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Investigation of distribution of air flow and contaminants in ventilated premises and in surrounding atmosphere using radioactive tracers

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A.A. Gusev
Institute of Civil Engineers
Leningrad, USSR

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INVESTIGATION OF DISTRIBUTION OF AIR FLOW AND CONTAMINANTS IN VENTILATED PREMISCS AND IN SURROUNDING ATMOSPHERE USING RADIOACTIVE TRACERS

A.A.Gusev
Institute of Civil Engineers
Leningrad, USSR

SUMMARY

Many tasks on ventilation are successfully solved by means of radioisotopic tracer method. It is characterized with a great sensitivity, high information accuracy, remotability of measurements, speed of response, simplicity of self-recording of results.

Some examples done in Leningrad Institute of Civil Engineers (LICE) have been discussed: radioactive gases measuring, air regime of buildings study, ventilation modelling, wind tunnel simulation of dispersion of industrial and ventilation emissions near buildings. Some of these works are predictive. Recomendations on increasing of ventilation efficiency are important because they are worked out on the basis of such investigations before the beginning of building. That allows to make correctives in a project in time in order to avoid some serious losses.

INTRODUCTION

Among the important tasks a modern building meets with those which are essential where air flow patterns are shown. Such examples as creating of favourable microclimate inside the buildings, providing of proper work of industrial ventilation, optimisation of effluents into atmosphere belong to these instances.

The following examples can be indicative of actuality of such problems. Over 50% of occupational diseas in the world industry is connected with a low quality of room atmosphere. The ventilation costs may amount more than 15% of the expenditure going to an erection and use of enterprise. Heating and ventilation load share in a thermal balance of the countries is as much as 60% and about 90% in the North. It leads to a great fuel expenditure, the level of this expenses for industrial buildings in the USSR only being more than 100 mln t of equivalent fuel per year (1). Hence, investigations directed to increasing of ventilation efficiency accompany essential economical and social effects.

Having applied the methods of radiotracers one can succesfully solve the whole number of tasks of a given type. Usually, an investigation is carried out using ^{85}Kr. The examples of similar investigations are given in review (2).

Since the sixties LICE has been using radioactive tracers in order to study air streams. The results of studies and an experience of their realisation in solving of ventilation practice tasks made by the beginning of the eighties has been stated in (3). Data on radiometry as a basic moment of operation with gaseous tracers and some new their applications are considered below.

RADIOMETRY OF GASEOUS TRACERS

Depending upon the task an tracer is introduced into the air flow or at first it is mixed with an admixture in order to study its transferring. Usually a basic element of a measuring system is Geiger counter. This instrument is placed either inside the chamber where a sample is taken or directly in a flow. Information of tracer concentration q in air volume, surrounding a receiver is kept in its signal N ($N = Kq$). K is a proportionality factor. The value of K depends upon type of radiation, its energy, characteristic properties of a receiver and geometry of measurements.

The author of this paper derived some equations of the general form and solved them on a computer BESM-6 . Solving of these equations for β-active gas have been discussed in (3). As compared with simplified decisions (for example, see (2,4)), these solutions make out and take into consideration a maximum range of β-particles path and a configuration of detectors. Theoretical conclusions are satisfactorily in agreement with experimental ones.

An example of plot of K against radius R of cylindrical air volume and cylindrical counter by even distribution of ^{85}Kr is shown in Fig.1. One can see that an effective radius R_e for ^{85}Kr makes up about 45 cm. In this case 90% of β-particles come to a receiver. The author of this paper defined that by maximum energy E_m of β-spectrum in range 0.16 - 0.67 MeV for end-window and in range 0.67 - 2.5 MeV for cylindrical counter

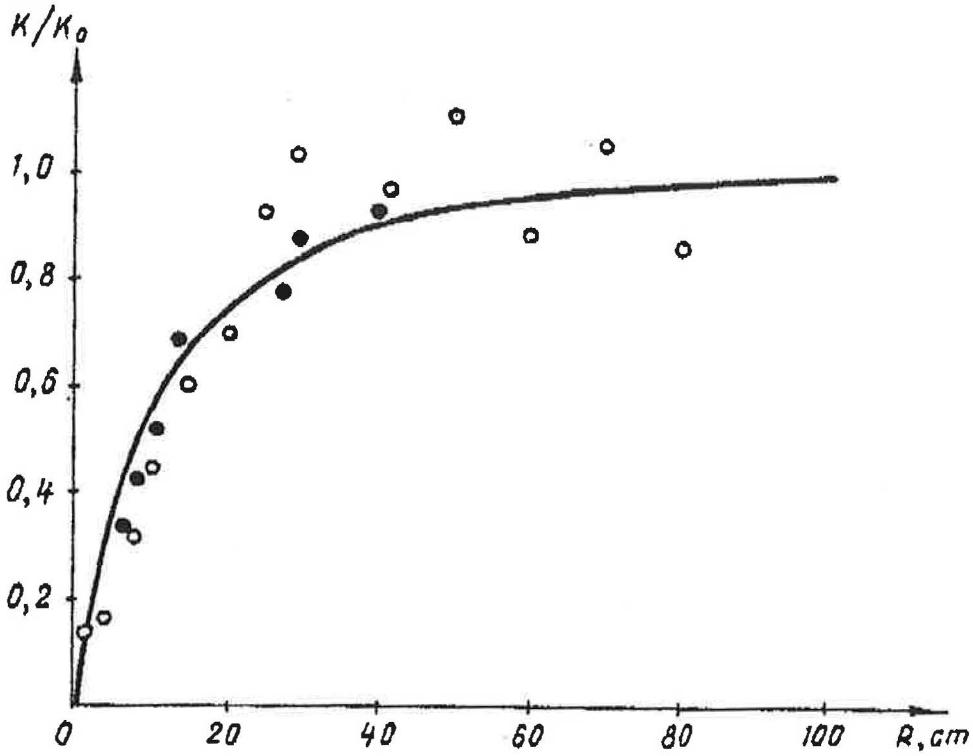

Fig.1. An example of depending $K/K_o = f(R)$:
o - experimental values (4), counter VA-Z-118 ($s = 45$ cm^2, $\rho d = 35$-55 mg/cm^2); ● - experimental values received by the author, counter STS-5 ($s = 23$ cm^2, $\rho d = 40$-48 mg/cm^2); —— - theoretical curve, counter STS-5; ρ - media density of counter's wall; d - the wall thickness; $E_m = 0.67$ MeV; K_o corresponds to K if $R \to \infty$

$$R_e = 6{,}8 + 260\,E_m^{3.2} \quad \text{and} \quad R_e = 69\,E_m^{0.87} \qquad (1)$$

where R_e expressed in cm and E_m - in MeV.

