FOREIGN TECHNOLOGY DIVISION

STRUCTURE OF TEMPERATURE FIELD IN TURBULENT FLOW

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STRUCTURE OF TEMPERATURE FIELD IN TURBULENT FLOW

A. M. Obukhov

(Presented by Academician A. N. Kolmogorov)

The mean square of the temperature difference at two points of flow is used as the characteristic of the temperature field structure. The relationship between this quantity and the distance between observation points is determined theoretically. The order of magnitude of the characteristics of the temperature pulsation field in the atmosphere is evaluated.

The microstructure of the temperature field in the atmosphere is a question of considerable interest in meteorology. Small thermal discontinuities lead to turbulent heat transfer and twinkling of stars; they also have a substantial effect upon the propagation of sound and a number of other phenomena in the atmosphere.

Comparatively rough measurements of temperature pulsations in the lowest layer of the atmosphere [1] show that the temperature field in the actual atmosphere is quite "variegated" and apparently has as complex a structure as the wind velocity field. This circumstance is directly connected with the turbulent state of the atmosphere.

In 1941 A. N. Kolmogorov [2] proposed the use of the mean square of the difference in velocities at two near points of flow, examined as a function of distance ℓ between the observation points, as the quantitative characteristic of the microstructure of the velocity field in turbulent flow. We shall call this function the structure function of the velocity field.

A completely analogous method can be used for the statistical description of the structure of the temperature pulsation field in the atmosphere after examining the mean square of the temperature difference at two points. The relationship between this quantity and the distance between observation points (structure function of the temperature field) characterizes the intensity of temperature pulsations for discontinuities of various scales, which makes it possible to speak of the "spectrum" of temperature discontinuities.

Although a number of theoretical and experimental works [2, 3, 4] have been dedicated to the problem of the local structure of the velocity field in turbulent flow, the structure of the temperature field in turbulent flow has not as yet been clearly established. Known data from observations on the temperature difference in the atmosphere do not allow us to evaluate even approximately the structural function of the temperature field since there are no proper measurements made with the aid of inertialless devices for sufficiently small distances between observation points.*

Now the first attempt has been made to examine theoretically the problem of the structure of the temperature field in turbulent flow. Based on the concepts in the theory of local isotropic turbulence, we manage to arrive at a number of conclusions relative to the structural function of the temperature field. Thus, for not very small distances between observation points, the mean square of the temperature difference, according to the theory developed below, is proportional to the distance to the power 2/3. We are assuming that the amplitudes of temperature pulsations are relatively small (as compared with the mean absolute temperature of the medium) and do not substantially affect the turbulent pulsation regime of flow velocity,

*From the methodological side, the question of measuring micropulsations of temperature is obviously even more complex than the measurement of instantaneous differences in wind velocity at two points of flow. We can hope, however, that these difficulties are surmountable so that, with time, we can have the necessary experimental data on the structural function of the temperature field in the atmosphere, i.e., data on the "spectrum" of temperature discontinuities.

brought about by external causes of a purely dynamic character. In other words, in this work we are considering it possible to disregard Archimedes forces arising in the medium (air) in a nonuniform temperature field and are treating the heat transferred by the flow as a "passive substance."* In accordance with the first assumption, it is further assumed that turbulent motion in the atmosphere can be taken as "incompressible" (based on the terminology of Freedman).

Luminous heat exchange in the medium is not taken into account in this work. However, the consideration of molecular heat conductivity in the medium (air) is essential for motions of very small scale.

The mechanism of equalizing temperature in sufficiently large volumes can be explained, obviously, only by the joint action of turbulent motion and heat conductivity in the medium; owing to irregular turbulent motion, particles of air having different temperatures can approach so closely that it becomes possible to equate temperature between them through molecular heat conductivity. In other words, the turbulent motion inside a nonuniformly heated medium with weak gradients at the beginning contributes to the "accentuation" of local temperature gradients which then are leveled off by the action of molecular heat conductivity.

