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U.S.R. LITERATURE ON AIR POLLUTION AND
RELATED OCCUPATIONAL DISEASES

VOLUME 6

B.S. Levine

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**U.S.S.R. LITERATURE ON AIR POLLUTION
AND RELATED OCCUPATIONAL
DISEASES**

Volume 5

A SURVEY

by

B. S. Levine, Ph. D.



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U.S.S.R. LITERATURE ON AIR POLLUTION AND RELATED OCCUPATIONAL DISEASES

Volume 6

A SURVEY

by

B. S. Levine, Ph. D.

**U.S. Public Health Service
(Health, Education, and Welfare)
Research Grantee**

Washington, D.C., U. S. A.

APRIL 1961

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The following is available from Academic Press, Inc., 111 Fifth Avenue,
New York 3, N.Y.

Russian-English Medical Dictionary, By Stanley Jablonsky. Edited by B. S. Levine.	\$11.00
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For comparison of metric and customary units from 1 to 10 see Handbook of Chemistry and Physics published by the Chemical Rubber Publishing Co., 2310 Superior Ave., N.E., Cleveland, Ohio.

Inches and millimeters, inches and centimeters, feet and meters, U.S. yards and meters, U.S. miles and kilometers - Page 2947

Square inches and square millimeters, square inches and square centimeters, square feet and square meters, square yards and square meters, square miles and square kilometers - Page 2948

Cubic inches and cubic millimeters, cubic inches and cubic centimeters, cubic feet and cubic meters, cubic yards and cubic meters, acres and hectares - Page 2949

Milliliters and U.S. ounces, milliliters and U.S. apothecaries' drams, milliliters and U.S. apothecaries' scruples, liters and U.S. liquid quarts, liters and U.S. liquid gallons. (Computed on the basis 1 liter = 1.000027 cubic decimeters). Page 2950

Liters and U.S. dry quarts, liters and U.S. pecks, decaliters and U.S. pecks, hectoliters and U.S. bushels, hectoliters per hectare and U.S. bushels per acre. (Computed on above basis). Page 2951

Other pertinent conversion tables are presented on succeeding pages.

RUSSIAN ALPHABET WITH TRANSLITERATION

А а а	Р р r
Б б b	С с s
В в v	Т т t
Г г g	У у u
Д д d	Ф ф f
Е е e	Х х kh
Ж ж zh	Ц ц ts
З з z	Ч ч ch
И и i	Ш ш sh
Я я i	Щ щ shch
К к k	Ъ ъ mute hard sign
Л л l	Ы ы y
М м m	Ь ь mute soft sign
Н н n	Э э e
О о o	Ю ю iu
П п p	Я я ia

FOREWORD

The general plan of the present "Survey" Volume 6 is the same as the plan of any of the preceding volumes in that representation was given to a variety of phases of air pollution studies. Items in the Table of Content were supplemented by names of journals in which they appeared to enable readers to determine, at a glance, whether or not the subject matter was approached from the angle of greatest interest to them. A perusal of the Table of Content, as now presented, will indicate to the reader that the greatest weight of Volume 6 was given to papers published in the Russian Journal of Applied Chemistry. Research students who are interested in the application of Pavlovian perception physiology to certain phases of air pollution investigations, such as limits of allowable pollutant concentrations, may find the Appendix, beginning with page 290, of special interest.

A new classification of industrial sanitary clearance zones appears beginning with page 117 of this volume. This clearance zone classification replaces the one which was presented in Volume 4 (O.T.S. No. 60-21913) beginning with page 165. The new classification contains many important changes. The 2000 m wide zones have been abolished, the 1000 m sanitary clearance zones becoming the widest, width of other sanitary clearance zones have been reduced either accordingly or to some degree. In addition, certain types of manufacturing and processing industrial plants have been taken out from their old groupings and placed into other groups. All this is of considerable significance, since it reflects improvement, on the one hand, in the methods of production, manufacturing and processing, and, on the other hand, in the operation and efficiency of air and gas purifying installations. Readers to whom the phase of sanitary clearance zones is of interest should make a careful comparative study of the classification appearing in this volume (page 117) with the classification which appeared in Volume 4, beginning with page 165.

Several readers of the Survey "Books" and "Volumes" had written suggesting that metric measures be converted into American and English customary measures. This would require a considerable amount of time on the part of the undersigned. Professional reference books have been published which contain convenient conversion tables of a wide range, one such book is the Handbook of Chemistry and Physics, issued by the Chemical Rubber Publishing

Co. A list of appropriate conversion tables, and pages on which they appear, is presented in this Volume for the convenience of those who might need such a facility.

Readers of the more recent "Books" and "Volumes" of the Survey undoubtedly noticed that bibliographies of translated papers have been presented as they originally appeared in the Russian publications. One reason for doing that was to save the valuable time and expense transliteration would take. It was also considered desirable, if not important, to enable readers to learn the Cyrillic Russian alphabet, and to become proficient, or urge their typists to become proficient, in transliterating such short items as Russian titles, names and journals. For the convenience of those who might wish to do their own transliteration of selected Russian items of bibliography, a Russian alphabet with transliteration is presented on the same page as the list of measures' converting tables.

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A C K N O W L E D G E M E N T S

By way of grateful acknowledgement each item in this collection is headed by the original title (in translation), the name of the author or authors, institutional affiliation, and periodical or book from which the item was selected. The volume, issue number, year of publication, and inclusive pages are indicated for the convenience of those who may wish to consult the Russian original, or may wish to make reference to same.

The material constituting the Appendix was taken from "Lectures on Conditioned Reflexes. Twenty-Five Years of Objective Study of the Higher Nervous Activity of Animals", by Ivan Petrovich Pavlov, M.D., translated by W. Hoarsley Gantt, M.D., S. D. Liveright Publishing Corporation, New York. To Dr. W. Hoarsley Gantt of the Johns Hopkins Pavlovian Laboratory, the undersigned is duly grateful and takes the pleasure of expressing his thanks.

B. S. Levine, Ph.D.
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Contents.

Foreword

Section I. Experimental Studies in Air and Gas Purification of Gaseous and Dust Pollutants by Adsorption and Absorption Methods.

Gas Flow Dispersion as a Means of Increasing Electrostatic Precipitator Efficiency. I. E. Idel'chik. Koks i Khimiya.	1
Rate of Nitrogen Oxides Absorption by Alkaline Solutions and by Nitric Acid. V. I. Atroshchenko and E. G. Sedashova. Zhurnal Prikladnoi Khimii.	16
Bubbling Air Through Viscous Fluid. I. P. Levi and O. B. Balandina. Zhurnal Prikladnoi Khimii.	25
Effect of Hydrodynamic Conditions on Rate of Nitrogen Oxides Absorption by $\text{Ca}(\text{OH})_2$ Solution, with the aid of a Mechanical Absorber under Semi-Industrial Conditions. S. N. Ganz. Zhurnal Prikladnoi Khimii.	39
Adsorption of Nitrogen Oxides by Aluminosilicates. S. N. Ganz. Zhurnal Prikladnoi Khimii.	52
Hydrogen Sulfide Absorption by Sodium Arsenate Solution in a Foam Apparatus. M. E. Posin, B. A. Kopylev and N. A. Petrova. Zhurnal Prikladnoi Khimii.	61
Rate of Hydrogen Sulfide Absorption by Sodium Arsenate Solutions. M. I. Gerber, V. P. Teodorovich and A. D. Shusharina. Zhurnal Prikladnoi Khimii.	75
Effect of Foam Layer Thickness over Screen Shelf on Carbon Dioxide Absorption by Alkaline Solution. M. E. Posin, B. A. Kopylev and E. Ya. Tarat. Zhurnal Prikladnoi Khimii.	79
Calculating the Phase Balance of Multi-Component Gas Mixtures. I. G. Plit. Zhurnal Prikladnoi Khimii.	86
Experimental Utilization of Manganese Dioxide in Purifying Gases from Hydrogen Sulfide and Recovery of Elemental Sulfur. Ya. Ya. Dodonov, L. D. Borzova, V. S. Kolosova and V. S. Pokaevskaya. Zhurnal Prikladnoi Khimii.	91
Effect of Low SO_2 Concentrations on the Organism of Animals. E. K. Lobova. In book: Vopr. Gigieny Atmosf. Vozdukha. (An abstract).	96
Wetting Agents Property to Catch Dust in a Dust Chamber. S. Kh. Zakieva and A. B. Taubman. Zhurnal Prikladnoi Khimii.	97

Section II. Sanitary Clearance Zone Studies. Regulations Pertaining to Location (Site), Planning and Construction of Industrial Production and Processing Plants. New Classification of Industrial Clearance Zones. Medical Examinations of Industrial Workers and Their Fitness To Engage in Certain Industrial Occupations.

Basic Data for the Determination of Sanitary Clearance Zone Widths Around Peat Burning Electric Heat and Power Stations. N. Ya. Yanysheva. Gigiena i Sanitariya.	101
Hygienic Basis for the Determination of Standard Sanitary Clearance Zone Widths Around Gasoline Filling Stations. Chjan Tssyu-chei. Gigiena i Sanitariya.	107
Sanitary Standards for Planning Industrial Production Plants. ISP 101-51. Replacing GOST 1324-47. Field of Application and Basic Requirements for General Planning.	113
Sanitary Classification of Production and Processing Plants in Relation to Sanitary Clearance Zones.	117
Sanitary Protection Zones in Meters for Regional and Factory Electric Heat, Light and Power Stations and for Boiler Operated Industrial Plants Having a Fuel Consumption of Three Tons or More per Hour. A Table to go with Supplement 1.	130
Height of Smokestacks in Relation to Tons per Hour Fuel Consumption.	131
Limits of Allowable Concentrations of Poisonous Gases, Vapors and Dust in the Air of Working Zones in Industrial Premises.	132
Limits of Allowable Concentration of Non-Toxic Dust in the Air of Actual Working Locations of Industrial Production Premises.	134
Periodic Medical Examination of Workers Employed in Different Industries.	135
Lists of Contraindications which Prevent the Employment of Workers in Industries in which Workers Undergo Periodic Medical Examinations.	139

Section III. Effect of Environmental Industrial Conditions on Immunity and Other Physiological Processes. Experimental Studies.

The Effect of Industrial Poisons on the Immuno-Biological State of the Organism. I. G. Fridlyand. Gigiena i Sanitariya.	149
Effect of Chronic Low Concentration Sulfur Dioxide Poisoning on the Immuno-Biological Reactivity of Rabbits. V. K. Navrotskii. Gigiena i Sanitariya.	157
Effect of Low and High Surrounding Air Temperature on the Immuno-Biological Reactivity of the Animal Organism. M. A. Razdobud'ko. Gigiena Truda i Professional'nye Zabolevaniya.	164
The Effect of External Industrial Production Environment on the Immuno-Biological Reaction of the Organism. Effect of Chronic Intoxication with Benzene and Its Nitro- and Amino-Derivatives on the Immuno-Biological Reaction of Rabbits. V. K. Navrotskii. Gigiena Truda i Professional'nye Zabolevaniya.	173

Effect of Chronic Benzene Intoxication on the Phagocytic Activity of Rabbits. A. P. Volkova. Gigiena i Sanitariya.	183
Air Temperature Effect on the Processes of Conversion and Detoxification of Aniline in the Animal Organism. Z. A. Volkova. Gigiena Truda i Professional'nye Zabolevaniya.	188
Sanitary-Hygienic Labor Conditions in the Production of Polymethylmetacrylate. S. E. Sandratskaya. Gigiena i Sanitariya.	197
Labor Hygiene Problems in the Use of Dichlorethane by the Aviation Industry. I. V. Kozik. Gigiena Truda i Professional'nye Zabolevaniya.	203
The Toxicity of Aromatic Hydrocarbons. Comparative Toxicity of Some Aromatic Hydrocarbons. Some Problems of the Toxic-Hygienic Properties of Aromatic Hydrocarbons. A. C. Faustov. Trudy Voronezhskogo Meditsinskogo Instituta. (An abstract).	212

Section IV. Studies in Analytical Procedures.

The Effect of Colloids on the Accuracy of Photocolorimetric Determinations. K. V. Flerov and B. V. Ozimov. Zhurnal Prikladnoi Khimii.	214
Chromatographic Partitioning and Analysis of Methane Chloro-Derivatives. D. A. Vyakhirev and L. D. Reshetnikova. Zhurnal Prikladnoi Khimii.	221
Colorimetric Determination of Benzene Losses. F. P. Nikonyuk. Koks i Khimaya.	226

Section V. Miscellaneous.

Safe Starting of Blast Furnaces. V. T. Shumilova. Gigiena i Sanitariya.	229
Standards for Maximum Permissible Dust Concentrations in the Air of Working Premises. N. I. Smetanin. Gigiena i Sanitariya.	233
Removal of Microorganisms from Air by the Filtration Method. E. Yu. Zuikova. Gigiena i Sanitariya.	235

Section VI. General and Didactic Papers.

Problems of Industrial Hygiene and Occupational Pathology in the Practice of a Modern Physician. Z. I. Israel'son. Sovetskaya Meditsina.	238
Population Mortality in the U.S.S.R. and in Capitalist Countries. A. M. Merkov. Gigiena i Sanitariya.	247
Industrial Sanitary Supervision. Editorial. Meditsinskii Rabotnik.	256
Soviet Health Protection Legislation Is Based on Scientific Findings. D. V. Gorfin. Sovetskoye Zdravo-okhranenie.	258

Futile Efforts to Control Air Pollution in English and American Cities. (A Survey of Foreign Literature). M. S. Gol'dberg. Gigiena i Sanitariya. 267

Problems in Planning and Building Cities and Protecting the Air in England. K. G. Beryushev. Gigiena i Sanitariya. 276

Section VII. A Conference Report.

Urgent Problems in Industrial Hygiene of Women Workers. M. A. Petrov-Malakov. Vestnik Akademii Meditsinskikh Nauk, U.S.S.R. 285

Section VIII. Appendix.

I. P. Pavlov. Dialectical Materialism, Conditioned Reflexes and Signal Systems. B. S. Levine. (Based on a series of excerpts from I. P. Pavlov's book, translated by Dr. William Hoarsley Gantt, of Johns Hopkins Pavlov Laboratory, published in 1925). 290

Gas Flow Dispersion as a Means of Increasing
Electrostatic Precipitator Efficiency.

I. E. Idel'chik.

[Master of Technical Sciences, Staff Member of NIIOGAZ (Scientific-Research Institute of Gas Purification). Giprogazoochistka (Government Institute for Designing Gas Purifying Installations)].

Koks i Khimiya, No. 1, 47-54, 1956.

Notations.

- D_o - Diameter of the gas conduit.
- D_p - Diameter of the screen (work chamber).
- \bar{f} - Ratio of the "live" (openings) area in the screen to the entire screen.
- F_k - Cross section area of the precipitator work chamber.
- F_o - Cross section area of the gas (air) conduit.
- F_{opn} - Total "live" (openings) screen area.
- F_{ctp} - Cross section area of the gas stream.
- H - Distance from the (top) screen to the top of the work chamber.
- H_p - Distance between the screen and the center line (axis) of the gas conduit.
- l - Distance between the screens.
- N_p - Number of screens.
- N_a - Kinetic energy coefficient of the core of the constant mass of the (gas) stream.
- N_o - Ditto of the gas stream at its inflow into the work chamber.
- N_{ctp} - Ditto of the gas stream between the end section of the gas conduit and the screen.
- ω - Speed of the gas at given points.
- ω_o - Gas speed at opening into the work chamber.
- ω_{max} - Maximum gas speed at opening into the work chamber.
- ω_{cp} - Median gas speed across the work chamber cross section.
- Z_{lmt} - Screen resistance coefficient limit.
- Z_s - Screen resistance coefficient.
- $Z_{s.opt}$ - Optimum screen resistance coefficient.
- $Z_{s.syst}$ - Screen system resistance coefficient.

The even distribution of gas flow through all the operating elements of electrostatic precipitators constitutes the most essential condition for the effective and efficient operation of electrostatic precipitators. One of the means by which even distribution of the gas can be attained is forced distribution of the gas flow with the aid of resistors placed in front of the operating elements of the apparatus, and exerting an even effect over the entire cross-section of the working chamber. Such resistors can be made of flat screens, perforated metal plates, Raschig rings, chord type partitions, strips of cloth, etc. In the absence of experimental data, such resistance devices (mostly screens) were selected in the past haphazardly and not as the result of rationally employed calculations.