The shown considerations may be used in ventilation tests. On installing a counter in a room it process information about admixtures out of volume, limited by value of R_e, that is, order 0.4 m^3. To avoid influence on a signal some objects such as walls, furniture and others, a receiver should be placed at a distance not less than 40-45 cm from them. While using gas-air mixture samplings taken from various points of room in chambers (it's shown in Fig.2), the described data could be applied for choosing their optimum sizes. In many cases a chamber with radius of 2.5 cm and height being on 10-15% bigger than that of a counter placed on its axle is advisable. A signal from such cell is equal to 20% of a maximum one (Fig.1); a time of its filling being equal to 1 min.

MEASURING DEVICES AND TEST PROCEDURE

For all investigations the plant for production of gas tracer labelling will be one. Tracer is mixed with gas-carrier (usually CO_2) in a given ratio A_1/M where A_1 is a tracer activity and M is a mass of gas-carrier. The value of A_1/M is defined proceeding from a mean concentration of tracer in a tested space. Some nomographs (for example, (3)) for finding A_1/M values have been used. The plant for production of tracer labelling is described in (5). A cylinder filled with gas labelling via reduction gear is joined up to a distribution system from where a tracer comes inside the test volume.

The counters can be placed directly into the tested volume while solving some problems using in life-size conditions. In doing so indicator's uniform distribution around a detector has been provided. The thing is that counter's signals will differ from each other depending upon a degree of uniformity tracer s distribution in a volume limited by R_e while its concentration being mean.

Proceeding from that in controlling of local ventilation or industrial covers the counter is placed in drawing air duct or gas duct with a diameter d being at a distance of several d from their end. A receiver finds itself in a flow with concentrations equalized because of turbulent diffusion.

A big scope of problems connected with air exchange ratio μ

measurement is met too. The counters are placed here inside the test object, the air in its volume being stirred. The tracer distribution uniformity is evaluated by coefficient of variation:

$$w = \frac{1}{\bar{N}_o}\left(\frac{\sum_{i=1}^{n}(N_{oi} - \bar{N}_o)^2}{n - 1}\right)^{0.5} \qquad (2)$$

where N_{oi} is an initial signal of a receiver in i-zone of room; N_o is a mean initial signal at measurement in n zones.

If the value of w is equal or less 10% it is sufficient for testing. In rooms the volume of which is not more than 15-20 m^3 it is achieved by releasing the tracer near central heating system radiators or other convection sources. Room fans are convenient in volumes up to 100-150 m^3. Under such conditions the tracer concentration is diminished according to the law

$$q = q_o \exp(-\mu\tau) \qquad (3)$$

where q and q_o correspond to time moments τ and it is equal to 0.

When solving equation (3) for μ, it is possible to get

$$\mu = \frac{\ln(q_o/q)}{\tau} \quad . \qquad (4)$$

As q is proportional with N and q_o proportionally varies with N_o the formula (4) is acquires the view used in practice:

$$\mu = \frac{\ln(N_o/N)}{\tau} \quad . \qquad (5)$$

One can judge of plenum air distribution in room by means of μ measurement in various zones. Small ranges μ having been indicated, some stall zone sizes and circulation flow boundaries had to be defined. Average ratio of air exchange with volume V

$$\bar{\mu} = \frac{\sum_{i=1}^{n}\mu_i \Delta V_i}{V} \qquad (6)$$

where μ_i is air exchange ratio in an element with volume ΔV_i. The value of n denotes a number of elements, there the receivers are placed. Their values are chosen on the base of the room configuration, μ difference in the neighbouring zones and volumes from where β-particles come into a counter. In studying of air exchange among several rooms more complicated procedures (6,7) are used.

The measurement accuracy of indicator concentration q depends upon sensibility S and signal N of receiver (3)

$$\sigma_q = \frac{N}{qS} \left(\sum_{i=1}^{j} \sigma_{Ni}^2 \right)^{0.5} \qquad (7)$$

where σ_q and σ_N are rms errors of q and N values measurements; j is a number of influening N factors; S is introduced as a value which is measured by signal changing caused by single changing of tracer concentration.

The sensibility of a radioisotopic method is by some orders greater than that of other gas analysis methods usually used in ventilation. Hence, the measurement accuracy of q for radioisotopic method is also higher than that of usual methods. An accuracy of air exchange ratio μ becomes higher too (formula (4)).

Optimum initial concentration of ^{85}Kr in room:

$$q_o = \frac{16 \exp(\mu \tau_n)}{K (\mu \tau_n \varepsilon_o)^2 \tau'} \qquad (8)$$

where τ_n is test time; τ' is N measurement time in n-point (the last one in the time indication course); ε_o is a maximum error of a μ measurement (for 95% reliability).

In order to define q_o it is necessary that the quantities of τ_n, τ' and ε_o should be set and the value of K should be taken by (3). In so doing it is necessary to give a rough evaluation to μ in a preliminary test. Nomograph (5) is offered for convenient using of formula (8).