In order to obtain any kind of quantitative conclusions from this overall physical picture, we must introduce a number of auxiliary assumptions, among which the basic one for the following discussion is the "measure of discontinuity" in the temperature field.

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*The problem of the effect of <u>systematic</u> discontinuities in a temperature field on the turbulent regime has been examined by us in a somewhat different aspect (by the method of semiempirical turbulence theory) in the work "turbulence in a medium with nonuniform temperature" [4].

§ 1. "Measure of Discontinuity" and "Free Energy" of Temperature Field

Let us examine the temperature field in a medium with a specific heat capacity c in a certain region V**.

Let T be the mean temperature of the field (averaged based on volume V):

$$\bar{T} = \frac{1}{M} \iiint\limits_V \rho T(x, y, z) dv, \tag{1}$$

where

$$dv = dx dy dz,$$

$$M = \iiint\limits_V \rho dv \quad \text{(mass of body).}$$

We shall introduce the special designation for temperature deviation from mean:

$$T'(x, y, z) = T(x, y, z) - \bar{T}. \tag{2}$$

As a measure of "temperature discontinuity" of the field in region V, it is natural to introduce quantity G which is the integral with respect to region V from half of the square of temperature deviation:

$$G = \frac{1}{2} \iiint\limits_V \rho (T')^2 dv. \tag{3}$$

It is obvious that G = 0 if and only if temperature is constant throughout the volume. The factor 1/2 is introduced in analogy with the expression for kinetic energy relative to motion in a fluid, which

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*In examining the temperature field in the atmosphere, heat capacity c should assume heat capacity of air c_p at constant pressure and, therefore, the total energy of the system should be replaced by the heat content.

is obtained if in the formulas described above temperature is replaced by the vector of flow velocity.

It is also expedient to introduce a special designation for the measure of discontinuity related to a unit of mass of the medium

$$g = \frac{G}{M} = \frac{1}{2M}\iiint\limits_V \rho\,(T')^2\,dv.$$

It should be noted that quantity G has a deep physical meaning, determining with an accuracy up to the factor maximum work W which can be obtained from a nonuniformly heated body, considering it as an isolated (in the heat sense) system. We can arbitrarily call this maximum work W the "free energy" of a nonuniformly heated body.*

The quantity W for a uniformly heated body is obviously equal to zero since, in this case, the body is in a state of thermodynamic equilibrium.

Let us actually calculate W for body V with a given temperature distribution T(x, y, z).

Obviously, in order to extract the maximum amount of work from a certain system, we must bring the system to a state of thermodynamic equilibrium with the aid of some reversible process. The difference in total energy of the system during such a transition from the prescribed initial state to the hypothetical final equilibrium state determines quantity W. Let us designate in terms of $\tilde{T}$ the temperature of the body in the final state. $\tilde{T}$ is obviously constant since it corresponds to the state of thermodynamic equilibrium. Thus, measuring the maximum work in thermal units, we have:

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*The term "free energy" of a nonuniformly heated body which we are using in this text should not be confused with the analogous concept in thermodynamics, which has a meaning only for isothermal processes. Since we shall nowhere use the classical expression for free energy, such terminology should not lead to a misunderstanding.

$$W = \iiint\limits_V c\rho T(x, y, z)\,dv - \iiint\limits_V c\rho \tilde{T}\,dv = cM(\bar{T} - \tilde{T}), \tag{4}$$

where $\bar{T}$ is the mean temperature of the body.

In order to determine $\tilde{T}$ we shall use the condition of process reversibility which brings the system from the initial to the final state. Total entropy of the system during such a process remains constant. When we write the equality of entropy of a heated body for the initial and the final states, we obtain an equation for determining $\tilde{T}$:

$$S = \iiint\limits_V c\rho \lg T(x, y, z)\,dv = \iiint\limits_V c\rho \lg \tilde{T}\,dv; \tag{5}$$

hence

$$\lg \tilde{T} = \frac{1}{M} \iiint\limits_V \rho \lg T(x, y, z)\,dv; \tag{6}$$

$\tilde{T}$ can be called the "mean geometrical" temperature of the body.