This author studied the problems of forced distribution of gas flow [1, 2]; the data presented in the reports referred to presented the possibility to determine with precision the type of the resistor screen most suited for the even distribution of the gas flow over the entire cross section of the work chamber of a given electrostatic precipitator. Calculations made on the basis of such results proved that the old resistor screens installed in the electrostatic precipitators used in the purification of coke gas from suspended tar particles (see Fig. 1 - precipitator type C-140) could not assure a sufficiently uniform distribution of gas flow rates. Replacement

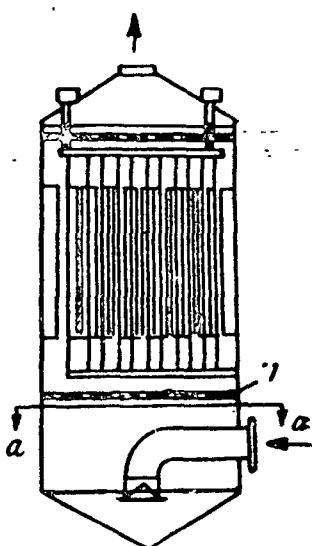


Fig. 1. Electrostatic precipitator for the purification of coke gas from tar.
1 - Screen.

of the old screens by screens selected on the basis of rational calculations should increase considerably the purification coefficient and result in a more than twofold increase in the precipitator productivity.

The above considerations and the work conducted at Giprogazoochistka (The Government Institute for Designing Gas Purifying Installations) on the development of a standard installation for the electrostatic purification of coke gases impelled this author to make special tests for the study of the gas distribution in type C-140 electrostatic precipitators.

The following is a preliminary report on calculations made for the determination of gas distribution in electrostatic precipitators and on the study

of the aerodynamics of an electrostatic precipitator model under laboratory conditions, using air as a working medium. The main purpose of the experiments was to determine the distribution of the air flow velocities over a cross section corresponding to that at the gas intake openings of the tubular electrodes of the electrostatic precipitator. To accomplish that it was necessary only to construct a model of the first section of the precipitator, which consisted of the intake extension and the first part of the precipitator work chamber without its electrodes (see Fig. 2). The model scale used was

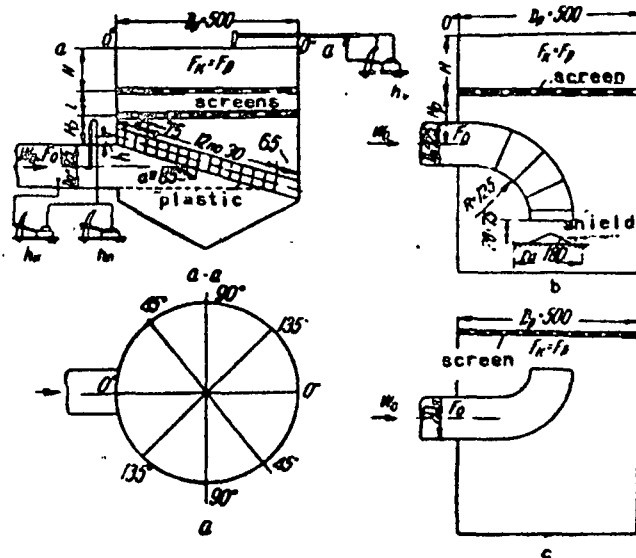


Fig. 2. Plan of the experimental electrofilter model.

a - Lateral gas entry; b - Central downward gas entry; c - Central upward gas entry.

1:9.5. The ratio of the cross section area of the model work chamber F_k to the cross section area of its gas inflow opening F_0 was: $F_k/F_0 = 16$.

Two ways of gas flow delivery into the model were tested. One with a lateral gas delivery (see Fig. 2), the other with a central (symmetrical) delivery through a downward directed inflow pipe facing an umbrella-shaped deflector at the end (see Fig. 2b). By means of theoretical calculations it was determined [1] that the magnitudes of an optimum resistance

coefficient of a single screen, adequate for bringing about the distribution of the gas flow over its entire area under given conditions of the field of velocities in the gas flow before the screen, depended only on the ratio F_k/F_0 ; it can be expressed by a formula:

$$Z_{s.opt} = N_a \left(\frac{F_k}{F_0} \right)^2 - 1 \quad (1)$$

where

$$Z_{s.opt} = \frac{\Delta p}{\gamma \omega_p^2} \frac{2g}{2g}$$

is an optimum screen resistance coefficient reduced to a median velocity ω_p in front of the screen;

and

$$N_a = \frac{1}{F_o} \int F_a \left(\frac{\omega}{\omega_o} \right)^3 dF$$

is the kinetic energy coefficient of the center (core) of the constant mass flow which depends upon the condition of the field of velocities at the given cross section.

The theoretical analysis and experimental results [2] show that flat screens or perforated sheets can act as gas flow distributors in installations having limited F_k/F_o ratios. However, in case of a lateral gas flow into a rectangular apparatus, and with the resistor screen placed at a distance $H_p/D_o > 1.4$ from the center line of the inflow opening (Fig. 2a), the limiting relation between the areas is:

$$\left(\frac{F_k}{F_o} \right)_{\text{limit}} \approx \sqrt{\frac{3}{N_o}} \quad (2)$$

where

$$N_o = \frac{1}{F_o} \int F_o \left(\frac{\omega}{\omega_o} \right)^3 dF$$

is the coefficient of kinetic energy at the initial cross section of the gas flow, that is, at the point of inflow.

In the case of central or symmetrical gas inflow, where the impact on the resistor screen (2b) is direct, the ratio of the areas will be:

$$\left(\frac{F_k}{F_o} \right)_{\text{limit}} \approx \sqrt{\frac{6.5}{N_o}} \quad (3)$$

Limiting area ratios imply or presuppose corresponding limiting screen resistance coefficients [1 and 2]:

$$Z_{s.\text{limit}} = N_a \left(\frac{F_k}{F_o} \right)_{\text{limit}}^2 - 1 \quad (4)$$

In apparatus installations with area ratios $F_k/F_o > (F_k/F_o)_{\text{limit}}$ and of single flat resistor screens, the resistance coefficients of which are higher than those derived from formula (4), new gas velocity profile distortions arise at the sections back of the resistor screens, which make equalization of gas flow unattainable.

Determination of the fitness of individual flat resistor screens for the even distribution of gas flow in electrostatic precipitators must be based on specific values of N_a and N_o ; such values can be arrived at by analyzing

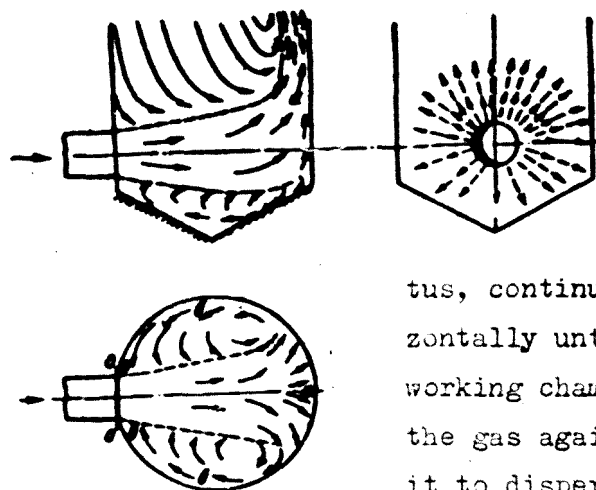


Fig. 3. Schematic picture of gas flow in the entering section of the work chamber having a lateral inflow and no resistance screen.

each of the gas flow pictures after the gas has entered the lateral and the central symmetrical types of apparatus, as illustrated in Fig. 3.

The lateral gas inflow, in this case the gas flow after entering the appara-

tus, continues to move by its own inertia axis horizontally until it encounters the opposite wall of the working chamber (a), as shown in Fig. 3; the impact of the gas against the wall of the apparatus body causes it to disperse along the walls of the working chamber (c) partially in an upward direction and partially horizontally along the lateral section of the walls of the body of the apparatus (b) in a reverse direction to a point where this part of the gas flow was no more in contact with the first section 0-0 along wall

C at the inflow position. Here the gas stream is divided again into 2 components: one directed upward along wall C, and the other sucked in by the inflowing gas creating an intermixing turbulence. Simultaneously, in the space between the side walls of the apparatus body and the main stream of the gas flow, there arises a horizontal circulatory (whirling) movement of the gas flow. A similar gas circulation is formed below and above the inflowing gas stream as illustrated in Fig. 3. The picture of gas flow is the same in all apparatuses regardless of the cross section of their work chamber. However, in the case of round-shaped work chambers the horizontal gas flow along the walls is of greater intensity. Therefore, the limiting relation $(F_k/F_o)_{\text{limit}}$ must be higher than in the case of rectangular work chambers. The actual value of this relation has not been established; however, its orientation values can be calculated with the aid of the following approximation formula:

$$\left(\frac{F_k}{F_o}\right)_{\text{limit}} \approx \frac{5}{N}$$

In the case under study the conditions for introducing air flow into the apparatus were such that the field of velocities at cross section 0-0 were practically uniform and it can be assumed that $N_o = 1.0$. Therefore:

$$\left(\frac{F_k}{F_o}\right)_{\text{limit}} \approx 5$$

and according to formula (4):

$$Z_{s.\text{limit}} = 25 N_a - 1 \quad (5)$$

Along with the gas spreading effected by the chamber walls, a usual flow spreading develops along the entire course of the gas flow beginning at the inflow point, which causes the static gas to intermix in a turbulent manner with the flowing gas [4]. This gas spreading is accompanied by a loss of energy which can be accounted for by the introduction in formula (1) of the value of N_a . Such complications normally arise in the lateral entry types of apparatus; in such cases the value of N_a can be estimated only roughly.

Calculated with the aid of free flow generalizations [4] N_a was assigned a value of the order of 0.25. ^{1/} Accordingly, and on the basis of formula (1):

$$Z_{s.\text{opt}} = 0.25 \times (16)^2 - 1 = 63$$

and on the basis of formula (5):

$$Z_{s.\text{limit}} = 25 \times 0.25 - 1 = 5.25$$

Thus, the optimum value of $Z_{s.\text{opt}}$ is considerably greater than the limit value $Z_{s.\text{limit}}$ and, hence, in such a case a single flat resistor screen cannot be used; instead it becomes necessary to install a system of resistor screens, or if a single resistor screen is used, additional resistance means should be introduced, such as directional blades, panels, honeycomb screens, etc.

The number of screens in the system can be determined with the aid of the following formula:

$$n_p > \frac{\left(\frac{F_k}{F_o}\right)}{\left(\frac{F_k}{F_o}\right)_{\text{limit}}} \quad (6)$$

In the case under study:

$$n_p > \frac{16}{5} \approx 3$$

^{1/} Because of a lack of space all intermediate calculations were omitted.

The resistance coefficient of an individual screen in a system of screens can be determined with the aid of the following formula proposed by this author [1]:

$$Z_{s.syst} = N_o \left(\frac{F_k}{F_o} \right)^{\frac{2}{n_p}} - 1 = (16)^{\frac{2}{3}} - 1 = 5.4$$

This value of $Z_{s.syst}$ correlates with the coefficient of the active area of the resistor screen perforations. ^{1/}

$$f = \frac{F_{opn}}{F_p} \approx 0.56 = 56\%$$

By slightly lowering the requirements for the uniformity of field velocities the number of resistor screens in the apparatus can be limited to 2 ($n_p = 2$); the resistance coefficient of each screen can be determined with the aid of formula:

$$Z_{s.syst} = \left(\frac{F_k}{F_o} \right)^{\frac{2}{n_p}} - 1 = 15$$

in correspondence with which $\bar{f} = 0.32 - 0.325$.

The above considerations show that an even distribution of the gas flow in the lateral gas entry type of apparatus can be attained with not less than 2 resistor screens, each having a resistance coefficient:

$$Z_{s.syst} = 15(\bar{f} \approx 0.32)$$

Central symmetrical downflow gas delivery. In this case the gas flow coming out of the delivery attachments meets an umbrella-shaped deflector, which forces the incoming gas stream to spread out in a horizontal direction; carried by its own inertia it reaches the walls of the apparatus work chamber. Here the gas stream is split into 2 uneven parts. The major part of the gas

^{1/} The relation of the resistance coefficient of flat resistor screens to the coefficient of the active area of the perforations is given by this author in his book [1] as:

$$Z_s = (1 + 0.707 \sqrt{1 - \bar{f}} - \bar{f})^2 \left(\frac{1}{\bar{f}} \right)^2$$

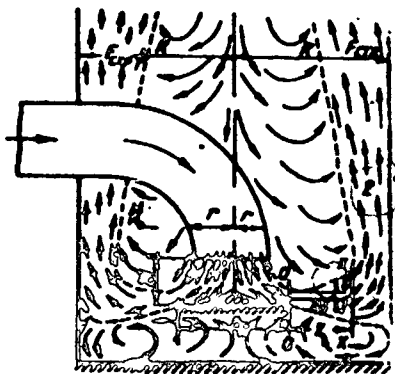


Fig. 4. Schematic picture of the gas flow in the entering section of the work chamber having a central inflow and no resistance screens.

- 1 - Fan-like stream;
- 2 - Ring-like stream.

is directed upwards along the chamber walls forming a circular stream; the lower part moves downward to the bottom in a circulatory movement, as is illustrated in Fig. 4.

The movement of the gas stream, after it leaves the space between the opening of the inflow attachment and the umbrella-shaped deflector and until it reaches the work chamber walls, follows the laws for fan-type flow expansion [5]; after it begins to flow upward it follows the laws for ring-shaped movement, or in approximate accordance with the laws for flat stream flows [4] restricted on one side by a solid wall.

The formation of a ring-shaped stream causes the formation of reverse streams in the central part of the apparatus due to the fact that it sucked in some adjacent gas from the central part of the work chamber, which in turn caused an identical amount of gas to descend from the distant upper levels of the apparatus. In this type of apparatus the initial cross section F_0 is an undefined value; therefore, the calculation of $Z_{s,opt}$ by formula (1), by substituting for F_0 the same values as in apparatuses of lateral gas delivery, will be incorrect. On the other hand, in this case it is possible to determine with a high degree of precision the area of stream F_{ctp} before it spreads out over the resistor screen. Therefore, the determination of the resistance coefficient $Z_{s,opt}$ can be made with the aid of formula (1) substituting F_0 by a calculated value for F_{ctp} and N_a by N_{ctp} (since in the small portion between the mouth of the inflow pipe F_{ctp} and the resistor screen there occur no losses of any consideration). Calculations made with the aid of formulas in the case of the fan-shaped stream [5] (the part between the rim of the umbrella-shaped deflector and the chamber walls) and of the ring-shaped stream [4] (the remaining space) yielded the following values for the test model with a work chamber cross section of $F_k = 0.196 \text{ m}^2$: $F_{ctp} = 0.124 \text{ m}^2$ and for $N_{ctp} = 4 \div 5$. Substituting these values in formula (1):

$$Z_{s,opt} = N_{ctp} \left(\frac{F_k}{F_{ctp}} \right) - 1 =$$

$$(4 \div 5) \left(\frac{0.196}{0.124} \right) - 1 = 9 - 11.5$$

The coefficient of the active resistor screen area which corresponds to the above value is:

$$\bar{f} = 0.36 - 0.38$$

Applying formula (3) to this type of gas entry apparatus, as previously done in the case of the central symmetrical entry type, and making appropriate safety allowance, it can be seen, on the basis of formula (4), that the value for $Z_{s.opt}$ obtained is considerably lower than the limiting value, and consequently in this case the use of a single flat resistor screen with the characteristics found for it ^{1/} would suffice.

The above considerations show that a uniform distribution of the gas flow in the apparatus with a central symmetrical downflow delivery of the gas, can be attained with one resistor screen which has a resistance coefficient of $Z_{s.opt} \approx 11.5$ ($\bar{f} \approx 0.36$).

In cases of a substantial decrease or increase in the value of the resistance coefficient of the screen, as compared with the theoretically calculated one, there can be no assurance of even distribution of the gas flow velocities past the screen. For example, with too high values of $Z_{s.opt}$, i.e., with lowered values of \bar{f} , the character of the field of gas velocities must become directly opposite to those which prevail in the absence of resistor screens, i.e., the field of speeds, will become "reversed".

Tests were made for the determination of flow velocities at various cross section points in the model apparatus in front of the electrodes; studies were also made of the flow spectrum using silk threads. The results are illustrated in Figs. 5 and 6 in the form of distribution curves of dimensionless velocities ω/ω_{cp} at separate cross section diameters (here ω = the speed at a specific point, ω_{cp} = the average cross section velocity). An examination of the curves brought out the following:

1. The spectral diagrams fully confirm the course of gas flow distribution in the absence of gas resistor screens for the lateral inflow and central

^{1/} In fact, from formulas (3) and (4) we receive: $Z_{s.limit} = (6.5)^2 N_a/N_o = 1$, but in this particular case $N_a = N_o = N_{ctp} = 1$; and thus, $Z_{s.limit} = 41$.