By taking some samples many other problem have been solved. In LICE mixture is taken from ventilated volume; usually it is continuously sucked through chambers equipped with counters. A diagram of cell (parameters of which have been discussed earlier) is given in Fig.2. The obligatory condition is equality of concentration q of tracer in a zone from where one collects a sample, and its mean concentration $\bar{q}$ in a chamber. Links of q and $\bar{q}$ can be defined from differential equation

$$V_c \, d\bar{q} = L_c \, q \, d\tau - L_c \, \bar{q} \, d\tau \qquad (9)$$

where $d\bar{q}$ is a change of a concentration in a chamber for elementary time interval of $d\tau$; q is a concentration in the mouth of extracted tube; L_c is rate of air flow through the chamber with volume V_c.

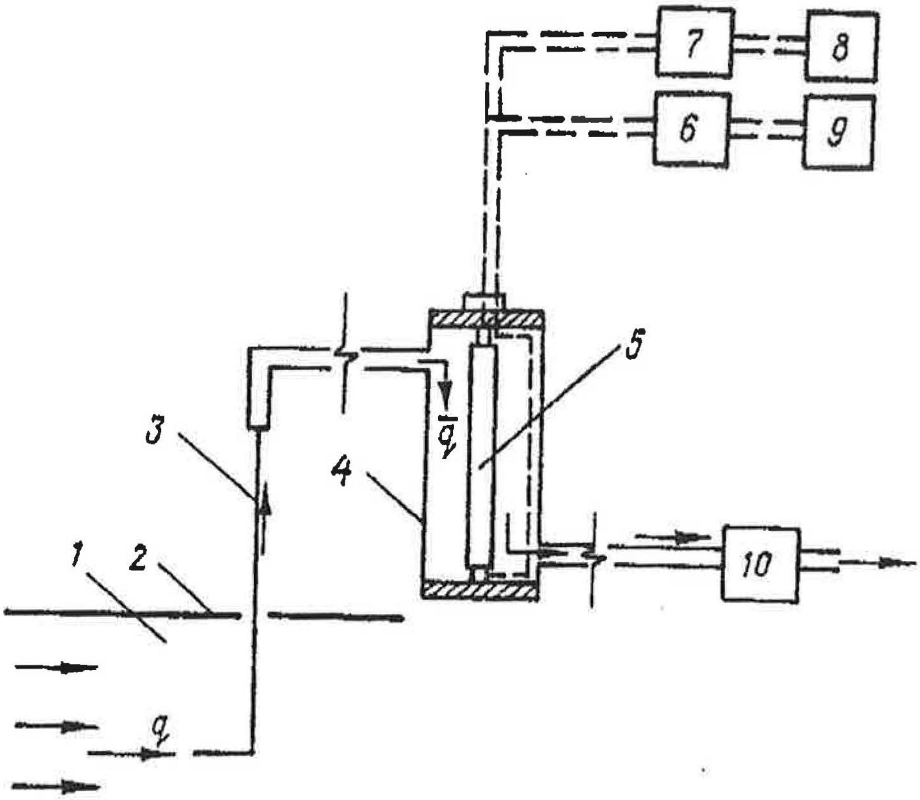

Fig.2. Diagram for determining of tracer concentration by the means of air sampling:
1 - flow; 2 - test object wall; 3 - pipe;
4 - chamber; 5 - counter (usually STS-6);
6 - radiometer; 7 - counting rate meter;
8 - self-recorder; 9 - printer; 10 - vacuum pump

Equation (9) solved on the base of a tentative view of dependence of $q = q(\tau)$. Thus, actual time evaluation since the switching-off moment of the emitter for which concentration in a ventilated volume will not exceed a given one. Some examples:

various failures, salvo effluents together with "momentary" releasing of admixtures inside the room or in air adjoining the building. Concentration drop can be described by the law $q = q_o \exp(-a\tau)$ where a is value as compared to which an inverse one is loss time of concentration in e times. The solution of equation (9):

$$\bar{q} = q \left(\frac{a \exp(a - k)\tau - k}{a - k} \right) \qquad (10)$$

where $k = L_c / V_c$.
From formula (10) follows that measurements are justified under condition that $a = 0$ (i.e. stationary process). Such measurements are admitted for studying non-steady slow process too ($a \ll k$). In both cases we can consider that $\bar{q} = q$.
With other combinations a and k measurements are not justified. Values of $\bar{q}$ and q are greatly differed; this difference is increasing in the course of time. If, for example, $a \gg k$, then $\bar{q} = q \exp(a\tau)$. A procedure error of σ_m ($\sigma_m = (\bar{q} - q)/q$) is quickly increasing too. This error is gradually achieving the value of 100% and more. In particular, it is impossible to model scattering of non-steady effluents correctly using low speed wind tunnels (WT). The point is that the filling time (t_f) of a chamber depends upon the rate of taking samples. This rate must be equal to the mean speed of air flow in WT. As an flow rate in WT makes up several m/s, the rate of sampling should be close to this value. On the whole the time in a model with a scale m of 1:100 and less will be less than t_f. Due to this fact σ_m is so big that it runs counter to common sense.
Full-scale test in buildings are complicated and should be carried on the base of acting technology. Under such conditions each correctness is connected with great losses. In connection with this fact modelling based on similarity theory is spread in USSR. The important purpose of such work is to realize an efficiency prediction of designed ventilation systems. It allows to work out recomendations on increasing of ventilation effectiveness before beginning of building. In consequence of this big losses are prevented. Sometimes they amount to some mln of roubles (8).

Fig.3 gives an idea of a model construction. This model was used for studying an air exchange directed on the fight with an excess heat and gas. A tracer ^{133}Xe was used. It was recorded with end-window counters placed in the model. ^{133}Xe was chosen in order to reduce an effective air volume. As ^{133}Xe has E_m 1.9 times less than ^{85}Kr has, we can see from formula (1) that ^{133}Xe has R_e 5.1 times less than ^{85}Kr has. It amounts approximately 15 cm. This type of record is worse than that using air sampling. There exist some uncertainty in arrangement of tracer around counter. That's why later on they began to take air sampling using ^{85}Kr.