Thus, the "free energy" of a nonuniformly heated body is equal to the product of the heat capacity of the body times the difference between the "mean arithmetical" and "mean geometrical" values of body temperature. Substituting $\tilde{T}$, determined from (6), into (4), we obtain the final expression for W:

$$W = cM\bar{T}\left\{1 - \exp\left[\frac{1}{M}\iiint\limits_V \rho \lg \frac{T(x, y, z)}{\bar{T}}\right]\right\}. \tag{7}$$

Expression (7) can be considerably simplified, assuming that the temperature deviation T' is very small as compared with $\bar{T}$. In this case, since

$$\iiint\limits_V \rho T'(x, y, z)\,dv = 0,$$

we obtain a convenient approximate representation for W (principal term of expansion in (7), disregarding integrals from ratio $T'/\bar{T}$ to a power higher than second:

$$W \approx \frac{c}{\bar{T}} \iiint\limits_V \frac{1}{2} \rho (T')^2 dv = \frac{c}{\bar{T}} G. \qquad (8)$$

Thus, the approximate expression (8) for "free energy" W differs only in factor $c/\bar{T}$ from the measure of discontinuity G of the temperature field, introduced above.

Let us calculate, in this same approximation, the increase in entropy ΔS during full equalization of temperature owing to irreversible processes (heat conductivity) while full energy of the system is preserved. Such a process brings the body to constant temperature $\bar{T}$ so that the change in entropy is easily calculated:

$$\Delta S = cM \lg \bar{T} - c \iiint\limits_V \rho \lg T(x, y, z)\, dv = -c \iiint\limits_V \rho \lg \left[1 + \frac{T'(x, y, z)}{\bar{T}} \right] dv;$$

hence, disregarding terms of a higher order, we obtain a very simple expression for entropy increment:

$$\Delta S \approx \frac{c}{\bar{T}^2} G. \qquad (9)$$

From (8) and (9) it follows that in the examined approximation

$$W = \bar{T} \Delta S, \qquad (10)$$

as would be expected on the basis of the common concepts of thermodynamics.

Thus, on the basis of the expression obtained above (8) for W and (9) for ΔS the quantity G, introduced by us in a purely formal manner, can be treated with the same law as the measure of "free energy of the field" or as the measure of the lack of entropy of the temperature field ("negative entropy").

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*We can assume that in problems of dynamic meteorology when analyzing processsess occurring inside a nonuniformly heated air mass,

§ 2. Time Variation in Measure of Temperature Field Discontinuity

We shall examine the motion of an incompressible fluid with density ρ (for simplicity assumed to be constant) which has variable temperature $T(x, y, z, t)$. Let λ be heat conductivity and κ be temperature conductivity of the fluid. The boundaries of the volume will be assumed solid and heatproof. We shall calculate with these assumptions the variation in quantity G, determined above, for the entire volume.

Temperature in the moving medium satisfies, under the assumptions made, the following equation:

$$c\rho \frac{dT}{dt} = \lambda \Delta T.$$

or

$$\frac{\partial T}{\partial t} + \operatorname{div}(\vec{v}, \operatorname{grad} T) = \varkappa \Delta T. \tag{11}$$

Since, according to assumption

$$\operatorname{div} \vec{v} = 0,$$

upon substituting into equation (11)

$$T(x, y, z, t) = \bar{T} + T'(x, y, z, t)$$

we obtain a completely analogous equation for deviation in $T(x, y, z, t)$:

$$\frac{\partial T'}{\partial t} + \operatorname{div}(\vec{v}, \operatorname{grad} T') = \varkappa \Delta T'; \tag{11bis}$$

here κ is the coefficient of temperature conductivity.

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*(Continued from p. 7) in order to estimate the energy reserves, it is advisable to use quantity W which is the thermal energy reserve and which can theoretically be transformed into the energy of motion of air masses.