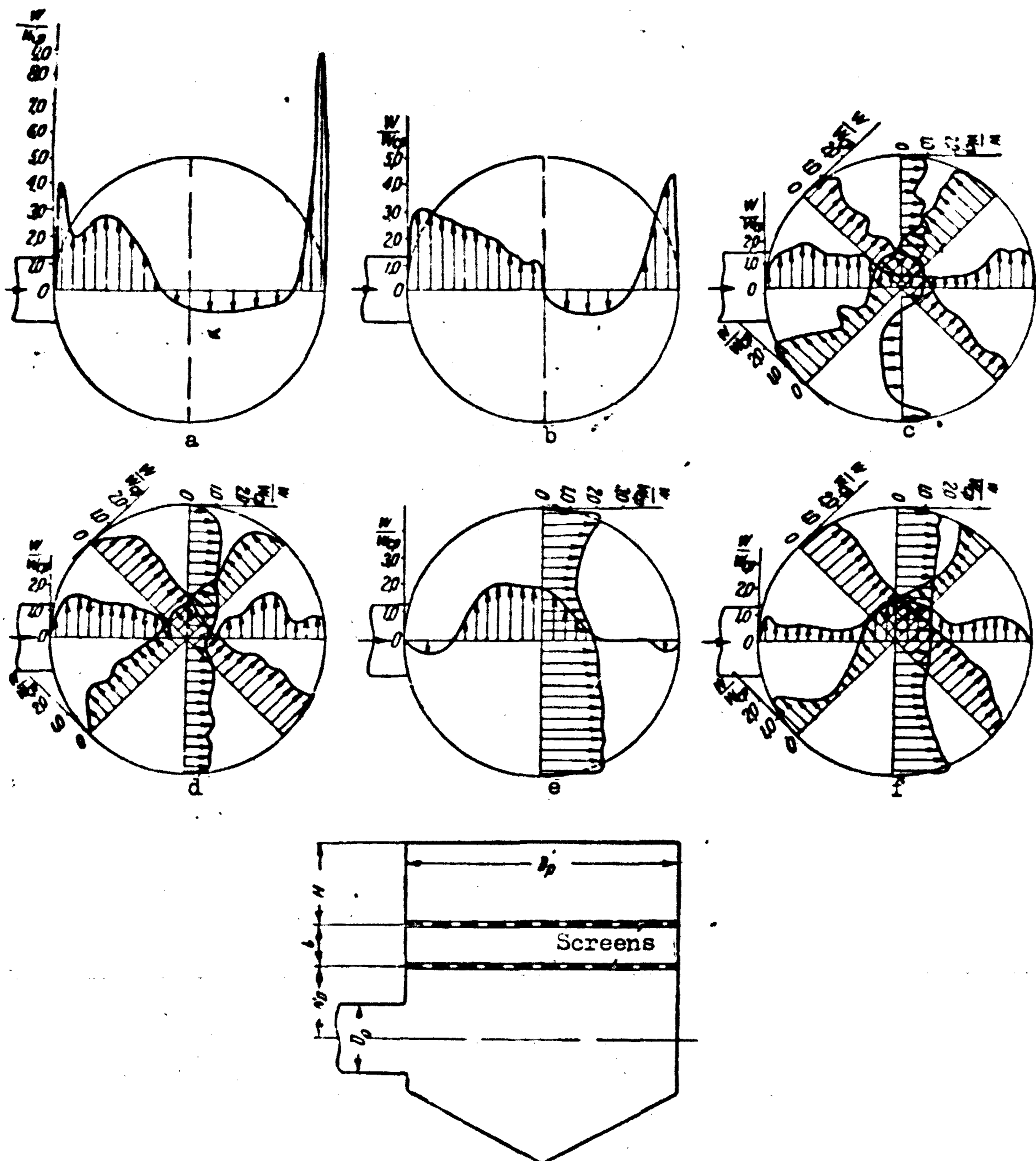


Fig. 5. Lateral gas inflow. Composite diagram of velocity fields in cross section past the resistance screen.

- a - Without the screen; b - One screen $\bar{f} = 0.3$ ($Z_s = 18$); $H_p/D_0 = 1.1$; $H/D_p = 0.18$; c - Two screens $\bar{f}_1 = \bar{f}_2 = 0.3$; $H_p/D_0 = 1.1$; $1/D_p = 0.16$; $H/D_p = 0.32$; d - Two screens $\bar{f}_1 = \bar{f}_2 = 0.3$; $H_p/D_0 = 1.1$; $1/D_p = 0.26$; $H/D_p = 0.22$; e - One screen $\bar{f} = 0.3$; $H_p/D_p = 1.1$; $H/D_p = 0.32$ and a system of laminae; f - Two screens $\bar{f}_1 = \bar{f}_2 = 0.3$; $H_p/D_0 = 1.1$; $1/D_p = 0.16$; $H/D_p = 0.32$ and a system of laminae.

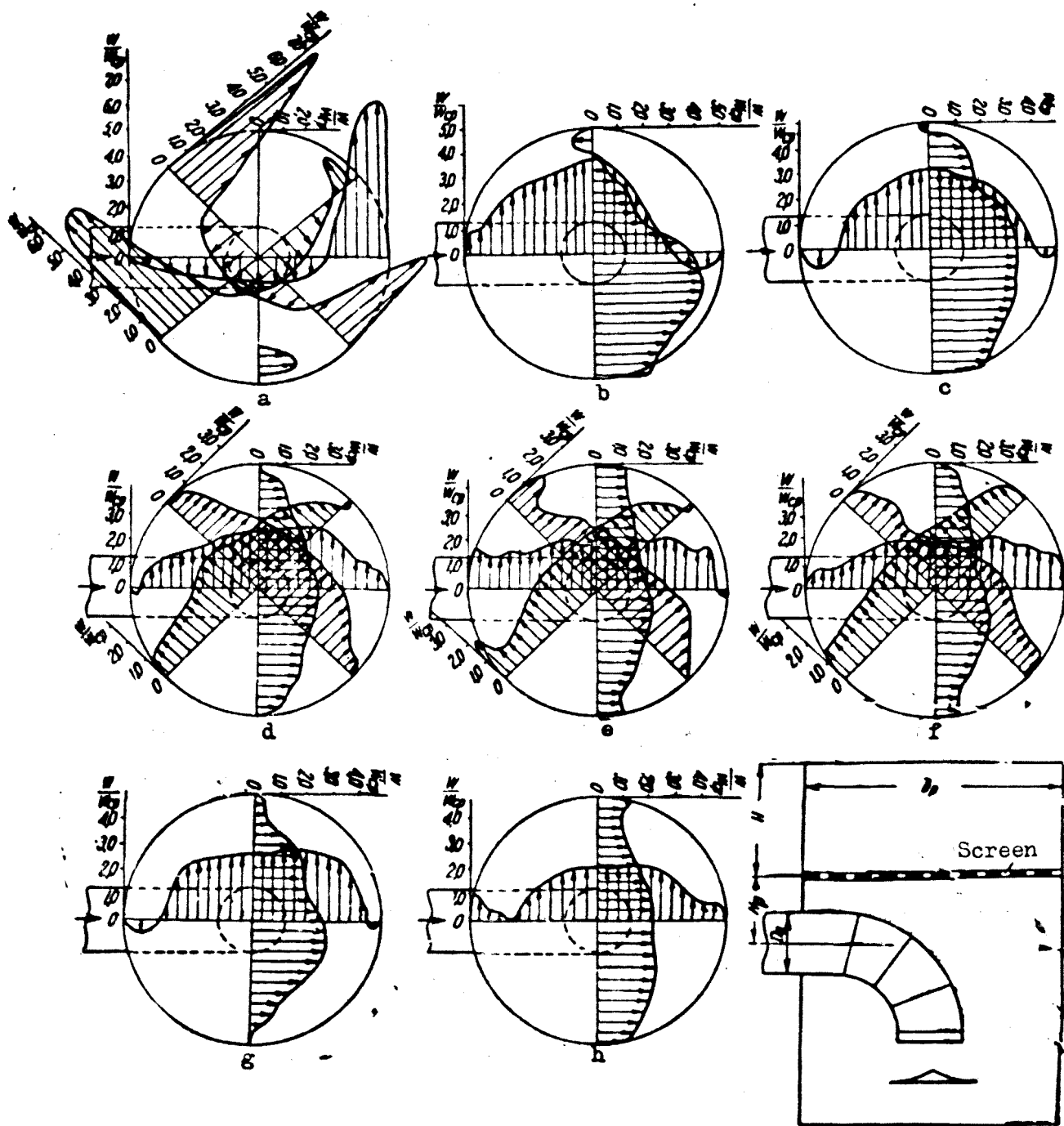


Fig. 5. Central downward gas inflow.. Composite diagram of velocity fields in cross section past the resistance screens.

- a - Without screens; b - One screen $\bar{f} = 0.11$ ($Z_p = 200$); $H_p/D_0 = 1.0$; $H/D_p = 0.41$; c - One screen $\bar{f} = 0.3$ ($Z_p = 0.18$); $H_p/D_0 = 1.0$; $H/D_p = 0.41$; d - One screen $\bar{f} = 0.35$ ($Z_p = 12.5$); $H_p/D_0 = 1.0$; $H/D_p = 0.41$; e - One screen $\bar{f} = 0.35$ ($Z_p = 12.5$); $H_p/D_p = 1.4$; $H/D_p = 0.32$; f - One screen $\bar{f} = 0.25$ ($Z_p = 12.5$); $H_p/D_p = 1.4$; $H/D_p = 0.84$; g - One screen $\bar{f} = 0.42$ ($Z_p = 7$); $H_p/D_0 = 1.0$; $H/D_p = 0.41$; h - Two screens $f_1 = 0.3$, $f_2 = 0.35$; $H_p/D_0 = 1.0$; $l/D_p = 0.1$; $H/D_p = 0.41$.

symmetrical downward inflow type of apparatus (see Figs. 5a and 6a).

2. The installation in a lateral gas delivery type of apparatus of one resistor screen with $Z_s = 18$ ($\bar{f} = 0.30$) instead of 2 screens with computed coefficients $Z_s = 15$, fails to insure an even distribution of gas flow over the entire cross section area of the work chamber. The characteristics of uneven gas distribution are similar to those manifested in the absence of resistor screens (see Figs. 5a and 6a).

3. The installation in a lateral gas delivery type of apparatus of 2 screens with a resistance coefficient approximating those theoretically computed, i.e., $Z_{s.syst} = 18$ at $\bar{f} = 0.30$, effects a thorough, even gas velocity field throughout the entire work chamber cross section. The degree of gas flow uniformity in this case is practically identical for between screen distances of $1/Do = 0.16$ (Fig. 5b) and $1/Do = 0.26$ (Fig. 5a).

4. A combination gas distributing system consisting of a system of directing plates (Fig. 2a) and one resistor $Z_s = 18$ ($\bar{f} = 0.30$), equalizes the gas flow to a high degree (Fig. 5d). However, the equalization would be better if two resistor screens were incorporated and omitting the directing plates.

5. The addition of a set of directing plates to 2 resistor screens resulted in no worthwhile improvement in the even gas flow distribution in the apparatus. However, the directional plates increased the stability of the gas flow and diminished their torsional and slope-like deflections (Fig. 5a).

6. The use of a single screen having an excessive resistance coefficient such as $Z_s \approx 200$ as compared with a low coefficient of the active screen area $\bar{f} = 0.11$ in connection with a central symmetrical downflow type of delivery sharply changes the whole picture of the gas flow. In the absence of resistor screens, maximum gas velocities may develop at the walls of the work chamber accompanied by central negative velocities, or reversed flows (Fig. 6a); the installation of a single resistor screen will shift the maximum gas flow velocities toward the center of the work chamber and the reduced and the negative velocities move toward the periphery (Fig. 6b). A similar set of conditions has been observed by Mr. P. J. Kuleshov [3] in testing an electropitator type C-140 equipped with a resistor screen of an approximate resistance coefficient. This author explained [6] the particular

behavior of the gas flow observed by P. Ya. Kuleshov. The explanation was based on the fact that for the spread of a ring-shaped gas flow over a screen with a high resistance coefficient, the flow must forcefully undergo a sharp change of direction from the periphery of the apparatus to the center (Fig. 7).

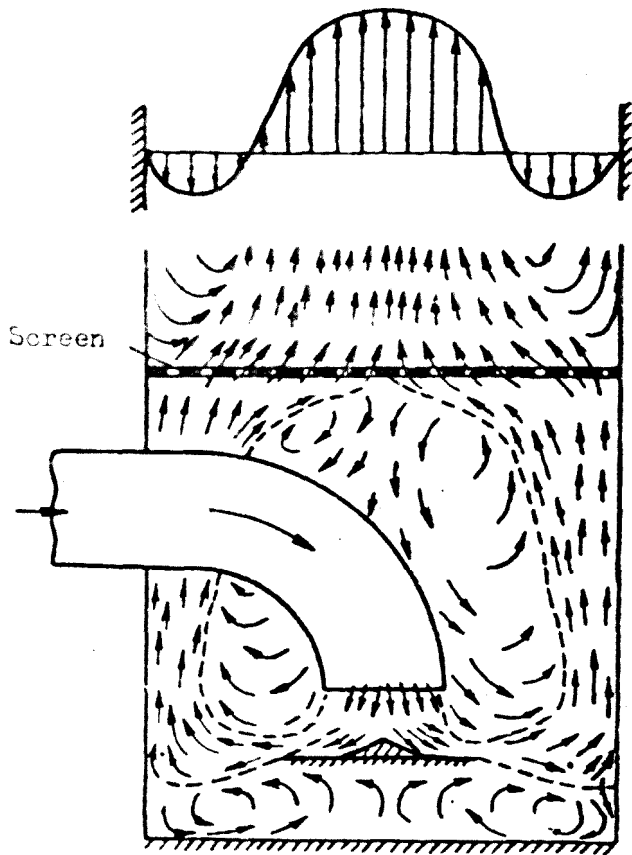


Fig. 7. Schematic picture of the gas flow before and after passing through a high resistance screen for symmetrical downward gas inflow.

This change in the direction of the gas flow is retained by the streamlets into which the major gas flow splits as it passes through the screen perforations, so that in the end the entire stream is diverted from its peripheral to a central direction, thereby creating at some distance from the screen a velocity profile with its maximum at the center. In the case under consideration this maximum velocity reaches the value $(\omega/\omega_{op})_{max} \approx 4.2$. It must be remembered that this flow of the gas stream from the periphery toward the central region is enhanced by the previously described tendency of the circular type of gas flow to converge toward the center even in the absence of a resistor screen.

7. With the reduction in the screen resistance coefficient, i.e., with the increase in the coefficient of its active area of perforations, the entire picture of gas flow velocity distribution at first changes in direction of enhancement. Thus, as it can be seen from Fig. 6b, the installation of a screen with $Z_s = 18$ ($\bar{f} = 0.30$), the maximum of the gas velocities at the center acquires a lower value of $(\omega/\omega_{cp})_{max} = 3.0 - 3.3$, which is 30 - 40% below that of the previous variant. With the installation of a screen having a resistance coefficient close to the one computed, i.e., $Z_s = 12$ ($\bar{f} = 0.35$), the maximum gas velocity decreases to $(\omega/\omega_{cp})_{max} = 2 - 2.2$ (Fig. 6b, c, d, e), which is approximately 50% below that of a screen variant in which $\bar{f} = 0.11$. Zones of negative velocities dis-

appear almost completely, the gas flow becomes stable, the torsion movement is reduced to a minimum.

Where the resistor screen is selected on the basis of theoretically computed results, further lowering of the screen resistance coefficient from the computed value to $Z_s = 7$ ($\bar{f} = 0.42$) creates unfavorable conditions in the velocity field cross sectionally (Fig. 6). This changes the character of the field of velocities causing them to approximate velocity fields of large Z_s and small \bar{f} . This character of the field of velocities results basically from the previously described sucking-in action in the central or axial part of the work chamber in front of the resistor screen. The relatively low screen resistance shifts the gas flow from the periphery to the inner central part of the section.

8. The installation of 2 resistor screens in an apparatus of central symmetrical downflow gas delivery is superfluous. It results in no noteworthy beneficial changes in the field of gas velocities accompanied with the effect of a single screen selected on the basis of theoretical calculations (Fig. 6h).

9. Shifts of the gas flow direction past the resistor screen from the work chamber periphery to its center may be caused by slanting the gas movement in that direction. To prevent the appearance of such slanting gas movement effects and of the occurrence of "reverse" velocity fields ^{1/} it is necessary to install a honeycomb screen above the regular resistor screen (Fig. 8).