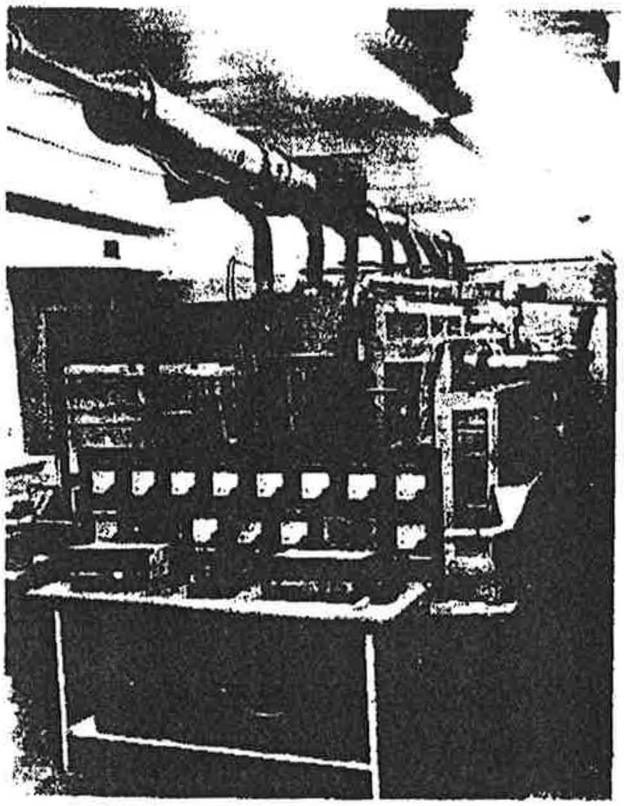

Fig.3. An appearance of a section of non-ferrous plant (m = 1:100)

As it's known, atmosphere quality indoors depends upon concentration of impurities in inflow air. If it is above an extremely admissible concentration (MPC) the effectiveness of ventilation is reducing. The main sources of air pollution in industrial site: aeration lantern, most exhaust pits, openly disposed production equipment and so on. Such effluents come to circulation zones (CZ) which are formed near buildings (Fig.4). If

air intake holes are in CZ, the impurities come again into a shop. Sometimes up to 50% of taken away impurities recirculate indoors again (9). Proceedings from this the scattering calculations of given effluents is actual. It is an extremely complicated problem due to a great number of influencing factors. It is difficult to carry out full-scale tests on acting objects as well as to correct the revealed defects under industrial conditions. That's why modelling is used here too.
WT is used in LICE, the length of working part and cross-section of which being equal to 3.5 m and 2 x 1.6 m^2, correspondently (Fig.5). The velocity of flow is equal 1-7 m/s, a degree of turbulence ε is ranged in interval of 1-9%. Air tests are taken by a tube which is travelled along the working part by means of an electromechanic device. The mixture on its way to vacuum pump was exposed to radiometry in a cell (Fig.2). Flow velocity in WT and its turbulence degree were measured by anemometer with a hot-wire filament. Turbulence scale J was calculated by recording output voltage pulsations using train-oscillograph. In doing so correlation function, spectral funktion and frequence are calculate too, the latter (frequence)

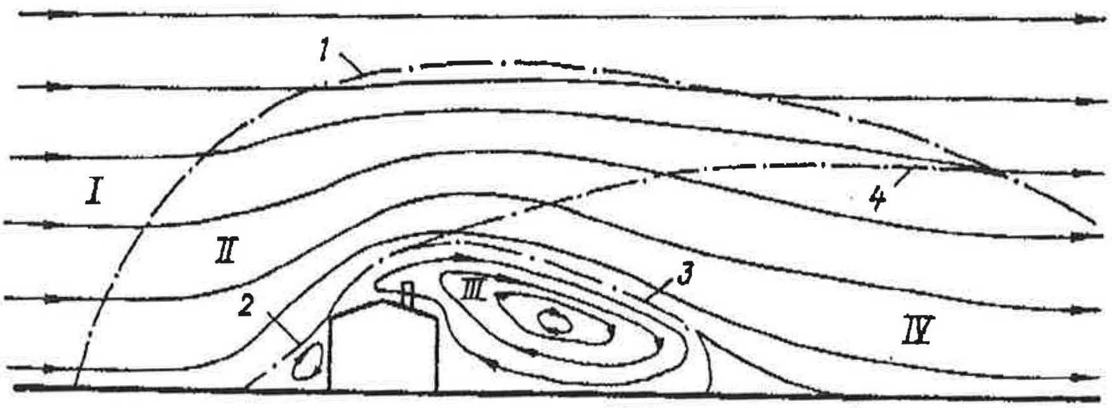

Fig.4. Scheme, illustrating the wind flow over building: I - covering flow; II - disturbance zone; III - cavity; IV - wake; boundaries: disturbance zones (1), windward CZ (2), lee side CZ (3), wake at $v/v_0 = 0,95$ (4); v is a local velocity; v_0 is ditto (only in a covering flow)

being in conformity with maximum of energy in a turbulence spectrum.