We shall multiply this expression by $\rho T'(x, y, z, t)$ and integrate with respect to region V. Applying the theorem of Gauss and observing that on the boundaries of the region

$$v_n = 0 \quad \text{and} \quad (\operatorname{grad} T)_n = 0,$$

we obtain:

$$\frac{dG}{dt} = -\varkappa \iiint\limits_V \rho (\operatorname{grad} T)^2 dv. \tag{12}$$

Using the measure of temperature discontinuity, relative to unit of mass $g = G/M$, equation (12) can be written in the form

$$\frac{dg}{dt} = -\varkappa \overline{(\operatorname{grad} T)^2}, \tag{12bis}$$

where averaging is accomplished with respect to volume V.

The equation obtained for its structure is fully analogous to the equation for energy dissipation. If we assume g is a formal analog of kinetic energy, the following expression will be an analog of the dissipative function of Stokes, relative to a unit of mass, for the temperature field:

$$N = \varkappa (\operatorname{grad} T)^2,$$

which determines the rate of temperature levelling. Let us remember that temperature conductivity κ and kinematic viscosity ν have identical dimensionality and for air have similar numerical values ($\nu = 0.14$, $\kappa = 0.19$ cm^2/s).

Equation (12) shows that in a hypothetical medium for which $\kappa = 0$ (there is no heat conductivity) inside closed volume V the measure of discontinuity G remains constant, whatever the motion inside the fluid (velocity field $\vec{v}(x, y, z, t)$. On the other hand, formula (12) also shows that in actual media with low heat conductivity (air, water) true levelling of temperature discontinuities (decrease in G) virtually occurs only if local gradients are sufficiently great.

Here we can draw a qualitative picture of what occurs with the temperature field during turbulent mixing in a medium which has very low heat conductivity. If the initial temperature distribution is sufficiently "smooth," then at a very low κ we can assume N is practically equal to zero not only at the initial moment but also during a certain period of mixing. As a daily test shows, irregular "turbulent" motion in a fluid affects the temperature field so that the temperature, averaged along a certain finite volume ω, has the tendency to level off (levelling "on the average"). If we break the initial volume V down into small cells (cubic form) of volume $\omega = V/k$, then during mixing the mean temperatures of the cells will have a tendency to approach constant $\overline{T}$. However, if the full measure of discontinuity G or, correspondingly, g is preserved, then inside each shell the field must be extremely nonuniform since, in this case, the mean amplitude of temperature fluctuations inside the small volume ω will approach the mean amplitude of temperature variations observed at the initial moment for the entire volume V. Owing to the fact that during an increase in mixing time the dimension of region ω, for which the above temperature levelling "on the average" will be observed, must decrease, true temperature gradients with such a process must increase, and, beginning at a certain moment, the mechanism of molecular heat conductivity must come into play. True levelling of temperature discontinuities, i.e., decrease in quantity G (entropy increase), will occur after this inside rather small elements of volume; there are less of them the lower the heat conductivity of the medium) owing to the action of molecular heat conductivity. It is easy to see that a quasistationary (statistically) regime must be established in a certain time interval inside the rather small cells, with which the increase in the measure of discontinuity inside volume ω, due to mixing, is compensated by the actual levelling off of the temperature field inside volume ω from the action of molecular heat conductivity.

Thus, the effect of turbulence leads to a redistribution of the measure of temperature discontinuity along the "spectrum" of temperature discontinuities. The concept of "spectrum" of the temperature field can be defined more accurately if we consider a

Fourier expansion in series (integral) of the temperature field and note then that quantity g will be computed in an additive manner from corresponding quantities relative to various spectral components. This method of the characteristics of the temperature field can be performed in the same manner as was done for the velocity field by A. M. Obukhov in 1941 [3] and somewhat later by Onzager [5] in solving the same problem.