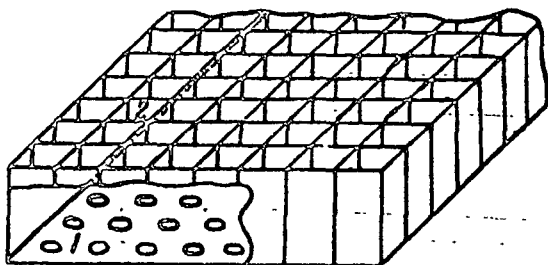


Fig. 8. Schematic drawing of a rectifying resistance screen.

1 - Flat screen; 2 - Honeycomb screen.

Similar results may be achieved by placing the screen supporting beams crosswise in several rows, directly over the resistor screen.

Conclusions.

1. The optimum operative characteristics of gas distributing resistor screens in electrostatic precipitators have been determined by experimentally verified theoretical computations. For any given apparatus of lateral type of gas delivery having a ratio $F_k/F_o = 16$, best gas distribution is achieved by in-

^{1/} For more information on this subject see [2].

stalling 2 resistor screens with a resistance coefficient $Z_s \approx 18$ (coefficient of the active perforated area to the total screen area $\bar{f} \approx 0.30$). The relative distance between the screens should be not less than $l = 0.15 D_o$, and between the first screen and the axis of the gas delivery conduit $H_p = 0.3 D_o$.

In central symmetrical downflow gas delivery, equipped with an umbrella-shaped deflector, best distribution of gas velocities can be achieved with the aid of one screen having a resistance coefficient $Z_s = 11 - 12$ ($\bar{f} = 0.35 - 0.36$). The relative distance of the screen from the axis of the inflow opening must be not less than $H_p = 0.9 D_o$.

2. Replacement in electrostatic precipitators of old screens of high resistance coefficient $Z_s \approx 200$ ($\bar{f} = 0.11 - 0.12$) by a theoretically computed screen with $Z_s = 11 - 12$ ($\bar{f} = 0.35 - 0.36$) lowers the maximum velocity of the gas cross sectionally by approximately 50%, correspondingly increases by more than 100% the productivity, and raises considerably the gas purification coefficient.

Bibliography.

1. И. Е. Идельчик. Гидравлические сопротивления. Госэнергоиздат, 1954.
2. И. Е. Идельчик. К экспериментальной теории принудительной раздачи потока с помощью решеток. «Теплоэнергетика», 1955, № 8.
3. П. Я. Кулешов. Исследование аэродинамики электрофилтра С-140 «Сообщение Гипрококса», Металлургиздат, 1954, вып. XII.
4. Г. Н. Абрамович. Турбулентные свободные струйки жидкостей и газов, Госэнергоиздат, 1948.
5. В. Н. Талиев. Аэродинамика вентиляции, Госстроя издат, 1954.
6. А. П. Андрианов, Е. Н. Тевзоровский и И. Е. Идельчик. Отклики на статью П. Я. Кулешова «Исследование аэродинамики электрофилтра». «Сообщение Гипрококса», 1954, вып. XIII.

Rate of Nitrogen Oxides Absorption by Alkaline Solutions and by Nitric Acid.

V. I. Atroshchenko and E. G. Sedashova.

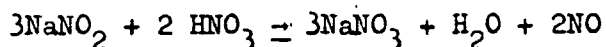
(Khar'kov Polytechnic Institute im. V. I. Lenina).

Zhurnal Prikladnoi Khimii, Vol. 25, No. 11, 1143-1150, 1952.

Absorption of nitrogen oxides by alkaline solutions has gained wide acceptance in the nitric acid industry. The process lowered considerably the cost of absorption, freed the capital ordinarily invested in construction equipment and maintenance of absorption towers, and yielded nitrate fertilizer as a by-product. Of equal importance is the concentrated nitric oxide obtained in the conversion of the alkaline nitrites into nitrates from which concentrated nitric acid can be produced by direct synthesis.

Many basic studies have been conducted in the U.S.S.R. dealing with the problem of nitrogen oxides absorption by alkaline solutions by the present authors [1 - 5], by Zhivotovskii [6] and by Perelman and Kantorovich [7], and with the conversion of alkaline nitrites into nitrates by Gogin and Miniovich [8, 9], Zhivotovskii [10, 11]; in this connection studies by Krichevskii and Kantorovich [12] and Perelman and Strakhova [13] established important and necessary constants. Of basic importance to the future expansion of the nitric acid industry is the enlargement of the so-called alkaline departments, so that greater volumes of nitrogen oxides could be absorbed, accompanied by a corresponding reduction in the absorption of nitric acid.

It has been known that the absorption of nitrogen oxides by water in the production of nitric acid was accompanied by nitric acid decomposition and a partial liberation of nitric oxide which had to be reoxidized repeatedly. Absorption of nitrogen oxides by alkaline solutions prevented the decomposition of nitric acid and eliminated the extra steps of regaining the nitric acid by repeated oxidation. Alkaline solutions absorbed not only NO_2 gas but N_2O_3 [$\text{NO} + \text{NO}_2$] as well; the formation of the latter is accomplished in a considerably shorter time than the formation of nitric oxide. It is pertinent to mention at this point that N_2O_3 (nitrogen trioxide), or an equivalent mixture of $\text{NO} + \text{NO}_2$ were absorbed by alkaline solutions most readily and more rapidly than nitrogen dioxide. The nitrites formed in the process of alkaline absorption were converted into nitrates according to the following equation:



The nitric acid formed as a by-product is returned to the initial stage of the absorption system; it can also be concentrated by centrifugation and can be used in the manufacture of concentrated nitric acid. Nitrogen oxides are absorbed at present by solutions of $\text{Ca}(\text{OH})_2$ instead of NaCO_3 . Absorption of nitrogen oxides by $\text{Ca}(\text{OH})_2$ can produce highly concentrated Ca and N by-products. The heretofore prevailing maximum absorption of nitrogen oxides ranged between 5 - 7%; absorption with solutions of $\text{Ca}(\text{OH})_2$ raised the maximum to 25 - 50%.

On the basis of the above cited studies, these authors [5] computed the slow reaction time and found that with a combination of acid and alkaline absorption of nitrogen oxides there was a minimum reaction time for the entire process and a minimum capacity for the absorption towers for each ratio between the degree of acid and alkaline absorption of nitrogen oxides.

Curves in Fig. 1 show that the maximum reaction rate, and consequently the minimum absorption volume, were attained when the nitric acid yield amounted to 40 - 70% and of nitrates 25 - 55%.

Curves in Fig. 1 are plots constructed on the basis of the following corresponding reactions:

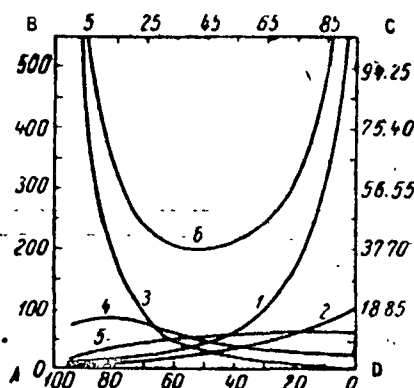
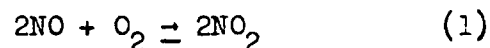


Fig. 1. Functional relation between reaction time and absorption volume on the one hand and the ratio between the resulting nitric acid and sodium nitrate on the other hand.

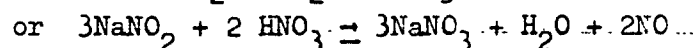
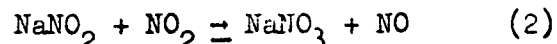
AB - Time in seconds; AD - Percent of HNO_3 ; DC - Reaction volume in m^3 ; BC - Amount of NaNO_3 .

1 - Curve of nitrogen oxide oxidation; 2 - Inversion curve; 3 - Curve of acid absorption; 4 - Curve of nitrogen oxide oxidation in 2nd tower; 5 - Curve of alkaline absorption; 6 - Curve of general process - amounts of treated gas per ton of ammonia per day.

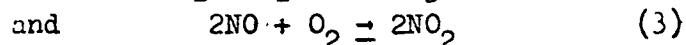
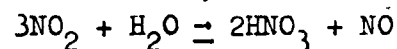
Nitric acid oxidation:



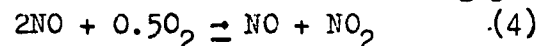
Alkaline nitrites inversion:



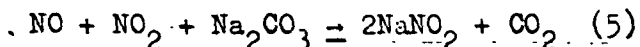
Acid absorption of nitrogen oxides:



Oxidation of the nitrogen oxides to N_2O_3 :

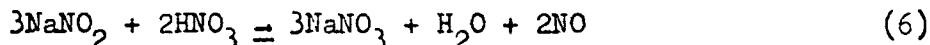


Alkaline absorption of nitrogen oxides:



At a given ratio between acid and alkaline absorption of nitrogen oxides under atmospheric pressure, the absorption volume is reduced from 171 to 40 m^3 per ton of ammonia oxidized in 24 hours.

A different reaction time ratio may have to come into play if consideration is to be given to the question of nitric oxide formed as the result of the inversion reaction:



for the purpose of obtaining concentrated nitrogen tetroxide without returning it for reconversion into acid and salt.

With a total 95% absorption the degree of alkaline absorption of nitrogen oxides must amount to 57%, as can be seen from equation (6), and the degree of acid absorption must be 38% (or in a 3:2 ratio). In all instances the nitric oxide amounts to 2/3 of the nitrate salts. In this case the gas remains in the towers 116 seconds and the absorption volume is 22 m³ per ton of ammonia oxidized in 24 hours. In the case of simultaneous preparation of dilute nitric acid, nitrate salts, and nitric oxide the changed time of the gas remaining in the towers can be determined from curves in Fig. 2.

In connection with the complex processes which take place in the formation of nitric acid and alkaline nitrites from nitric oxide, these authors made an experimental study of the relative velocity of the total nitric oxide conversion (reactions 1, 3, 4 and 5) at different ratios between acid and

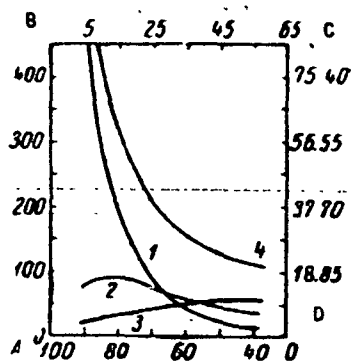


Fig. 2. Functional relation between reaction time and absorption volume on the one hand and the ratio between the resulting nitric acid and sodium nitrates on the other hand at simultaneous removal of alkaline salts of nitric acid formed by the inversion reaction.

AB - Time in seconds; AD - Percent of HNO_3 ; DC - Reaction volume in m³; BC - Amount of NaNO_3 .
1 - Curve of nitrogen oxides oxidation and nitrogen dioxide absorption in acid towers; 2 - Curve of nitrogen oxide oxidation to N_2O_3 ; 3 - Curve of nitrogen oxides absorption in alkaline towers; 4 - Curve of the general process - amounts of treated gas on the basis of 1 ton of ammonia per day. Amount of resulting nitrogen oxide amounted to 2/3 of the produced NaNO_3 .

alkaline absorption. The apparatus used in this study is illustrated diagrammatically in Fig. 3.

The absorption apparatus consisted of 5 individual absorption units (4), performing as independent horizontal towers. Acid or alkali

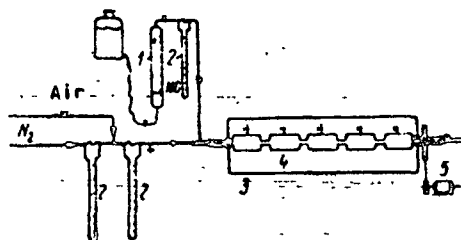


Fig. 3. Plan of the installation employed in studying the rate of nitrogen oxides absorption at different acid and alkaline absorption rates.

1 - Gas meter for nitrogen oxide; 2 - Flow meter; 3 - Constant air temperature chamber; 4 - Absorber apparatus; 5 - Electric motor.

was poured into each absorption unit and the absorption apparatus was rotated with the aid of an electric motor until the absorption unit walls were wetted by the liquid. A mixture of a constant composition of air, nitrogen, and nitric oxide were run into the first absorption unit and then into the others, after which it was discharged into the atmosphere.

The volume of a single absorption unit was 110 ml, and the free volume was 100 ml. The liquid-wetted surface of a single absorption unit was 100 cm². The diameter of the absorption unit was 3.9 cm; with such a combination of dimensions each m³ of the absorber had a surface area of 110 m². Ten ml of acid or alkali were poured into each absorber unit. The nitric oxide liberated during the experiment ranged between 800 ml with high degrees of absorption, and 1200 ml with a low degree of absorption. The chosen ratio of the liquid volume to the nitric oxide volume was such at which no marked changes could take place in the concentration of the liquid, but which could increase the accuracy of the analytical results. The gas volume was regulated so as to obtain a mixture containing 10% of NO, 9.5% of O₂, and 81.5% of N₂. The nitrous gases remained in the absorption apparatus 50 to 300 seconds. The absorption system was placed into a constant temperature chamber kept at 25° C. During the first experiment, acid was poured into all the absorber units. In subsequent experiments, in place of the acid, alkaline solutions were poured first into one, then into 2 absorbers, etc., beginning with the end of the absorption apparatus, thereby creating different ratios between the acid and the alkaline absorption. The distribution of the acid concentration in g/li in the absorption units was as follows: 1 - 610.3; 2 - 536.4; 3 - 358.9; 4 - 222.7 and 5 - 85.5. The distribution of the NaOH concentration in g/li in the absorption units was: 5 - 32.6; 4 - 112; 3 - 177; 2 - 254.9 and 1 - 396.1.

Determination of the degree of absorption was attained by analyzing the liquid phase for total acidity or alkalinity. The results were checked by several parallel experiments and also by gas analysis. Thus, this set-up accorded with all the conditions of the technological process, with the exception of the linear gas velocity, which in the experimental tests was several times below the ones prevailing under industrial conditions.

Results of the experiments are listed in Table 1. Curves in Figs. 4, 5 and 6 are plots of data listed in Table 1; they illustrate the changes in the absorption rate of nitrogen oxides corresponding to changes in the degree of acid and alkaline absorption.

T A B L E 1.

Changes in the degree of nitrogen oxides absorption in the absorbers at different ratios between acid and alkaline absorption, at different time-duration of the gas remaining in the absorbers and at different rates of gas flow.

(Temperature 25°; concentration of NO = 10%, and of O₂ = 9.5%;
τ = absorption in seconds; α = percent of absorption).

Absorber No.	1	2	3	4	5
Rate of gas flow 114.6 (in cm ³ /min) or 12.6 m ³ /hour					
Acid absorption					
τ	52.5	107.6	164.0	221.0	285.0
α	6.3	30.1	49.2	61.8	71.9
τ	52.5	107.6	164.0	221.0	288.0
α	5.9	28.8	48.6	61.4	81.6
τ	52.5	107.6	164.0	223.0	292.0
α	6.1	29.4	48.3	93.7	96.4
τ	52.5	107.6	170.0	229.0	293.0
α	6.4	30.4	58.7	97.0	98.2
τ	52.5	112.7	171.0	230.0	293.0
α	6.1	80.9	95.4	99.5	99.5
τ	57.0	115.0	172.0	230.0	293.0
α	91.1	99.0	101.0	101.5	101.5
Alkaline absorption					
Rate of gas flow 344 (in cm ³ /min) or 37.8 m ³ /hour					
Acid absorption					
τ	17.5	35.6	54.3	72.7	92.3
α	4.1	21.6	40.6	53.6	62.3
τ	17.5	35.6	54.3	72.7	93.1
α	3.6	21.0	40.5	53.3	70.5
τ	17.5	35.6	54.3	74.8	94.5
α	3.9	20.2	39.7	71.8	84.9
τ	17.5	35.5	56.1	75.7	95.0
α	4.2	21.8	77.4	87.5	91.1
τ	17.5	37.5	56.8	76.2	95.5
α	3.7	73.5	88.1	94.8	96.7
τ	18.8	38.1	57.3	76.5	95.8
α	81.6	94.1	98.1	100.3	100.3
Alkaline absorption					

Rate of gas flow 688 (in cm³/min) or 75.6 m³/hour

Acid absorption

T	8.72	17.52	26.9	36.3	46.8
a	0.00	7.10	29.3	44.6	54.1
T	8.72	17.52	26.9	36.3	47.2
a	0.00	7.10	29.1	43.9	58.0
T	8.72	17.52	26.9	36.8	47.5
a	0.00	6.80	28.4	58.3	67.0
T	8.72	17.52	27.5	37.3	47.8
a	0.00	6.70	56.2	72.8	81.3
T	8.72	18.40	28.1	37.8	48.5
a	0.00	62.10	78.6	86.4	88.1
T	9.35	19.00	28.6	38.3	49.0
a	72.90	93.00	96.1	98.2	99.3

Alkaline absorption

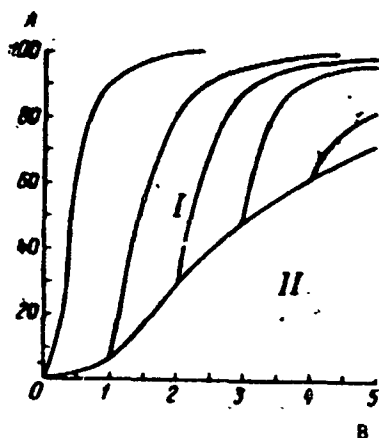


Fig. 4. Degree of nitrogen oxides absorption at different acid and alkaline absorption ratios at gas volume rates of 12.6 m³/hour. Temperature 25°, concentration of nitrogen oxide 10%, oxygen 9.5%.