METHODS OF MODELLING

Baturin-Elterman method (8) is spread in studying of ventilation. In developed form (including the scientific contribution to it of the author himself) this method brings to following:
- geometrical similarity are observed; geometrical scale of model is chosen so that Re would exceed critical value Re_c for in-

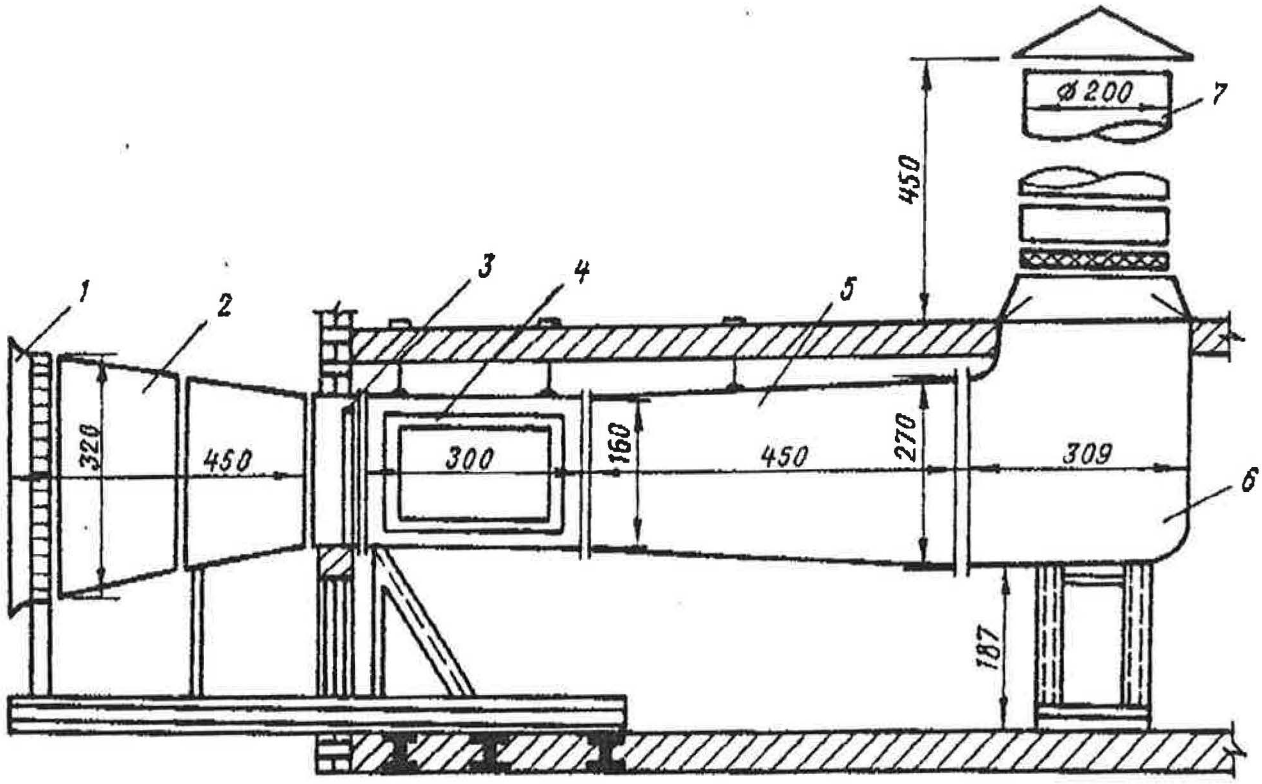

Fig.5. Diagram of the wind tunnel in LICE:
1 - intake; 2 - collector; 3 - cassette with turbulization grates; 4 - working part; 5 - diffuser; 6 - turning bend; 7 - air pit

flow and air holes ($Re_c \approx 2400$); Ra should be more than critical one ($Ra_c = 10^4 - 10^8$ depending upon orientation of heat exchange surfaces);
- a condition where Ar = idem is provided; in doing so a scale of temperature differences Δt is taken so that temperatures in

model and in nature should be like ($\Delta t = t_i - t_o$; t_i and t_o are temperatures of inside and outside (inflow) air);

- if process is non-stationary a requirement Ho = idem should be observed;
- heat losses similarity is provided by the outside protection enclosures having chosen a suitable thermal resistance of the model.

Re, Ra, Ar and Ho are Reynolds, Reley, Archimed and homochronism numbers:

$$Re = \frac{v\,l}{\nu_i}\,; \quad Ra = \frac{g\,l^3 \beta_i \Delta t_s}{\nu_i\, a_i}\,; \quad Ar = \frac{g\,l\,\Delta\rho}{v^2 \rho_i}\,; \quad Ho = \frac{v\tau}{l}$$

where v is a flow velocity; l is a determining size; ν_i, ρ_i, a_i and β_i are kinematic viscosity, density, coefficient of temperature transver and coefficient of volumetric expansion of inside air correspondently; g is a free fall acceleration; Δt_s is a temperature difference between the surface of heater and ambient air; $\Delta\rho$ is the difference in air densities at t_i and t_o; τ is a duration of a phenomenon.

The scale of other values are determined on the base of geometrical scale and a scale of Δt. A scale of concentration difference ΔC is found by assuming a scale of gas emission and taking into consideration the sensitivity of gas analyser ($\Delta C = C_i - C_o$; C_i and C_o are concentrations of admixtures in inside and outside (inflow) air).

The outer problem solving depends upon a fact how much boundary layer in WT is similar to a real atmosphere. The similarity is provided without any serious complication of an experimental plant for neutral and isothermic conditions of atmosphere. Most of procedures have an attitude to a scattering of stationary low temperature effluents. For example, LICE uses such method (10):

- a model geometrical scale is chosen so that it would be flown by a free flow and the condition l/J = idem be provided;
- velocity-averaged flow is created in the WT under which Re is more than a critical one ($Re_c \approx 4 \cdot 10^4$);
- velocity profile which is similar to nature and obeys the law according to which $v/v_o = (z/z_o)^p$ is determined; v and v_o res-

pond to heights z and z_0 ($z > z_0$); p is an index depending upon spreading under surface roughness ($p = 0.14-0.32$);

- the degree of turbulence of a running flow increases up to critical ($\varepsilon_0 \approx 5\%$);
- a requirement for ω/v = idem is observed (ω is an emission outflow velocity);
- a matter, imitating a natural admixture is chosen from the condition of $1.4 < Fr < 6$ (Fr is Froude number which is equal to $v/(g\,h\,\Delta\rho\,/\,\rho_0)^{0.5}$; h is a typical size, for example, the height of CZ; $\Delta\rho = \rho - \rho_0$; ρ and ρ_0 are the densities of ejected matter and ambient air).