In this work we shall not carry out the method of spectral expansion in detail as applied to the problem of the microstructure of the temperature field, but will attempt, on the basis of the above qualitative assumption, to go directly to the study of the structural function of the temperature field, using the assumptions from the theory of similitude and the analysis of dimensionalities. This method, to a considerable extent, is analogous to the method which was used by A. N. Kolmogorov [2] in his research on the microstructure of the velocity field in turbulent flow.

§ 3. Structural Function of the Temperature Field

In the introductory paragraph we spoke of the structural function of the temperature field. The structural function is the mean (in the statistical sense) value of the square of difference of the temperature values at two observation points M and M':

$$H(M,\ M')=\overline{[T(M')-T(M)]^2}. \tag{13}$$

We shall assume the temperature field to be locally isotropic. This means that function H(M, M') virtually depends only upon distance ℓ between points M and M' under the condition that M and M' are selected from a certain region V_0 and the distance between them is small as compared with the outer scale of turbulence ℓ_0. Scale ℓ_0, under these test conditions, is determined by the geometry of the flow; we can take as ℓ_0, for example, the mixing length according to Prandtl. This definition is fully analogous to the definition of a locally isotropic velocity field in a turbulent flow, which was given by Kolmogorov in 1941. The assumption of local isotropicity for the temperature field in a turbulent flow is, thus, completely natural.

Using this condition of local isotropicity, we can write

$$H(M, M') = H(l) \tag{14}$$

when $\ell < \ell_0$, where

$$l = \sqrt{(x' - x)^2 + (y' - y)^2 + (z' - z)^2}.$$

It is obvious that when $\ell = 0$, H is zero and also $H'(0) = 0$ from symmetry considerations.

The second product of the structural function in zero, as is easy to see, is directly expressed in terms of the mean value of the square of temperature gradient. We shall examine the coordinates of points M and M' as independent variables (x_1, x_2, x_3, x_1', x_2', x_3') and vary in sequence the right and left sides (13) with respect to points M and M':

$$((\nabla\nabla' H(M, M')\, \delta M \cdot \delta M')) = -2((\overline{\text{grad}\, T(M) \cdot \text{grad}\, T(M')}\, \delta M \cdot \delta M'));$$

Here the point designates the tensor product of the vectors, and the right and left sides are the biscalar products. Due to the arbitrariness of vectors δM and $\delta M'$, it follows that

$$\overline{\text{grad}_\alpha T(M) \cdot \text{grad}_\beta T(M')} = -\frac{1}{2} \frac{\partial^2}{\partial x^\alpha \partial x'^\beta} H(l). \tag{15}$$

Using the condition of local isotropicity (14), it is easy to calculate the right side of (15)

$$\overline{\text{grad}_\alpha T(M)\, \text{grad}_\beta (M')} = \frac{1}{2l} H'(l)\, \delta_{\alpha\beta} + \frac{1}{2}\left[H''(l) - \frac{1}{l} H'(l)\right] n_\alpha n_\beta$$

$$\alpha, \beta = 1, 2, 3, \quad \delta_{\alpha\beta} = \begin{cases} 1 & \alpha = \beta; \\ 0 & \alpha \neq \beta \end{cases}$$

$$n_\alpha = \frac{x'_\alpha - x_\alpha}{l}$$

are components of a unit vector determining the direction from point M to M'.

Passing to the limit when $M' \to M(\ell \to 0)$ and summing up with respect to subscripts $\alpha = \beta$, we obtain the unknown formula for the mean square of the temperature gradient:

$$\overline{(\mathrm{grad}\, T)^2} = \frac{3}{2} H''(0). \tag{17}$$

Multiplying the right and left sides of (17) by the temperature conductivity κ, we get the expression for the mean value of characteristic N introduced above (§ 2) – "the levelling rate of temperature discontinuities"

$$\overline{N} = \frac{3}{2} \kappa H''(0) \tag{18}$$

and, consequently, at very small ℓ (later we define more precisely the meaning of the expression "small" ℓ, introducing the corresponding scale):

$$H(l) \approx \frac{1}{2} H''(0) l^2 = \frac{1}{3} \frac{\overline{N}}{\kappa} l^2. \tag{19}$$

The structural function of the temperature field $H(\ell)$, roughly speaking, can be treated as the measure of intensity of temperature discontinuities g (calculated per unit of mass) for scales not exceeding ℓ. This follows from the fact that discontinuities considerably exceeding ℓ will not substantially affect the temperature difference at distance ℓ. More accurately, the connection between the spectrum of temperature discontinuities and the structural function can be established by applying a Fourier expansion.