A - Percent of absorption; B - Number of absorbers.

I - Range of alkaline absorption; II - Range of acid absorption.

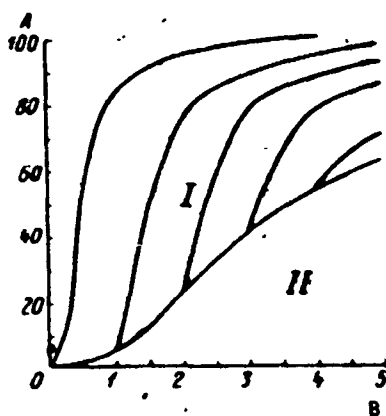


Fig. 5. Degree of nitrogen oxides absorption at different acid and alkaline absorption ratios at gas volume rates of 37.8 m³/hour. Other notations same as in Fig. 4.

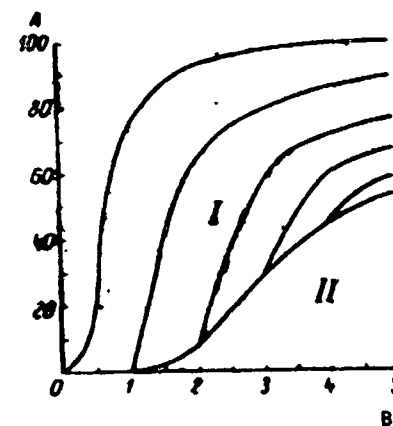


Fig. 6. Degree of nitrogen oxides absorption at different acid and alkaline absorption ratios at gas volume rates of 75.6 m³/hour. Other notations same as in Fig. 4.

Data in Table 1 show that the degree of nitrogen oxides absorption was determined largely by the time the gas remained in the absorption unit, which,

in its turn determined the degree of NO oxidation, and in particular by the linear velocity of the gas, by virtue of its effect on the degree of nitrogen oxides absorption. Thus, an increase in the time the gas remained in the absorber units from 47 to 285 seconds, and a consequent reduction in the linear gas velocity to 1/6 of the initial, resulted in an increase in the total nitric acid yield from 54.1 to 71.9%. This indicated that a comparison of the rates of nitrogen oxides absorption, as a function of the ratios of acid to alkaline

absorption, must be made at identical linear velocities. Replacement of acid absorption by alkaline sharply increased the absorption rate of the (higher) nitrogen oxides. Thus, at volume velocity of $12.6 \text{ m}^3/\text{hour}$, or 114.6 ml/min , the total degree of the (higher) nitrogen oxides absorption in a nitric acid absorption unit amounted to 71.9%. Replacement of the 5th acid absorption unit by an alkaline increased the degree of absorption of the (high) nitrogen oxides to 81.6%. Replacement of the acid solutions in the 5th and 4th absorption units by alkaline solutions increased the absorption degree of the (higher) nitrogen oxides to 96.4%. Similar replacement in the 5th, 4th and 3rd absorber units increased the absorption degree to 98.2%, and similar replacement in the 5th, 4th, 3rd and second units raised the absorption to 99.5%.

When alkaline absorbing solutions alone were used, 99% of the (higher) nitrogen oxides were absorbed in as few as 2 absorber units, as compared with only 30% in the case of acid absorber solutions. Approximately the same ratio in the rates of acid and alkaline absorption was noted at other gas flow velocities. The fact that the difference in the absorption rates of the (higher) nitrogen oxides by acid and alkaline solutions increased sharply with the change from low to higher concentrations of the higher oxides is of great significance in the absorption of (higher) nitrogen oxides by nitric acid solutions. The reaction time in the region of the low degree of absorption can be determined approximately by the equation:

$$\tau = a + \frac{1}{K} \ln \frac{1}{1 - \alpha} \quad (7)$$

where τ is the time in seconds; α the degree of absorption of the (higher) nitrogen oxides; a is the lag in the absorption of the (higher) nitrogen oxides after their oxidation in seconds; and K is the reaction velocity constant. In absorption of the (higher) nitrogen oxides by NaOH solutions the reaction time at high absorption degree can be determined approximately from the equation:

$$\tau = \frac{1}{K} \ln \frac{1}{1 - \alpha} \quad (8)$$

Data in Table 2 present the values of a and K for acid and alkaline absorption. In addition, the numerical value of a depends on the gas and acid concentration. These data can be used for the determination of the relative rate of nitric oxide conversion into nitric acid and alkaline nitrites.

T A B L E 2.

Values of a and K at 25°C and $110\text{ m}^3/\text{m}^3$ of specific inflow offset surface area.

Gas flow volume rate m^3/hour	Absorber HNO_3		Absorber NaOH
	a in seconds	K	K
12.6	40.0	0.00533	0.0412
37.8	17.5	0.01392	0.0778
75.6	15.0	0.02790	0.1193

At greater linear gas velocity, such as prevailed under industrial conditions, the absorption rate of the higher nitrogen oxides is controlled by the oxidation rate of nitric oxide. The latter rises with the increase in the nitric oxide and oxygen concentration and rapidly declines at low gas concentrations. Under such conditions the reaction velocity is determined by the speed of the nitrogen oxides dissolution in the liquid, as can be seen from equation (7).

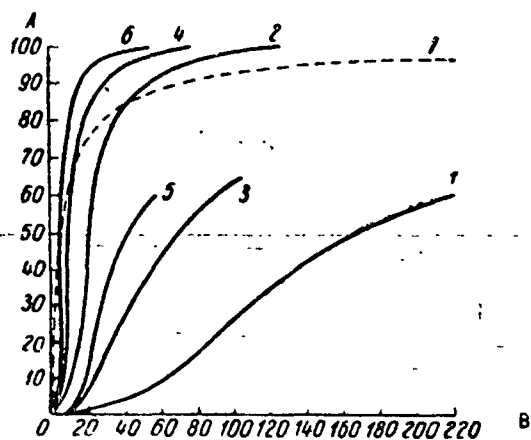


Fig. 7. Ratio of rates of nitrogen oxide and nitrogen oxides oxidation in alkaline and nitric acid solutions.

A - Treatant in %; B - Time in seconds.
1 & 2 - Corresponding degree of acid and alkaline absorption at gas flow volume rate of $12.6\text{ m}^3/\text{hour}$; 3 & 4 - Ditto at $37.8\text{ m}^3/\text{hour}$; 5 & 6 - Ditto at $75.6\text{ m}^3/\text{hour}$; 7 - Nitrogen oxide oxidation to nitrogen dioxide; curve 7 was constructed on the basis of the course of trimolecular oxidation of nitrogen oxide in a mixture containing 10% NO in 9.5% of O_2 .

A direct study was made of the effect of specific gravity of the alkaline absorber solution on the change in volume of the absorption apparatus; the results showed that 70% absorption of the higher nitrogen oxides required 5 absorbers; whereas the same degree of nitrogen oxides absorption by alkaline solution was attained with one-half the absorber solution volume of one unit.

The functional relationships between the rates of nitric oxide oxidation and the absorption of the oxides of nitrogen by nitric acid and by alkaline solutions are plotted in the form of curves in Fig. 7.

For efficient absorption of nitrogen oxides by solutions of nitric acid, the nitric oxide must be oxidized to the point at which the NO_2 concentration exceeded the NO_2 nitric acid balance concentration. For 47.5% concentration of the acid in the first absorber unit the nitrous gas containing 10% NO and 9.5% O_2 must be oxidized to the extent of 55%. Therefore, prior to the gas oxidation in the initial stage the acid may be reduced by the nitric oxide; and only when the acid will

have been reduced to 55% will the NO_2 absorption by the acid become active again. The time required to reach such degree of nitric oxide oxidation is the factor which determines the delay in the absorption of the nitrogen oxides (value a). This also explains the low degree of nitrogen oxides absorption in the first absorber unit.

In alkaline absorption, on the other hand, the formed nitrogen dioxide is absorbed together with an equivalent amount of nitric oxide. This fact is responsible for the sharp increase in the absorption rate of the nitrogen oxides in an alkaline absorber.

In nitrogen oxides absorption by nitric acid solutions, the process is controlled in the initial stage by the rate of nitric oxide oxidation and later by the absorption rate of nitrogen oxides and at the end of the process, again, by the rate of nitric oxide oxidation, as indicated by the curves depicted in Fig. 7.

The data presented above show that under the same conditions the absorption rate of nitrogen oxides by alkaline solutions is many times greater than absorption rate attained with nitric acid solutions.

The basic data produced by this study show that with an increase in the rate of alkaline absorption of nitrogen oxides and a corresponding decrease in the rate of acid absorption, the reaction volumes will be lower than those plotted in Figs. 1 and 2.

Conclusions.

1. The results of the study demonstrated that a functional relationship existed between the degree of nitrogen oxides absorption and the increase in the specific gravity of alkaline absorbers, accompanied by a corresponding reduction in the degree of nitric acid absorption.

2. The results also established that at the combined production of nitric acid and sodium nitrate by the method of increasing the degree of nitrogen oxides absorption by alkaline solutions, the reaction volume can be reduced considerably.

Bibliography.

- [1] В. Атрошенко. Технология азотной кислоты. Госхимиздат (1949). —
- [2] В. Атрошенко. Укр. хим. ж. 3, 215 (1935) и 10, 444 (1937). — [3] В. Атрошенко, ЖПХ, 2, 167 (1939). — [4] В. Атрошенко, ЖХП, 1, 26 (1938). —
- [5] В. Атрошенко, Тр. Харьк. ХТИ, 5, 75 (1945) и 6, 29 (1946). — [6] А. Животовский, Химстрой, 3, 158 (1935). — [7] Перельман и Л. Канторович, ЖХП, 6, 3 (1940). — [8] В. Гогин и М. Минянович, Химстрой, 9, 2470 (1933). —
- [9] М. Минянович, ЖХП, 2, 108 (1937). — [10] А. Животовский, ЖХП, 20, 1221 (1936). — [11] А. Животовский, Химстрой, 7, 380 (1934). — [12] И. Кричевский и Л. Канторович, ЖХП, 2, 139 (1935). — [13] С. Перельман и В. Страхова, ЖХП, 12, 28 (1938).

Bubbling Air Through Viscous Fluid.

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Determination of pressure drop in the bubbling process is necessary for the hydraulic calculation of reactivation columns, bubble towers, bubble absorbers, gas purification scrubbers, distilling columns and other similar apparatuses in the chemical and food industry. Hydrodynamics of bubble apparatuses was studied by Stabnikov [1, 2], Ramm [3], Zhavoronkov and Furmer [4], Usyukin and Axelrod [5], Axelrod and Dil'man [6-9], Pozin, Mukhlenov, Tumarkina and Tarat [10], Aerov and Darovskikh [11] and others. Experiments of the above authors were conducted in relation to operation of bubble towers or foam apparatuses with height of fluid layer often not exceeding 5 cm. The following bubble systems were used: water-steam [1, 2], low-concentration salt solutions-air [10], water-air [10, 7], ethyl alcohol-air [7], water-nitrogen [9], liquid air-air [5], organic solvents-air [9] and other systems of low viscosity in liquid phase. Because of the low liquid phase viscosity due consideration was not given to viscosity effect on pressure drop in the bubbling process, and many authors entirely disregarded viscosity in making hydrodynamic calculations of bubbling processes. There are practically no data on bubbling through thick viscous fluid layers.

In this paper results are presented of a study of air bubbling through an aqueous glycerine solution layer of 1 to 80 centipoises viscosity and 0.3 to 70 cm thick, using a laboratory column; equations were derived for the calculation of pressure drop developed in the process of bubbling at given fluid viscosities. Glycerine solution was chosen for these experiments because changes in viscosity occurring in this liquid phase within wide limits had a negligible effect on surface tension and specific gravity of the fluid (γ_{fl}).

The course of the process. At high rate gas feeding into the bubbler, placed deep below the surface of the liquid phase, an emulsion is formed by the rising gas bubbles, which accumulate over the bubbler. Under such circumstances the hydraulic resistance which the gas layer has to overcome depends upon the hydrostatic pressure of the emulsion column and the hydro-

dynamic resistances created during the gas passing through the liquid phase layer. The hydrostatic pressure is determined by the specific gravity of the emulsion, which depends upon the degree of liquid saturation with the gas. Saturation of the liquid with the gas reduces the specific gravity of the emulsion and thereby decreases its hydrostatic pressure. But, an increase in the saturation requires an increase in the gas supply rate, which, in turn, creates increased hydrodynamic resistance. Thus, in the process of bubbling hydrostatic pressure and hydrodynamic resistance act as functions of one another: increase in hydrostatic pressure automatically leads to a decrease in hydrodynamic resistance. Both factors act as functions of the fluid viscosity μ , in kg/sec/m², and of the gas quantity supplied V , in m³/sec, provided the thickness or height of fluid layer H in m, the fluid's specific gravity γ_{fl} in kg/m³, specific gravity of gas γ_g in kg/m³, the diameter of the bubbling column D in m, the diameter of the bubbler d in m, the fluid volume in the column V_{fl} in m³ and the surface tension σ in kg/m remained constant.

A study of viscosity effect on the bubbling process at constant rate of gas supply established that an increase in fluid viscosity increased hydrodynamic resistances, decreased specific gravity of the gas emulsion and changed the course of the bubbling process. Change in viscosity automatically results from an increase in the hydrodynamic resistance, as can be seen from the following equation:

$$\Delta P_g = \lambda \cdot \frac{l}{d} \cdot \frac{w^2}{2g} \gamma \quad (1)$$

where ΔP_g denotes hydrodynamic resistance in kg/m², λ denotes the friction coefficient, l the distance of gas movement in m, d the bubble or gas jet diameter in m, w the rate of the gas flow in m/sec, g gravity acceleration in m/sec². It is known that $\lambda = \phi(Re)$, where Re is the Reynolds criterion. Hence, all other values being constant, $\lambda = \phi(\mu)$ and $\Delta P_g = \phi(\mu)$. A change in specific gravity of the gas emulsion with a change in fluid viscosity is connected with an increase in the diameter of the rising bubbles. For the determination of the bubble diameters in relation to viscosity the assumption is made that during the bubbling process a transitory intermediate state comes into being; with such an assumption in mind Zrelov's [12] generalization can be used for the calculation of bubble diameters.

$$w = \sqrt[n]{\frac{\pi \cdot d^{3-n} \cdot (\rho_1 - \rho) \cdot g}{6 \cdot K_n \cdot \nu^{2-n} \cdot \rho}} \quad (2)$$

where d stands for the bubble diameter in m , ρ_1 and ρ for the densities of the fluid and gas in $kg/sec^2/m^4$, K_n and n are coefficients related to the rate of bubble movement, ν is the coefficient of kinematic viscosity in m^2/sec .