The more proximity of results is, the better boundary and time conditions of a natural processes are in agreement with those of studied on a model. The share of admixture in a natural space as a rule is not more than 0.1% from air mass. Such admixtures are passively transferred by air flow. Due to a little sensitivity of usual gas analysers in model it is necessary to create so large concentrations because of that the flow will be overloaded with admixtures. This can influence the field on their concentrations as compared with natural. The conditions of feeding of gases are violated. In nature they are shown in a passive way, but in model they will be injected into a flow. These errors are removed by using a radiotracer method. Tracer is mixed with a gas modelling a natural harmfulness in a trace amount (10^{-6}- 10^{-3}%). Nondimensional fields of tracer and this gas in turbulent media will coincide. Because of small quantities of a carrier gas in a model and in nature the conditions of their evolving and transferring will be similar. In this case the difference of molecular masses will have no effect on results of their distribution. That's why various gases can be modelled by means of the most accessible economical matters (for example, by CO_2). The field of concentrations of a studied harmfulness in a natural object is determined knowing the way of a tracer distribution in the model.

Thanks to tracer methods it is possible to study quick processes on large models. It's impossible to do so having only the common gas analysers as it is necessary to spend several minutes in order to make only one measurement of concentration. As result a studied process is forced to be replaced by a stationary one. Due to this fact a complementary error is brought in the results of study and the worked out recomendations.

THE EXAMPLES OF USING

Natural tests. Ventilation of different spaces has been according to the over mentioned method. In particular, the dependence of natural air exchange ratio μ in vehicles from velocity v of their moving has been studied. For example, in the soft sleeping cars during the stop values of μ in compartment were equal to 1.0-1.3 1/h, the doors being shut, deflectors being switched off and the temperature difference of inner and outer air being equal to 5-6°C. By opening the compartment door air exchange was increasing up to 10-40%; this value being more (30-80%) in case a deflector was put into operation. Ratio μ was essentlially increasing when the train moved. The value of v being equal to 35-40 km/h the air exchange in the compartment of a middle of car was twice more than it had been observed by $v = 0$. In approaching to beginning of car (facing the engine) the air exchange in compartments was increasing. For example, if v was equal to 60-70 km/h the value of μ in the first and last compartments (facing the engine) became three times as much. The air fed by a plenum ventilation system was uniformly mixed with compartment air, but it was unevenly spread along the car: the compartment situated quite near ventilation plant got fresh air on 20-25% more than those situated apart it.

Actual is investigation on improving of air-heat regime of movable buildings. They are used by development of remote territories. Such buildings are assembled from light-weight units. In inclement winter the living conditions in block-containers are unfavourable, as protection enclosures in the main are outward and thermal inertia is small.

For example, block-container in form of parallelepipedon the volume of which is 34 m^3 have been investigated. Safeguard panels had a wooden framework filled with mineral wool or rigid foam. External wall sheathing is made of wooden batten and internal wall lining is made of boardsandwich plates. The dimension of window is 2.1 m^2 overall with a triple glazing. Hot-water heating operates from a 10-section radiator battery with a built-in electric heaters. Ventilation being nature: by means of infiltration and through air vent. The investigations showed that air-heat regime in such building is small efficiency in winter. At outer temperature t_o of -30°C a room is overcooled up to inner temperature t_i of 12°C and even below. If air vent is closed, at the t_o being -20 - -50°C and wind velocity v being up to 5 m/s μ is exchanged from 0.3 to 0.8 1/h. These values are below sanitary normal ($\approx$2.5 1/h). In case air vent was open, the air exchange increased from 2 to 5 times, making a room overcooled.

A new developed block-container has been designed. Floor electric heating was used in it, the number of sections in the battery of radiators being increased to 18, the window area being reduced on 30%, deflector with regulating valve being mounted on the roof, special equipment was worked out and mounted for more complete using of heat emission of radiator, whole additionally heating an induced air (11). These decisions allowed to improve microclimate. In case an air vent was closed, for example, the air exchange required practically provident with during the whole period of severe winter ($t_o <$ -25°C, $v \leq 2.3$ m/s). Summary showed that

$$\mu = B_1 \Delta t + B_2 \quad \text{and} \quad \mu / \Delta t = B_3 v + B_4 \qquad (11)$$

where B_1-B_4 are coefficients; $\Delta t = t_i - t_o$.

The meanings of B_1-B_4 and boundaries of equations applicability have been seen in (11). Correlation coefficients, as a rule, exceed 0.9 showing close connection of the given values. Using such regressions one can predict an air exchange.

Industrial ventilation modelling. Among the papers of this type it is expedient to fix on those which take into consideration nonstationarity of real process. In some branches of industry giving off admixtures into the room is variable in time. Rate of stream consumption L of induced air is usually specificated having the intensity of getting off fumes $\overline{G}$ to be constant and equal to $\overline{M}/\overline{\tau}$ ($\overline{M}$ is mass of substance having come into the room during the time $\overline{\tau}$). In such case $L = \overline{G}/(C_m - C_o)$

where C_m and C_o are concentrations of admixtures, that is MPC and in outer (inflow) air. Quantities of harmful matters even more than for MPC in air of factories during the most part of working time is result of such method of approach.

