Phi(v, \mathrm{r}, t) = \frac{1}{2}\int_0^v n(v-u, \mathrm{r}, t)\, n(u, \mathrm{r}, t)\, \sigma(v-u, u)\, du. \quad (9)$$

Expression σ (v, u) reflects mechanics and the statistics of the reaction between the pair of cloud particles.

Equations (7), (8), (9) are the system of the integral equations, which characterize the kinetics of the coagulation of cloud particles. The structure of these equations is such, that easily it is possible to produce the exception/elimination of functions Π, of Φ and to obtain one integral equation for the distribution function of cloud particles.

Page 474.

Substituting (8), (9) in (7), we have

$$n(v,\ \mathbf{r},\ t)=n\,[v,\ \mathbf{r}-(t-t_0)\mathbf{c},\ t_0]\exp\left\{-\int_{t_0}^{t}\left[\int_0^{\infty}\sigma(v,\ u)n(u,\ \mathbf{r}-\right.\right.$$

$$\left.-(t-q)\mathbf{c},\ q)\,du\right]dq\Bigg\}+\int_{t_0}^{t}\exp\left\{-\int_{\tau}^{t}\left[\int_0^{\infty}\sigma(v,\ u)n(u,\ \mathbf{r}-\right.\right.$$

$$\left.-(t-q)\mathbf{c},\ q)\,du\right]dq\Bigg\}\left[\frac{1}{2}\int_0^{v}n(v-u,\ \mathbf{r}-(t-\tau)\mathbf{c},\ \tau)\,n(u,\ \mathbf{r}-\right.$$

$$\left.-(t-\tau)\mathbf{c},\ \tau)\sigma(v-u,\ u)\,du\right]d\tau. \qquad (10)$$

Let us use the operation

$$\frac{d}{dt}=\frac{\partial}{\partial t}+(\mathbf{c}\cdot\underline{\Delta})$$

to both parts of equation (7); taking into account the relationship/ratios:

$$\frac{d}{dt}\{n\,[v,\ \mathbf{r}-(t-t_0\,\mathbf{c},\ t_0]\}=0,$$

$$\Pi(\mathbf{r},\ v,\ t)=\Delta,$$

$$\frac{d\Pi}{dt}=-\Pi\int_0^{\infty}\sigma(v,\ u)n(u,\ \mathbf{r},\ t)\,du,$$

we obtain

$$\frac{dn}{dt} = \Phi(v, \mathbf{r}, t) - \int_0^\infty \sigma(v, u) n(u, \mathbf{r}, t)\, du \left\{ \int_{t_0}^{t} \Phi[v, \mathbf{r} - (t-\tau)\mathbf{c}, \tau] \times \right.$$

$$\left. \times \Pi(\mathbf{r}, v, \tau, t)\, d\tau + n[v, \mathbf{r} - (t-t_0)\mathbf{c}, t_0]\, \Pi(\mathbf{r}, v, t, t_0) \right\}.$$

If, according to (7), expression in curly braces in the last/latter relationship/ratio is replaced through n (v, r, t), and function Φ (v, r, t) - with expression (9), then we will obtain the known integrodiff equation of the kinetic theory of the coagulation of the cloud particles

$$\frac{dn}{dt} = -n(v, \mathbf{r}, t)\int_0^\infty \sigma(v, u)n(u, \mathbf{r}, t)du +$$

$$+\frac{1}{2}\int_0^v \sigma(v-u, u)n(v-u, \mathbf{r}, t)n(u, \mathbf{r}, t)du.$$

As the numerical methods of the approximate solution of the system of integral equations (7), (8), (9) it is possible to utilize a method successive approximation, an iterative method, and also a method of torque/moments [5, 6].

Page 475.

Accepting as zero approximation either the initial distribution or any analytical solution of the simplified problem of the kinetics of the coagulation of cloud particles, we compute the function of generation Φ_0 and the probability of free motion Π_0. Substituting Φ_0 and Π_0 in equation (7), we obtain the first approximation of distribution function n_1. Further we compute Φ_1, Π_1, n_2. The following approximations are constructed analogously.

In conclusion let us note that the proposed above form of the notation of the physical derivation of the system of the integral

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equations of the kinetics of the coagulation of cloud particles can be successfully used also in the examination of the kinetics of the coagulation of dispersed particles and, in particular aerosol particles.

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