For the transitory stage and with $Re = 25$ to 350 , according to Zrellov's data [12], $K_n = 10 \cdot \pi/8 = 3.92$, $n = 1.5$. Under such conditions equation (2) assumes the following form:

$$w = \sqrt[1.5]{\frac{\pi \cdot d^{1.5} \cdot (\rho_1 - \rho) \cdot g}{6 \cdot 3.92 \cdot \nu^{0.5} \cdot \rho}} \quad (3)$$

On the basis of experimental data of previous investigators presented by Ramm [3], the speed of rising gas bubbles $d > 6$ mm increases only slightly with increase in the diameter and constitutes about 0.25 m/sec. Consequently, with a certain approximation allowance, it can be accepted that $w = \text{const}$. It was previously shown that $\rho_1 = \text{const}$. and $\rho = \text{const}$.; accordingly:

$$d = K \cdot \sqrt[3]{\nu} \quad (4)$$

where K is a numerical coefficient of all the constant values: π , ρ_1 , ρ , g and others. For different diameters d_1 , d_2 and different viscosities μ_1 , μ_2 use can be made of the following equations:

$$d_1 = K_1 \cdot \sqrt[3]{\mu_1} \quad (5)$$

$$d_2 = K_2 \cdot \sqrt[3]{\mu_2} \quad (6)$$

It was previously indicated that $K_1 \approx K_2$, hence:

$$\frac{d_2}{d_1} = \sqrt[3]{\frac{\mu_2}{\mu_1}} \quad (7)$$

Assuming that $d = 1$ cm and $\mu_1 = 1$ centipoise, determinations can be made of bubble diameters at $\mu_2 = 10$ centipoises, $\mu_3 = 20$ centipoises, etc. The sizes of gas bubbles, in relation to viscosity, calculated in accordance with generalization (7) are presented below:

Viscosity in centipoises	1	10	20	30	40	50	60	70
Diameter of bubble (in cm)	1	2.16	2.72	3.11	3.43	3.69	3.91	4.13

Reynolds criterion in the case of bubble movement of above values is within the limits of 150 - 250, which corresponds to stage III of the transitional movement course.

The above calculation is only approximate since single bubble movement does not exist even when gas is bubbled through fluid phases of very high viscosity. However, this calculation demonstrates the increase in the bubble diameter with increase in fluid viscosity, which can be clearly observed during the tests; this actual increase in the size of bubbles is greater than indicated by the values obtained according to equation (7).

Changes in the bubbling system created by increase in viscosity lead to loss in kinetic energy of the gas jet in overcoming the increased hydrodynamic resistance. The general picture of changes appears as follows: in the initial low viscous fluid a stream-like movement of gas is formed in the shape of a clearly defined torch as shown in Fig. 1. The hydrodynamic resistance in the case under consideration depends on the fluid viscosity; therefore, with the increase of the latter, the rate of gas flow diminishes correspondingly while its incoming volume remains constant; as a result, the cross section of the torch-like or funnel-shaped gas stream increases, simultaneously minor individual jets of the torch flow together and the torch-like formation begins to break up into gas bubbles.

With the increase in the fluid viscosity the torch-like jet gradually disintegrates and, at sufficiently high viscosity, it completely disappears,



Fig. 1. Gas bubbling through low viscosity fluid.

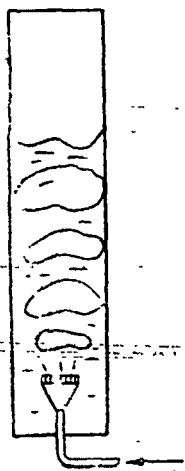


Fig. 2. Gas bubbling through high viscosity fluid.

transforming into large bubbles (Fig. 2). Consequently, as the fluid viscosity increases the system of the bubbling process must become transformed from the stream to the bubble system. This was substantiated by our experiments.

Change in the rate of gas inflow causes changes in hydrodynamic resistance, in specific gravity of the gas emulsion and in the performance of the bubble system. Specific gravity of the emulsion is determined by the degree of fluid

saturation with gas, which increases with the increase in rate of gas inflow. The increase of hydrodynamic resistance depends upon the increase in the rate of the gas flow in the medium. At constant viscosity the bubbling process changes from a continuous stream into a succession of bubbles as the gas supply decreases, and vice versa. Hence, a change in the rate of gas inflow must noticeably affect the hydrodynamic system of the bubbling process.

The suggested bubbling system characteristically presents 2 extreme possibilities: bubbling through a low-viscosity fluid with a clearly defined torch-like gas jet, and bubbling through a high-viscosity fluid with an almost completely disintegrated jet and the formation of single large gas bubbles. It follows from the aforesaid that an increase in the fluid viscosity created the following paradoxical conditions: an increase in the hydraulic resistance as the gas flows through the fluid phase, and a decrease in the hydrostatic pressure of the gas emulsion column over the bubbler due to the lowered specific gravity of the emulsion. Depending upon the prevalence of one or the other of these factors, the total hydraulic resistance in the process of bubbling, with viscosity rising, may increase or decrease. The effect of viscosity becomes more pronounced as the height or thickness of the fluid layer increases, which is a consequence of the very nature of such forces, since their absolute value increases with the increase in the surface and the path of their action. With low height (thickness) of the fluid layers the viscosity effect will be considerable.

The proposed bubbling system points to some means of deriving equations for the calculation of hydraulic resistance of bubbling apparatuses. The following is offered as a general equation:

$$\Delta p = \Delta p_1 + \Delta p_2 + \Delta p_3 \quad (8)$$

where Δp is the hydraulic resistance of a bubbling installation in kg/m^2 , Δp_1 hydraulic resistance of the bubbler screen in kg/m^2 , Δp_2 resistance resulting from the forces of surface tension in kg/m^2 , Δp_3 resistance of the fluid layer in kg/m^2 .

The value of Δp_1 is determined with the aid of the usual equation for the calculation of different types of partial resistance [10, 13].

The nature of surface tension forces in relation to the systems under study gives rise to the following equation:

$$\Delta p_2 = \phi(\sigma \pi) \quad (9)$$

where σ is surface tension in kg/m, π wet screen perimeter in m.

Evaluating the functional interrelations in equation (9) and with the aid of the theory of differential values the following equation is derived:

$$\Delta p_2 = A \cdot \frac{\sigma}{\pi} \quad (10)$$

where A is dimensionless coefficient.

Equation (10) has been verified by many authors [6, 10].

The value of Δp_3 can be derived from the following equation:

$$\Delta p_3 = H \cdot \gamma_{fl} \cdot (k + c) \quad (11)$$

where k is a dimensionless coefficient which takes into account the effect of viscosity on hydrodynamic resistance of the medium layer, c is a dimensionless value, which takes into account the effect of fluid saturation with gas.

Other values remaining constant, fluid saturation with gas will depend on the gas volume passing through the fluid layer.

In this study the volume of gas (n) bubbled through the fluid phase is derived with the aid of the following equation:

$$n = \frac{V_{fl}}{V_{sec}} \left(\frac{sec \cdot m^3}{m^3} \right) \quad (12)$$

where V_{fl} is the volume of fluid passing over the area of the bubbler screen F .

In the present study it can be assumed that:

$$V_{fl} = H \cdot F \quad (13)$$

$$c = B \cdot \left(\frac{n}{n_0} \right)^{k_1} \quad (14)$$

where n is the quantity of gas bubbled through the fluid phase, n_0 is the initial gas volume, B is the proportionality coefficient, k_1 is the experimental coefficient.

In determining the value of coefficient k the fact should be taken into consideration that in the bubbling process the effect of viscosity on value Δp_3 is invariably connected directly with the amount of gas (n) bubbled through the fluid phase.

The functional relationship of the basic physical principle of the process of bubbling can be expressed by the following equations:

$$k = \phi(n, \nu, g, D, d) \quad (15)$$

where ν is the coefficient of the kinematic fluid viscosity in m^2/sec .

If the functional relations of (15) are expressed in the form of an experimental equation:

$$k = A \cdot n^a \cdot v^b \cdot g^c \cdot D^e \cdot d^m \quad (16)$$

and the differential values are substituted as shown below:

$$0 = [\text{sec}]^a \cdot \left[\frac{M^2}{\text{sec}} \right]^b \cdot \left[\frac{M}{\text{sec}^2} \right]^c \cdot [M]^e \cdot [M]^m \quad (17)$$

then it will follow that:

$$0 = \text{sec}^{a-b-2c} \cdot M^{2b+c+e+m} \quad (18)$$

Assume that $e = 0$ and $m = 0$. Then $a = 3/2 c$; $b = -c/2$. For the determination of the interrelation between e and m , assume that $a = 0$; $b = 0$; $c = 0$, in which case $e = -m$. As a result, the following is derived:

$$k = A \cdot \left(\frac{n^{1.5} \cdot g}{v^{0.5}} \right)^c \cdot \left(\frac{D}{d} \right)^e \quad (19)$$

introducing into the calculation the following m value:

$$m = \frac{1}{n} = \frac{V_{\text{sec}}}{V_{f1}} \left[\frac{1}{\text{sec}} \right]$$

and designating it as the specific rate of gas inflow, then equation (19) will become as follows:

$$k = A \cdot \left(\frac{g}{m^{1.5} \cdot v^{0.5}} \right)^c \cdot \left(\frac{D}{d} \right)^e \quad (20)$$

where

$$\frac{g}{m^{1.5} \cdot v^{0.5}} = \frac{g^{0.5} \cdot \gamma^{0.5}}{m^{1.5} \cdot \mu^{0.5}} = \text{Re}_\sigma$$

Re_σ , the dimensionless value, will be designated as the Reynolds bubbling criterion. $D/d = G$ is the criterion of geometric similtude. To prove that Re_σ , by the nature of physical values inherent to it, is analogous to Re , m must be evaluated as shown below:

$$m = \frac{V_{\text{sec}}}{V_{f1}} = \frac{w_g \cdot F}{H \cdot F} = \frac{w_g}{H} \quad (21)$$

where w_g is the rate of gas movement over the entire surface area of the bubbler screen in m/sec. Substituting the derived value of m the following is obtained:

$$\text{Re}_\sigma = \frac{g \cdot H^{1.5}}{w^{1.5} \cdot v^{0.5}} \quad (22)$$

A comparison of Re_σ value with the usual $Re = w \cdot l/r$, where l is the length of the flow stream to be determined, discloses that H is the determining dimensional factor in the bubbling process, and that the appearance of g is predetermined by the presence of a free rise of gas bubbles. Hence, Re_σ is to a degree analagous to Re .

Substituting in equation (11) the determined values for K and c and with the aid of some simple conversions, the following equation can be derived:

$$\frac{\Delta p_3}{H \cdot \gamma_{fl}} = A \cdot (Re_\sigma)^c \cdot G^e + B \cdot \left(\frac{m}{m_0}\right)^{k_1} \quad (23)$$

where $\Delta p_3/H \cdot \gamma_{fl} = E$ is a dimensionless value characteristic of hydrodynamic turbulence in bubbling processes.

Finally, the following criterion type of equation is derived:

$$E = A \cdot Re_\sigma^c \cdot G^e + B \cdot \left(\frac{m}{m_0}\right)^{k_1} \quad (24)$$

which holds true in cases where an increase in fluid viscosity lowers the hydraulic resistance of layer Δp_3 .

Next, an equation is derived for cases where an increase in fluid viscosity increases the hydraulic resistance in the course of gas bubbling. In this connection it should be noted that $b = -c/2$, $a = 3/2 c$, and hence, $c = -2b$, $a = -3b$.

Substituting the determined coefficients in equation (16) the following equation is obtained:

$$k = A \cdot \left(\frac{v \cdot m^3}{g^2}\right)^b \cdot \left(\frac{p}{d}\right)^e \quad (25)$$

In equation (25) $r \cdot m^3/g^2 = 1/Re_\sigma^2$. Consequently, the general form of equation (11) becomes:

$$E = A_1 \cdot (Re_\sigma^{-2})^b \cdot G^e + B_1 \cdot \left(\frac{n}{n_0}\right)^{k_1} \quad (26)$$

Equation (26) holds true in cases where the increase in fluid viscosity increases the hydraulic resistance of the layer during the bubbling process.

Experimental part. The experimental part of the work was intended for the clarification of the basic principles underlying the physical picture of the bubbling process, and to check the derived equations.

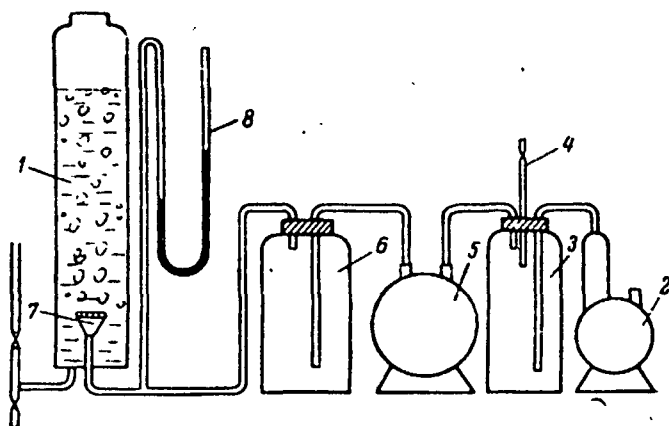


Fig. 3. Scheme of the bubbling apparatus.

Air was bubbled through a layer of glycerine in glass cylinder (1) 6 cm in diameter and 110 cm high (Fig. 3). The air was forced into the cylinder by a rotating blower (2) through a buffer vessel (3), provided with a valve (4) for air supply regulation. From the buffer vessel (3) the air passed into the gas meter (5), and from there

into another buffer vessel (6), through a flat screen (7), of the bubbler, and into the layer of fluid. Hydraulic resistance Δp of the bubbling installation was registered manometrically (8).

The bubbler screen was made of a nickel plate 2.1 cm in diameter and 0.14 cm thick. Nineteen apertures 0.13 cm in diameter were distributed concentrically. The tests were conducted with glycerine of 100, 90, 80, 60, 40 and 20% by volume having the following corresponding viscosities: 80, 30, 10, 5, 2.5, 1.7 centipoises; pure water and aqueous hyposulfite solutions were used as the diluents. The height (thickness) of the fluid layer in the bubbler was of the following range: 0.3, 5, 15, 20, 50 and 70 cm. Rate of air flow through the apertures of the bubbler screen was $w = 2$ to 16 m/sec. The glycerine sp. gr. was determined pycnometrically. Solution viscosity was determined by the Ostval'd viscosimeter. Surface tension of glycerine solutions σ was determined by measuring the maximum pressure at the bubbles' breaking point in Rebinder's apparatus; the data are presented below:

Concentration of glycerine solutions (in volume %)	Water	20	40	60	80	90	100
Surface tension (dyn/cm)	73.05	70.50	68.91	68.01	67.41	69.32	70.03

Experiments were conducted in the following order: hydraulic resistance of the bubbler with a moist screen was determined first, then the resistance of the fluid layers of 0.3 cm - 5.10 cm and up to maximum 70 cm-thickness was established. Resistance of different layer heights was determined for solutions of same viscosity at air flow rates of 2, 4, 6, 8, 10, 12, 14 and 16 m/sec. A series of experiments were conducted thereafter with glycerine of higher concentration.

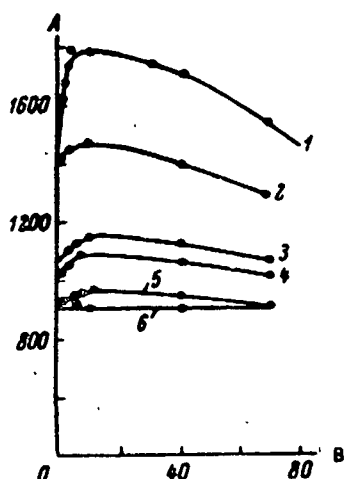


Fig. 4. Total hydraulic resistance (pressure drop) of the bubbling set-up in relation to glycerine solution viscosity at $w = 10$ m/sec.

A - Hydraulic resistance (pressure drop) Δp in mm water; B - Glycerine solution viscosity μ in centipoises.

Layer thickness of bubbling fluid in cm: 1 - 70; 2 - 50; 3 - 20; 4 - 15; 5 - 5; 6 - 0.3.

Pressure drop curves were constructed with the aid of the experimental data throughout the entire bubbling installation (Δp) in relation to different viscosities. Some of the curves are presented in Fig. 4; curves indicating changes in hydraulic resistance of the fluid layers of different thickness during the bubbling process (Δp_3) in relation to air flow rate over the bubbler screen (w) are presented in Figs. 5 and 6. Computed values of hydraulic resistance of the fluid layer Δp_3 , are presented in Tables 1 and 2.

To facilitate the calculations, equation (24) was converted to the following form:

$$\Delta p_3 = A \cdot H \cdot \gamma_{fl} \cdot \left[\left(\frac{g^{0.5} \cdot \gamma_{fl}^{0.5}}{m^{1.5} \cdot \mu^{0.5}} \right)^c + B \cdot \left(\frac{m}{m_0} \right)^{k_1} \right] \quad (27)$$

where $m_0 = 1 \text{ m}^3/\text{sec}/\text{m}^3$. Experimental values of coefficients for equation (27) were: $A = 0.1$, $B = 1.2$, $c = 0.25$, $k = 0.5$.

Equation (26) was converted into:

$$\Delta p_3 = A_1 \cdot H \cdot \gamma_{fl} \cdot \left[\left(\frac{m^{1.5} \cdot \mu^{0.5}}{g^{0.5} \cdot \gamma_{fl}} \right)^{2b} + B_1 \left(\frac{m}{m_0} \right)^{k_1} \right] \quad (28)$$

where the values of the experimental coefficients were: $A_1 = 2.30$, $b = 1/8$, $B_1 = 0.3$, $k_1 = 1/3$.