One should find such solution that during the whole working day the quality of air medium would be not worse than extremely permissible and air exchange on minimum coming of impurities would be reduced. This gives economy at the expense of elimination of heat and electric energy overexpenditure

The problem was solved for closed motor parks working in one-shift regime. Nonstationarity in exhausting of toxic gases is especially shown by leaving of motor-cars (12). Value of $\tilde{G}$ greatly depends upon $\tilde{\tau}$; correlative ratio is equal to 0.94. $\tilde{G}$ is an intensity of giving off the impurities standardized on the value of $\bar{G}$; $\tilde{\tau}$ is a current time standardized at the time of departure. To describe dependence $\tilde{G} = \tilde{G}(\tilde{\tau})$ is given a formula

$$\tilde{G} = 1 + \sin(2\pi\tilde{\tau} - \pi/2) \quad . \qquad (12)$$

This expression approximates the connection as precisely as a regression equation with coefficients of which we define by method of least squares. Using formula (12) and having taken into consideration that room air is stirred quickly and uniformly we were a success to get a function described changing of admixture concentration C (because of its complication the expression is not given here). Having compared the value C at a given moment with MPC one could come to conclusion about rational air exchange. On base of such accounts a simple way of multistaged regulation of air exchange is offered. Its essence is to switch part of ventilation plants on (or off) at a schedule data during a certain time in order to make harmful matter content not to be excessed of MPC the rate of air flow being minimum.

This procedure was elaborated in detail on a model of covered car-stand for 160 cars (m = 1:25). A mean consumption of plenum air L at the stop, determined from the value of $\tilde{G}$ for CO is equal to $1.6 \cdot 10^5$ m^3/h. In doing so the conditions will be worse than extremely admissible for a half of time period of cars departure. If one can determine L so that $C = C_m$ the giving off of CO being the most, it would be exceed and equal to $3.1 \cdot 10^5$ m^3/h. One can see from Fig.6 that $C \leqslant C_m$ can be provided by a small quantity of plenum air when using several steps of controlling. Some ventilation systems were found out which switching off does not lead to formation of stall zones. Date for a working zone recalculated from a model for a natural object correspond to calculation for the mean concentrations (Fig.6). The more steps the control has, the more perfect it is, but more complificated is its construction. A making of automated systems with gas analysers is still a problem. Hence, controlling must be as complicated as two- or three-position one acting by timer or manually. Realizing of such controlling on the examined object gave 47 ths of roubles for year economy.

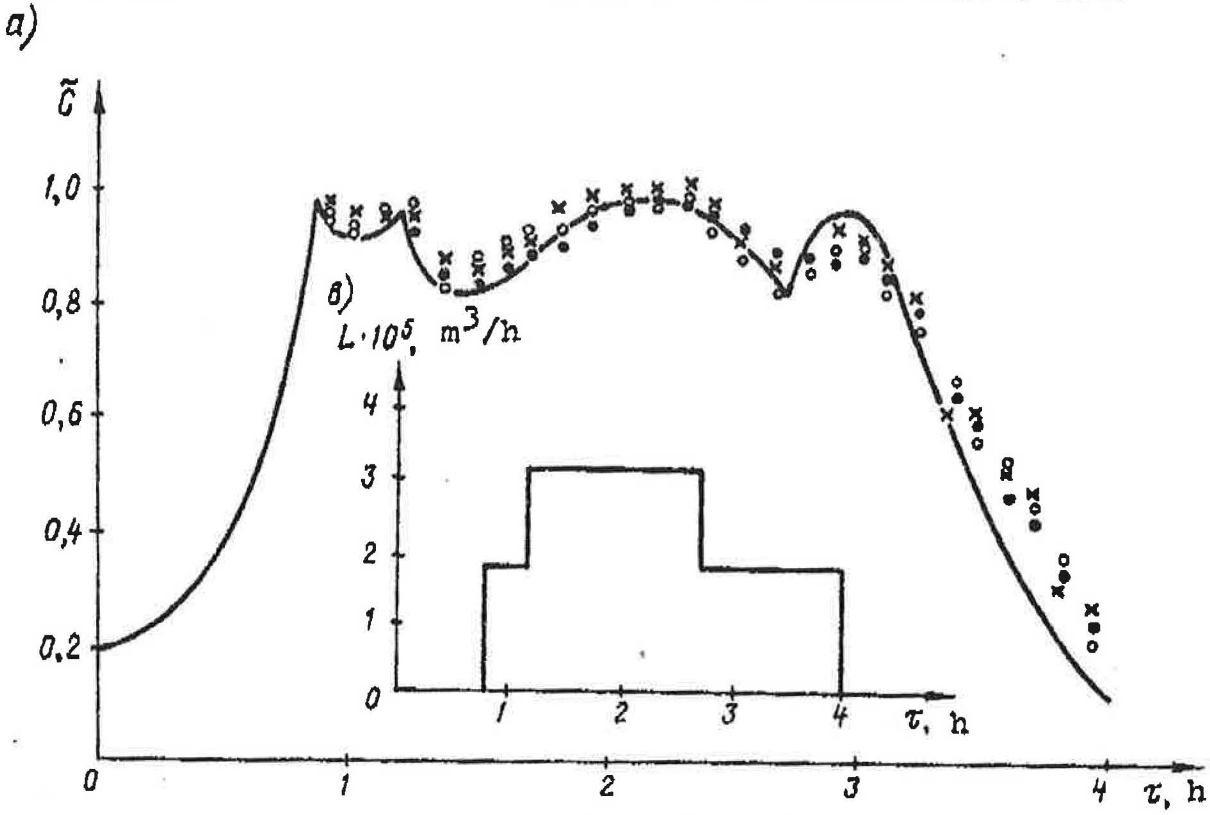

Fig.6. Illustration to a two-steps adjustment: a) monograph of CO concentration changing standardized on MPC during the leaving of cars; o, •, x are the test points; b) schedule of plenum air feeding

<u>Modelling of effluents scattering.</u> Various problems are solved by the WT testing, many of which have a character of a forecast, preceding the designing.