Using the above qualitative picture of the levelling process for temperature discontinuities in turbulent flow, we can now attempt to find an expression for structural function $H(\ell)$ for "not very small" values of ℓ corresponding to scales where the direct effect of heat conductivity of the medium is negligible. It is natural to assume that with a quasistationary regime for temperature pulsations in this region of scale variation, the value of $H(\ell)$ must be determined only by quantity $\overline{N}$ (analog of energy dissipation in the theory of Kolmogorov for velocity pulsations) and by turbulence characteristics. The coefficient of heat conductivity, consequently, must not directly enter into the set of determining parameters. According to the theory of Kolmogorov, in this region of the scales the structure of the field of turbulent pulsations in flow velocity is completely determined by mean energy dissipation $\bar{\Phi}$ calculated per unit of mass of the medium. Thus, we can write in the general form:

$$H(l) = F(N, \Phi, l). \qquad (20)$$

Before proceeding to the study of the form of function $H(\ell)$ on the basis of dimensionality analysis, it is necessary to make one essential comment relative to temperature dimensionality. Since we assumed a "passive" character in the transfer of heat by the flow, with which randomly distributed discontinuities in the temperature field do not affect turbulent motion (this corresponds to relatively small temperature deviations from mean and considerable turbulence of a purely dynamic origin) the mechanical equivalent of heat is not among the "determining parameters." In connection with this, when analyzing dimensionalities for temperature, we can use an arbitrary scale independent of the choice of scales for dynamic quantities.* Thus, we can assume the special dimensionality θ for temperature.

Let us write the dimensionality of quantities which enter into formula (20):

$$[H] = \Theta^2, \quad [\bar{\Phi}] = L^2 T^{-3}, \quad [N] = \Theta^2 T^{-1}, \quad [l] = L.$$

(in these formulas T is the dimensionality of time).

From these quantities we can set up only one dimensionless combination

$$\frac{H\bar{\Phi}^{1/3}}{N l^{2/3}} = k^2 \text{ (number)};$$

*Let us also note that the reverse transition of mechanical energy into heat (from dissipation) in a turbulent flow causes such an insignificant temperature variation that this process can also be disregarded.

hence it follows that structural function $H(\ell)$ has the form:

$$H(l) = k^2 \frac{\bar{N}}{\bar{\Phi}^{1/3}} l^{2/3} \tag{21}$$

or

$$\sigma_{\Delta T}(l) = \sqrt{\overline{(T(M') - T(M))^2}} = B l^{1/3}, \tag{22}$$

where k is a numerical constant apparently having the order of unity; $B = k \frac{\sqrt{\bar{N}}}{\sqrt[6]{\bar{\Phi}}}$ is the basic characteristic of the local structure of the temperature field.

The relationship obtained between the mean square of the temperature difference in turbulent flow and the distance between observation points is completely analogous to the "law of two thirds" for the velocity field, obtained by Kolmogorov and Obukhov in 1941 [2, 3]:

$$\overline{[\vec{v}(M') - \vec{v}(M)]^2} = c \Phi^{2/3} l^{2/3}, \tag{23}$$

where c is a numerical constant on the order of unity.

Thus, there is a peculiar similarity in the structure of the temperature field and the velocity field in a locally isotropic turbulent flow. It lies in the fact that the ratio of mean-square amplitudes of temperature difference and velocity difference does not depend upon the distance between observation points and has the order of $\sqrt{\frac{\bar{N}}{\bar{\Phi}}}$.