Discussion of experimental results. The picture of the bubbling process appeared as follows: the air passed unevenly through the screen mesh; it failed to pass through some apertures and passed as a pulsating stream through others. The pattern of operating apertures of the bubbler screen continually changed, pointing to a mode of chance operation. The character of the bubbling process with a constant air supply depended on the fluid viscosity. With fluid viscosity of 1 - 10 centipoises and an adequate air supply the gas penetrated the fluid thickness as a churning turbulent stream; its further movement was of a whirling type and in the upper section of the bubbling column a layer of foam was formed. In reducing the rate of gas flow through the fluid of same viscosity the spiral type of movement was more clearly outlined and its span increased.

T A B L E 1.

Hydraulic resistance rates of a fluid layer of viscosity $\mu = 1 - 10$ centipoises, computed with the aid of equation (28) and obtained experimentally. (At $\mu = 1$ centipoise $\gamma_{fl} = 1000 \text{ kg/m}^3$; at $\mu = 10$ centipoises $\gamma_{fl} = 1200 \text{ kg/m}^3$).

μ in centi- poises	w in m/sec	H in m	m in l/sec	Re_{σ}	$Re_{\sigma}^{-0.25}$	$\frac{0.33}{m^{0.33}}$	Δp_3 in kg/m ²	Experi- mental Δp_3 in kg/m ²	Rela- tive error in %	E
1	4.0	0.70	0.40	36,500	0.073	0.40	760	690	+11.0	0.98
1	6.0	0.70	0.62	19,850	0.084	0.35	695	680	+ 1.0	0.98
1	10.0	0.70	1.04	9,250	0.104	0.29	640	620	+ 3.0	0.89
10	4.0	0.70	0.42	12,700	0.093	0.40	950	840	+13.0	1.00
10	6.0	0.70	0.62	6,870	0.110	0.96	890	860	+ 4.0	1.02
10	10.0	0.70	1.04	3,220	0.134	0.29	795	870	- 7.0	1.04
1	4.0	0.50	0.59	21,100	0.082	0.36	505	500	+ 0.5	1.00
1	8.0	0.50	1.18	7,670	0.108	0.28	449	520	-14.0	1.04
1	12.0	0.50	1.77	4,240	0.123	0.25	426	455	- 6.0	0.91
10	4.0	0.50	0.59	7,340	0.108	0.25	426	455	- 6.0	0.91
10	8.0	0.50	1.18	2,660	0.139	0.36	645	610	+ 7.0	1.02
10	12.0	0.50	1.77	1,450	0.164	0.28	584	600	- 3.0	1.00
1	4.0	0.20	1.45	5,560	0.116	0.26	174	180	- 3.0	0.90
1	6.0	0.20	2.20	3,020	0.135	0.23	168	190	-11.0	0.95
1	12.0	0.20	4.40	1,070	0.175	0.18	164	170	- 3.0	0.85
10	4.0	0.20	1.45	1,940	0.151	0.26	229	230	- 0.5	0.96
10	6.0	0.20	2.20	1,040	0.176	0.23	225	240	- 6.0	1.00
10	12.0	0.20	4.40	368	0.228	0.18	220	210	+ 8.0	0.87
1	4.0	0.05	5.90	687	0.127	0.17	45	58	-12.0	1.15
1	8.0	0.05	11.30	242	0.260	0.13	45	50	-10.0	1.00
10	4.0	0.05	5.90	236	0.254	0.17	58	75	-22.0	1.25
10	8.0	0.05	11.80	84	0.329	0.13	64	70	- 9.0	1.17
1	8.1	0.04	37.50	42	0.390	0.09	44	40	+10.0	1.10

In case of high-viscosity fluids with $\mu = 60$ to 80 centipoises the stream-like flow of the gas was disrupted at the surface of gas outflow, the minor flow streams combined forming large bubbles, the size of which increased with viscosity rise, and at maximum values reached 6 cm in diameter and more.

Thus, even the observed picture of the bubbling process (Figs. 1 and 2) brought into evidence the considerable effect which viscosity had on the process under study, since changes in other values, such as surface tension (σ) and fluid specific gravity (γ_{fl}) were of insignificant magnitudes.

The quantitative effect of viscosity on hydraulic resistance during the bubbling process is shown in Fig. 4, where curves $\Delta p - \mu$ manifest a clear maximum with $\mu = 5$ to 10 centipoises. This maximum is noticeable in a very

T A B L E 2.

Hydraulic resistance rates of a fluid layer of viscosity $\mu = 10 - 70$ centipoises, computed with the aid of equation (27) and obtained experimentally.

μ in centi- poises	w in m/sec	H in m	m in l/sec	Re_{σ}	$Re_{\sigma}^{0.25}$	$1.2m^{0.5}$	Δp_3 in kg/m ²	Experi- mental Δp_3 in kg/m ²	Rela- tive error in %
70	4	0.70	0.42	4,920	8.37	0.77	792	740	+ 7
70	6	0.70	0.62	2,640	7.20	0.84	700	710	- 1
70	10	0.70	1.04	1,230	5.92	1.21	624	580	+ 8
10	4	0.70	0.42	12,710	10.62	0.77	965	840	+15
10	6	0.70	0.62	6,870	9.10	0.95	887	860	+ 1
10	8	0.70	0.93	3,820	7.86	1.16	760	860	-12
70	4	0.50	0.59	2,720	7.21	0.93	510	490	+ 4
70	8	0.50	1.18	1,020	5.65	1.32	435	400	+ 9
70	10	0.50	1.45	750	5.21	1.45	415	360	+15
70	12	0.50	1.77	560	4.87	1.59	403	340	+17
10	4	0.50	0.59	7,350	9.30	0.93	611	610	0
10	8	0.50	1.18	2,660	7.20	1.32	516	600	-14
10	10	0.50	1.45	1,940	6.65	1.45	490	540	- 9
10	12	0.50	1.77	1,520	6.25	1.59	474	540	-13
70	4	0.20	1.45	750	5.21	1.44	166	140	+18
70	6	0.20	2.20	402	4.50	1.78	159	160	- 6
70 ^{1/}	12	0.20	4.40	141	3.41	2.52	148	110	+34
10	4	0.20	1.45	1,940	6.61	1.44	193	220	-12
10	6	0.20	2.20	1,040	5.70	1.78	179	210	-15
10	12	0.20	4.40	370	4.40	2.53	166	195	-15
70 ^{1/}	4	0.05	5.90	91	4.50	1.55	37	30	+23
70 ^{1/}	8	0.05	11.80	32	3.18	1.85	31	30	+ 3
70 ^{1/}	12	0.05	17.70	18	2.62	2.06	28	22	+28
10 ^{1/}	4	0.05	5.90	240	6.21	1.55	46	70	-33
10 ^{1/}	8	0.05	11.80	84	4.37	1.85	37	50	-26
10 ^{1/}	12	0.05	17.70	46	3.60	2.06	33	25	+31

^{1/} Calculations were made on the basis of $A = 0.1$, $B = 1.0$, $k_1 = 0.25$, $c = 0.33$.

deep layer; it almost disappears in layers of 5 cm and less in depth. Effect of viscosity is particularly noticeable in Figs. 5 and 6, which show that this effect is more clearly outlined with the increase in the depth of the fluid layer. Increase in viscosity from 1 to 10 centipoises caused an increase in hydraulic resistance of the layer (Δp_3) 1.2 to 1.3 times (Fig. 5). Further viscosity increase from 10 to 70 and 80 centipoises reduced the hydraulic resistance 1.3 to 1.5 times (Fig. 6). In case of viscosity $\mu = 60$ to 70 centipoises, the value of Δp_3 is considerably lower than the hydrostatic pressure of the pure liquid column.

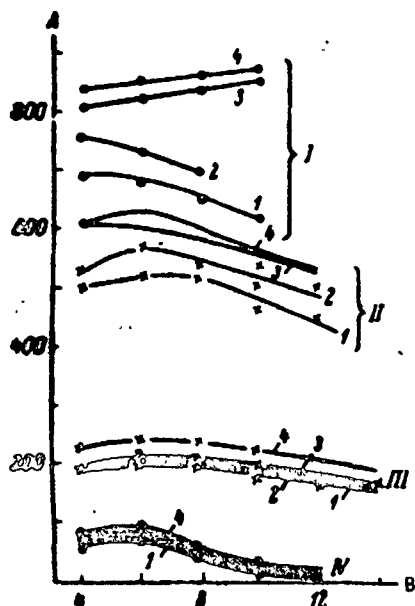


Fig. 5. Hydraulic resistance (pressure drop) of glycerine solution of 1 - 10 centipoises viscosity in relation to rate of air passing through screen openings. A - Hydraulic resistance Δp_3 in cm water; B - Plots of air flow through screen openings w in m/sec. Thickness of fluid layer in cm: I - 70; II - 50; III - 20; IV - 5; Glycerine solution viscosity in centipoises: 1 - 1; 2 - 2.5; 3 - 5; 4 - 10.

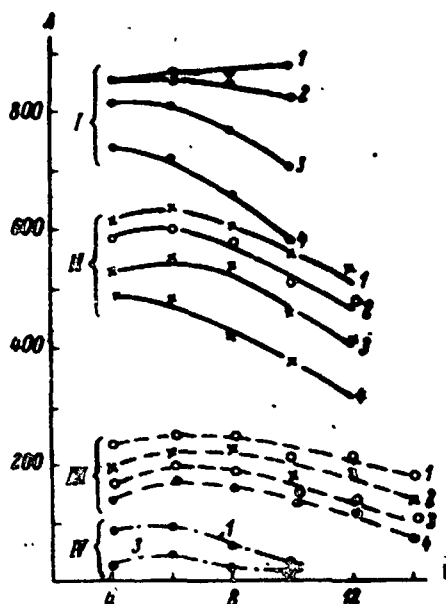


Fig. 6. Hydraulic resistance (pressure drop) of glycerine layer of viscosity $\mu = 10-70$ centipoises in relation to rate of air passing through screen openings. A - Hydraulic resistance of fluid layer in cm water; B - Rate of air flow through screen openings w in m/sec. Thickness of fluid layer H in cm: I - 70; II - 50; III - 20; IV - 5. Glycerine solution viscosity in centipoises: 1 - 10; 2 - 30; 3 - 50; 4 - 70.

increases the hydraulic resistance (pressure drop) in the layer (Δp_3) as viscosity rises.

Comparison of values calculated according to equation (28) with experimental Δp_3 values, indicated (Table 1) that in case of glycerine solutions with 1 to 10 centipoise viscosity, the calculated values of Δp_3 produced deviation from experimental data within $\pm 15\%$. In most cases such deviations noted in this study with $H > 5$ cm did not exceed $\pm 7\%$. In cases of fluid layer depth $H < 5$ cm and specific air flow rate $m > 6$, the relative error in calculations increased considerably. At the same time the processing of Pozin's [10] experimental data, where $m = 25$ to 100 with $H = 1$ to 5 cm, indicated that the Δp_3 values calculated according to equation (28) produced deviations of 10 to 15% from the experimental data. Thus, equation (28) can be used in the calculation of Δp_3 within wide limits.

Comparison of calculated Δp_3 values for glycerine solutions with $\mu = 10 - 70$ centipoises indicated (Table 2) that the relative error in using formula (27)

Such phenomena in the viscous medium can be explained by high gas saturation of the fluid which lowers the system's sp. gr. which in turn controlled the hydrodynamic resistance in the layer. In low viscosity solutions, where $\mu = 1$ to 10 centipoises and the fluid saturation with gas is lower, the hydrodynamic resistance of the system prevails; in such cases the hydrodynamic resistance was determined by the larger dimensions of the torch-like gas stream which

was within $\pm 15\%$ limit. Here the relative errors were determined for solutions with $\mu = 20$ to 70 centipoises and $H = 15$ to 70 cm. Deviations from experimental data increased noticeably with the decrease in viscosity to $\mu = 10$ centipoises. Greater deviations of calculated and experimental Δp_3 values were observed with $Re_0 < 400$, enabling to draw preliminary conclusion regarding change in the bubbling system having Re_0 values previously mentioned. More accurate checking of experimental and calculated Δp_3 were obtained for this new system with coefficients values in formula (27) of $A = 0.1$, $B = 0.1$, $K = 0.25$, $c = 0.33$. However, here also, with small absolute deviations in the value of the Δp_3 the relative error was within $\pm 30\%$ limit, which may have been due to the determining effect of the criterion of geometric similitude. In most cases the effect of the criterion of geometric similitude is not great, which we confirmed in particular by Axelrod's [9] conclusions emphasizing a lack of noticeable absorber geometric dimensions effect on bubbling hydrodynamics.

Consideration must be given to the fact that with $H < 5$ to 10 cm layer and extensive gas flow, the effect of foam on hydraulic resistance in the process of bubbling begins to be noticeable; the resistance of the latter must be ascribed to the surface tension σ of the foam. Under conditions mentioned, i.e., in the presence of a relatively high resistance of foam proper, as shown by Axelrod [9], it may be necessary to introduce the μ/σ ratio into the equation in calculating the value of Δp_3 . For layers of $H > 10$ cm, as indicated by previous calculations and experimental data, the effect of σ may be ignored, particularly since it is taken into account as Δp_2 in determining total hydraulic resistance (pressure drop) of the bubbling installation; derived equations (27) and (28) are suitable for such calculations.

Conclusions.

1. A bubbling through a fluid system is suggested with $\mu = 1$ to 80 centipoises viscosity and layer height of $H > 10$ cm. It was demonstrated that viscosity was one of the most important factors affecting hydrodynamics of bubbling, particularly in a sufficiently deep layer.
2. Based on the theory of differential values and of empirical functional interdependence an equation was derived for the determination of hydraulic resistance in a bubbling system.
3. Experimental results demonstrated that the functional pictures of bubbling through low-viscosity and high-viscosity fluids differed greatly. Hydraulic re-

sistance of fluid layers (Δp_3) of different viscosities and specific air flows were also determined.

4. Experimental and computed Δp_3 values were compared. Results indicated that computed values coincided satisfactorily with the conditions of the experiments at $H > 10 - 15$ cm and with experimental results of other investigators. Calculation error in most cases did not exceed $\pm 15\%$.

Bibliography.

- [1] В. Н. Стабников, Тр. Воронежского химико-техн. инст., 3-4 (1939). — [2] В. Н. Стабников, Хим. машиностроение, 1, 6 (1938). — [3] В. М. Рамм. Абсорбционные процессы в химической промышленности. М.-Л. (1951). — [4] Н. М. Жаворонков, И. Э. Фуршер, Кислород, 5 (1947). — [5] Н. П. Усюкин, Аксельрод Л. С., Кислород, 1 (1952). — [6] Л. С. Аксельрод, В. В. Дильман, Кислород, 5 (1952); 1 (1954). — [7] Л. С. Аксельрод, В. В. Дильман, Хим. пром., 1 (1954). — [8] Л. С. Аксельрод, В. В. Дильман, ЖПХ, XXVII, 5 (1954). — [9] Л. С. Аксельрод, В. В. Дильман, ЖПХ, XXIX, 12 (1956). — [10] М. Е. Поян, И. И. Мухленов, Е. С. Тумаркина и Э. Я. Тарат. Пенный способ обработки газов и жидкостей. Л. (1955). — [11] М. Э. Авров, Е. П. Даровских, Хим. пром., 2 (1957). — [12] Н. П. Зрелов, Тр. гидравлической лаборатории ВОДГЕО, 4, М. (1955). — [13] А. Г. Касаткин. Основные процессы и аппараты химической технологии. М. (1955).

Effect of Hydrodynamic Conditions on Rate of Nitrogen Oxides Absorption by Ca(OH)_2 Solution, with the Aid of a Mechanical Absorber under Semi-Industrial Conditions.
(Communication I).

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The effect of hydrodynamic conditions on the rate of nitrogen oxides absorption by a solution of Ca(OH)_2 was studied with the aid of a rapidly rotating mechanical absorber under semi-industrial conditions, using industrial gas from a nitric acid shop. ^{1/} Similar laboratory investigations were made at an

^{1/} The study was made with the active cooperation of B. G. Ovcharenko, M. A. Petrichenko and Yu. V. Yastrebov. M. A. Lokshin, S. B. Leibovich, A. S. Kaigorodova and O. V. Avilov participated in this work.

earlier date [1]. The horizontal mechanical absorber of the semi-industrial installation was 1.54 m long and 0.88 m in diameter. The absorber equalled 1 m^3 . A shaft with 4 attached perforated discs extended from end to end. Each disc had 14 paddles bent toward one another. The discs were attached to the shaft so that their concave sides faced each other. Rapid rotation of the shaft and of the attached discs created heavy foam layer and spray curtain. Nitrous gas coming from a contact apparatus was cooled to $60 - 70^\circ$ in a gas cooling chamber; it then entered pipe 1 and was driven by fan 2 into absorber 3. The collector was equipped with a valve through which air was sucked into the absorber. Such an arrangement made it possible to mix the gas with any desired nitrogen oxides concentration.