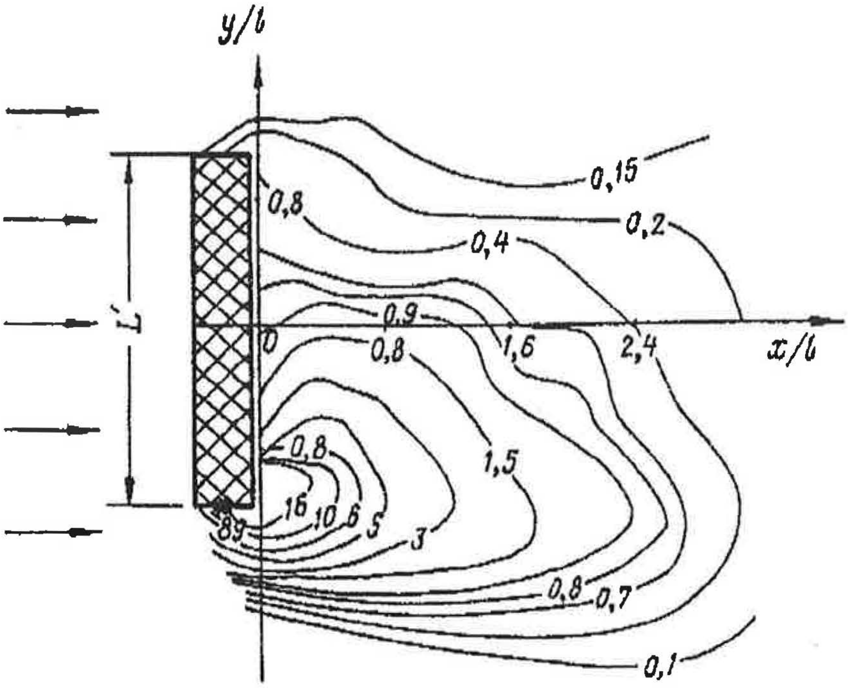

Fig.7. A field of nondimensional near-earth concentrations from a ground point source by the end of a building: $\omega = 0.1$ m/s; $v = 1{,}95$ m/s

It is actual in particular, to determine the features of cavity (Fig.4). Its extent is the longest if a building is orientated by its length to be perpendicular to the flow. The cavity region boundary goes at the distance of $x = 2.2\sqrt{A}$ from the lee edge of building (A is area of projection of windward front of buildings which is normal to flow). Near the surface of ground a flow in cavity is orientated against a main one. As the height is increasing more than $0.2\sqrt{A}$ its direction is such as main flow has. The height of wake is equal to $1.5\sqrt{A}$.

The structure of cavity is complicated. E.g., a horse-shoe eddy is formed from lee ward by a building orientated by length L' perpendicularly to flow. In the near-earth zone of its adjoining to a wall there appear two symmetric eddies relative to a horizontal axle of the building. Their centres coordinates are: $x = 0.4\sqrt{A}$ and $y = \pm 0.8\sqrt{A}$ (y is a lateral coordinate counting off from middle of L'). If an earth effluent gets inside the eddy, it pollute only the proper part of cavity. An example of the arrangement observed in the WT is given in Fig.7. The results were presented as Q-values coinsiding in a model and in a natural object:

$$Q = \frac{N / N_m}{F\omega / (A v)} \qquad (13)$$

where N and N_m are signals from a given point WT and a source mouth; F is a mouth area.

An influence upon pollution of cavity, location of sources, values of ω and v, wind direction is determined in these papers. A prover characteristic for air pollution of space among the buildings is given for some industrial sites. Some conclusions about their ventilation improving and location of air intakes have been made. Some results were incladed in the All-Union normative document (13).

REFERENCES

(1) Grimitlin, M.J. Ways of the further raising of industry ventilating system efficiency. News in projecting and exploatation of the industrial ventilation system. Ed. by the Home of technical-scientific popularization, Leningrad, 1986, 4-9.

(2) Gilath,Ch. Ventilation und air pollution studies using radioactive tracers. Int. J. Appl. Radiat. Isotopes, 1977, 28, 10/11, 847-854.

(3) Gusev, A.A. Methods of nuclear physics in construction and building industry. Ed. by Energoatomizdat, Moscow, 1985.

(4) Gläser, M., Klich, W., Greifels, A. Vergleichende Untersuchungen an ^{85}Kr und ^{133}Xe als Tracer. Isotopenpraxis, 1986, 22, 11, 411-416.

(5) Gusev, A.A., Kylatchanov, A.P. Air exchange investigation in rooms by means of radioactive tracers. Water Supply and Sanitary Engineering, 1978, 6, 13-18.

(6) Sandberg, M., Blomqvist, C. A quantitative estimate of the accuracy of tracer gas methods for the determination of the ven-

tilation flow rate in buildings. Building and Environment, 1985, 20, 3, 139-150.

(7) Wadden, R.A., Scheff, P.A. Indoor air pollution. John Wiley & Sons, Inc., New York, 1983.

(8) Elterman, V.M. Ventilation of chemical industry. Ed. by Chemistry, Moscow, 1980.

(9) Meroney,R.N. Turbulent diffusion near building. Engineering meteorology. Els. Sci. Publ. Co., Amsterdam - Oxford - New York, 1982, 1, 481-525.

(10) Gusev, A.A., Yablonski, K.V., Datsuck, T.A. Estimation of the impurities concentration field polluting the air near buildings. Methods and controlling means of an air pollution and industrial effluents and their application. Ed. by Hydrometeoizdat, Leningrad, 1988, 96-1o2.

(11) Gusev, A.A., Zvetkov, V.N., Karpushenko, V.P. On a heat-air regime of the block-container buildings under conditions of a severe climate. Improvement of heating and ventilation systems. Ed. by LICE, Leningrad, 1985, 20-27.

(12) Obuchov, I.A. To a problem of organizing an air exchange in industrial rooms with a nonstationary evolving of impurities. Investigations in the sphere of heating and ventilation. Ed. by LICE, Leningrad, 1988, 13-19.

(13) A calculation method of harmful impurities in a free air which are in the effluents of the enterprises (OND-86). Ed. bu Hydrometeoizdat, Leningrad, 1987.