Now we can evaluate the scale of the least temperature discontinuities, inside of which the field approaches linear because of the action of heat conductivity. This scale corresponds to the region of application of an asymptotic representation of the structural function $H(\ell)$ for small ℓ. Let us define the corresponding scale of ℓ_1 as a point at which two asymptotic representations of $H(\ell)$ (19)

and (21), which correspond to "small" and "large" values of ℓ, join (Fig. 1; here the dashes represent the hypothetical curve of $H(\ell)$ in the transition zone).

With such a definition, ℓ_1 must satisfy equation

$$\frac{1}{3}\frac{N}{\varkappa}l_1^2 = k^2\frac{\overline{N}}{\Phi^{1/3}}l^{2/3};$$

hence

$$l_1 = \sqrt{\frac{3k^6\varkappa^3}{\Phi}}. \qquad (24)$$

The scale of ℓ_1 does not depend upon the intensity of temperature pulsations. Due to the fact that for air the Prandtl number $Pr = \nu/\kappa$ has the order of unity, the scale of ℓ_1 agrees in order of magnitude with the internal scale of turbulence η, introduced in the paper of Kolmogorov cited above ("smallest size of vortex"):

$$\eta \sim \sqrt[4]{\frac{\nu^3}{\Phi}}. \qquad (25)$$

The concepts developed above concerning the microstructure of the temperature field in turbulent flow can be used in meteorology when studying the pulsations of temperature in the lowest atmospheric layer under the condition that wind speed is sufficiently great and turbulence has a dynamic origin.

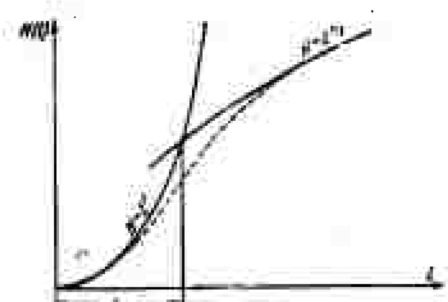

Fig. 1.

We can attempt to give a rough estimate of the order of magnitude of basic characteristics of the structural function of the temperature field in the atmosphere. Using the above formulated condition of "similarity" in the characteristics of the temperature field and the velocity field, we can determine the "transfer coefficient" from the amplitude of the wind velocity to the amplitude of the temperature pulsations by comparing two recordings of temperature and wind velocity obtained under similar conditions. On the basis of the data presented in Lettau's book [6], we can evaluate this "transfer coefficient" as a quantity or the order of 0.5° at 1 m/s or $5 \cdot 10^{-3}$ $cm^{-1}s$.

Then, in accordance with the measurements of the wind velocity pulsations made by Gödecke [7] and the author [8] the microstructure characteristic of the temperature field B (coefficient of proportionality when $\ell^{1/3}$ in the expression for mean square temperature difference) can be estimated at several hundredths of a degree per $cm^{1/3}$. This corresponds for a base at 1 m to a mean amplitude of temperature difference on the order of a tenth of a degree.

According to Gödecke's data, the internal scale of turbulence can be estimated as a quantity on the order of 1 cm; this same quantity must have the above scale of ℓ_1 which characterizes the size of the "smallest grains" causing the temperature discontinuity of the atmosphere.

These rough estimates must be, of course, defined more precisely on the basis of special measurements of rapidly pulsating temperature differences in the atmosphere at small distances (from several centimeters to a meter).

Such research is of interest not only in connection with the above theory but is important in order to explain a number of problems relating to atmospheric acoustics and optics.

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11. SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY
Foreign Technology Division
Wright-Patterson AFB, Ohio

13. ABSTRACT

The mean square of the temperature difference at two points of flow is used as the characteristic of the temperature field structure. The relationship between this quantity and the distance between observation points is determined theoretically. The order of magnitude of the characteristics of the temperature pulsation field in the atmosphere is evaluated.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Turbulent Flow						
Air Temperature						
Temperature Pulsation Field						

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