The amount of gas entering the system was governed by a control gas valve in pipe 1 located between the pipe and the contact apparatus. Precise adjustments could be made by a control sliding gas valve installed on a by-pass pipe above fan 2. The amount of entering gas was determined by a membrane manometer 4.

From the absorber the gas passed through separator 5, where it was freed of liquid droplets; it was then discharged into the atmosphere through conduit 6. The $\text{Ca}(\text{OH})_2$ solution was prepared in a tank equipped with a mixer 7. From the tank the solution was measured out into a small circulating tank 8, into

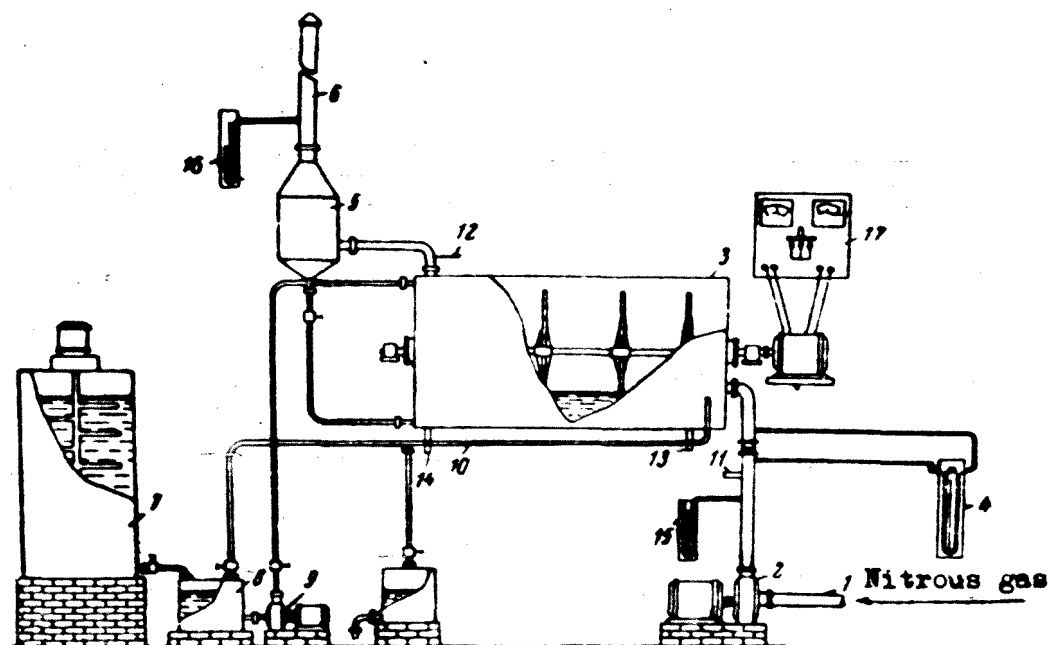


Fig. 1. Plan of the semi-industrial installation. (Description in text).

which were fed the alkalized nitrite-nitrate solutions circulating through the system. Each addition of $\text{Ca}(\text{OH})_2$ solution was followed by the removal of an equal volume of the alkaline nitrite-nitrate solution. The solution was taken from tank 8 by means of centrifugal pump 9 and fed into the absorber from above. Whenever the solution in the absorber rose to $1/4$ of its diameter, it automatically drained back into tank 8 through level controlling flow pipe 10. The total volume of the liquid circulating in the system was 5 m^3 . Samples of gas to be analyzed were taken directly at the absorber outflow at points 11 and 12. Samples of liquid to be analyzed were taken at points 13 and 14, and the pressure was measured in front and in back of the apparatus; it was recorded by manometers 15 and 16. Power consumption was determined by a control ammeter and voltmeter installed on panel 17.

Experimental part. The investigations made with the semi-industrial installation were conducted in 2 stages: 1) a study of the effects of the system's hydrodynamic, physical and chemical factors on the absorption rate; during this study the installation was operating periodically for time intervals determined by the requirements of each test; the phases investigated were: the effect of the peripheral speed of the discs, the volume rate of gas flow, the quantity of liquid in the absorber, the CaO and nitrite-nitrate salt concentrations in the solution, the degree of gas oxidation, etc.; 2) during the second stage, the installation operated continually under one set of conditions, selected on the basis of results obtained during the first stage of the investigation; results of the second stage indicated that the process of nitrogen oxides absorption had to be based on a rationally (empirically) developed and controlled technological procedure. The first study stage extended over more than 1-1/2 months, and the second over more than 2-1/2 months. More than 3,000 analyses of the gaseous and liquid phases were made, which yielded sufficient experimental data for the determination of optimal technological conditions.

Effect of peripheral disc speed. Results of previous studies [1] showed that peripheral disc speed was a basic hydrodynamic factor which determined the rate of the process. This factor was studied using the semi-industrial installation as follows: CaO concentration in the solution varied between 70 to 80 g/li, and the concentration of the nitrite-nitrate salts between 10 to 20 g/li, the volume rate of gas flow 400 m^3 of gas per m^3 of the absorber solution per hour; the concentration of $\text{NO} + \text{NO}_2$ in the gas varied from 0.14% to 4%, and

the degree of NO oxidation from 65 to 75%, depending upon the concentration of nitrogen oxides and oxygen in the gas and upon the temperature. The following peripheral disc speeds were tested: 14 - 15, 22 - 23, and 27 - 28 m/sec. Changes in the peripheral disc speeds were attained by shifting interlocking gears and motor pulleys. Power was transmitted by V-shaped belts.

Averages of experimental results are presented in Table 1; plots of the data in the form of curves are shown in Fig. 2.

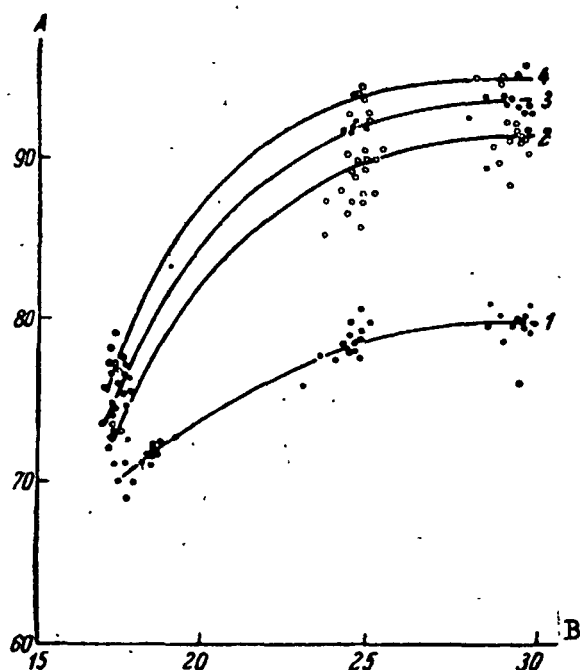


Fig. 2. Changes in nitrogen oxides absorption degree at peripheral disc velocity $w = 400 \text{ m}^3/\text{hour}$ at $t = 60^\circ$ at nitrite-nitrate salts concentrations 10 - 20 g/li.

A - Absorption degree in %; B - Peripheral disc velocity in m/sec. NO + NO₂ concentrations in the gas in %: 1 - 0.14 + 0.3; 2 - 0.6 + 0.8; 3 - 0.9 + 1.5; 4 - 3.5 + 4.

Under production conditions NO + NO₂ concentrations in the gas are frequently of a close range, as is the case, for instance, in curve 1 for 0.14 - 0.3% and in curve 2 for 0.6 - 0.8%, etc. Corresponding data in Table 1 represent averages of such close concentrations along with the computed rates of absorption, the motive force and absorption coefficients. Deviations of individual points followed no regular patterns, and it appeared as though these deviations were the results of some variations in the NO + NO₂ gas concentrations and of some experimental errors.

The experimental data were the results of analyses of the gaseous and liquid phases. CaO, Ca(NO₂)₂ and Ca(NO₃)₂ concentrations were determined in the liquid phase. Analysis for nitrogen oxides was made by the calibrated flask

method, total nitrogen in the liquid phase was determined according to Devard, and calcium nitrite was determined by titration with 0.1 N permanganate solution.

The absorption rate, i.e., productivity of the absorber unit reaction volume expressed in kg of nitrogen per 1 m^3 of the mechanical absorber per hour, was determined by the following generalization:

T A B L E 1.

Changes in rate of absorption at different peripheral disc velocities and different NO + NO₂ concentrations in the gas.
(w = 400 m³/hour; t = 60 - 70°; CaO = 70 - 80 g/li; Ca-nitrite-nitrate = 10 - 20 g/li; oxidation of NO = 60 - 68%).

Peripheral disc velocity	Average percent concentration of NO + NO ₂ at		Degree of absorption α	Absorption rate G/v · τ	Absorption motor force ΔP	Absorption coefficient K _g
	Inflow	Outflow				
v _g in m/sec.	x ₁	x ₂	$\frac{100(x_1 - x_2)}{x_1}$ in percent	$\frac{28 \cdot w(x_1 - x_2)}{22.4 \cdot 100}$ in kg/m ³ /hr.	$\frac{0.01(x_1 - x_2)}{2.3 \lg x_1/x_2}$ in at.	G/delta p in kg/m ³ /hr/atm
15 } 22 } 28 }	0.220	{ 0.066 0.048 0.045	70.0 78.3 79.7	0.770 0.860 0.875	0.00128 0.00113 0.00110	601 760 793
15 } 22 } 28 }	0.700	{ 0.190 0.075 0.060	73.0 89.0 91.0	2.550 3.125 3.200	0.00392 0.00280 0.00261	651 1115 1226
15 } 22 } 28 }	1.200	{ 0.300 0.100 0.080	75.0 91.6 93.3	4.500 5.500 5.600	0.00650 0.00443 0.00414	692 1241 1352
15 } 22 } 28 }	3.750	{ 0.870 0.260 0.205	76.8 93.0 94.5	14.400 17.450 17.725	0.01974 0.01309 0.01221	729 1332 1451

$$\frac{G}{v \cdot \tau} = \frac{28 \cdot w(x_1 - x_2)}{22.4 \cdot 100} \frac{\text{Kg N}_2}{\text{m}^3 \cdot \text{hour}} \quad (1)$$

where x₁ and x₂ are respectively the initial and the final NO + NO₂ concentrations in the gas in percentage, w is the volume rate of the gas flow in m³ per hour.

The absorption motive force was determined as the mean logarithmic difference of nitrogen oxides concentrations at the inflow and outflow. The buoyancy of nitrogen oxides over the solution was assumed equal to zero.

$$\Delta P = \frac{0.01(x_1 - x_2)}{2.3 \lg \frac{x_1}{x_2}} \text{ atm.}$$

The absorption coefficient was determined according to the following formula:

$$K_g = \frac{G}{\Delta p} \quad (2)$$

Values of the absorption coefficients derived from equation (2) are listed in Table 1 and are also plotted in Figs. 3 and 4.

Analysis of the data obtained leads to the conclusion that the degree of nitrogen oxides absorption increased with an increase in the peripheral disc velocity irrespective of the oxides concentration. However, such disc velocity increase had its limit. During the initial increase of the peripheral disc velocity the absorption rate increased rapidly, and the curves showed a steep upward trend, particularly conspicuous with an increase of V_g to 20 - 23 m/sec. Later the upward rise diminished markedly with the continued increase in V_g , and at V_g equalling 27 - 28 m/sec curves ran approximately parallel to the abscissa.

Laboratory experiments in nitrogen oxides absorption by alkalies and other absorbent agents conducted at rapid disc rotation rates disclosed the existence of critical values for peripheral velocities, which, if exceeded, resulted in decreased absorption rates. It should be noted that the absorption rate of nitrogen oxides corresponding to $V_g = 28$ m/sec was only slightly higher than the absorption rate corresponding to $V_g = 22 - 23$ m/sec. The power consumed by the rotation of the shaft with the discs [2] was proportional to the number of revolutions to the 2.02 power. Therefore, the peripheral velocity $V_g = 22$ m/sec was selected as the most expedient.

Curves in Fig. 2 show that with increase in the concentration of nitrogen oxides in the gas, the curves which represented the $\text{NO} + \text{NO}_2$ concentrations rose to higher levels. It should be noted, however, that with an increase in the peripheral disc velocity these curves tended to approach one another. Curve 1 was an exception, since it corresponded to an extremely low $\text{NO} + \text{NO}_2$ concentration. This fact confirmed the conclusion mentioned elsewhere [3] that the effect of the $\text{NO} + \text{NO}_2$ concentration in the gas upon the absorption rate slightly diminished under highly turbulent conditions.

The data listed disclosed that in low concentrations, such as 0.14 to 0.3%, the gas was comparatively well absorbed even under highly turbulent conditions. The practical results obtained with many industrial installations disclosed that nitrogen oxides at concentrations lower than 0.3% were absorbed slowly in the regenerating towers, and virtually had not been absorbed in concentrations ranging between 0.15 and 0.18%, in the existing reaction volumes.

By applying the method of graphical analysis for formulating experimental data [4], it was found that the equation for determining partial values of the

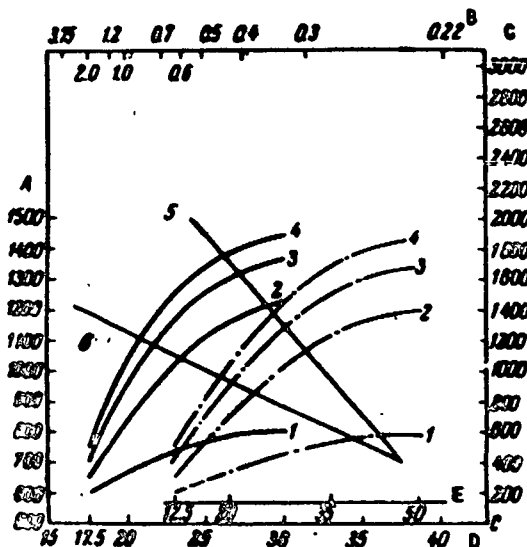


Fig. 3. Nitrogen oxides absorption coefficient in relation to peripheral disc velocity at $w = 400 \text{ m}^3/\text{hour}$, $t_{\text{gas}} = 60^\circ$ and nitrite-nitrate salts concentration $10 - 20 \text{ g/l}$.

A - Absorption coefficient in $\text{kg}/\text{m}^3/\text{hr}/\text{atm}$;
B - $\text{NO} + \text{NO}_2$ concentration in gas $1/x$ scale;
C - Coefficients m and n in $K = m \cdot \sqrt[3]{v_g} + n$;
D - Peripheral disc velocity in m/sec ; E - scale $\sqrt[3]{v_g}$.

$\text{NO} + \text{NO}_2$ concentration in gas in %: 1 - 0.22; 2 - 0.7; 3 - 1.2; 4 - 3.75.
Solid lines - $\text{NO} + \text{NO}_2$ concentration in the gas, proportional scale coordinates; dash-dot line $\sqrt[3]{v_g}$ scale coordinates. Lines determining coefficients m and n : 5 - $n, 1/x$; 6 - $m, 1/x$.

absorption coefficient was: $K = f(x_1 \cdot v_g)$. It was also found that the generalized equation for the determination of the absorption coefficient within the limits of concentrations $\text{NO} + \text{NO}_2 = 0.22 - 3.75\%$, and for peripheral disc velocities ranging from 14 to 30 m/sec . was:

$$K = m \cdot \sqrt[3]{v_g} + n \quad (3)$$

Coefficient values m and n for each value of x were found in the curves shown in Fig. 3.

By selecting two points on each curve two equations can be derived:

$$K_1 = m \cdot \sqrt[3]{v_1} + n$$

$$K_4 = m \cdot \sqrt[3]{v_4} + n$$

By substituting experimental values for K_1, v_1 and K_4, v_4 and solving these equations, actual values for coefficients m and n can be derived. In this manner the following partial absorption coefficients were derived.

$$K_1 = 390 \cdot \sqrt[3]{v_g} - 400; \text{ at } x_1 = 0.22\% \quad (4)$$

$$K_2 = 1130 \cdot \sqrt[3]{v_g} - 2260; \text{ at } x_2 = 0.7\% \quad (5)$$

$$K_3 = 1300 \cdot \sqrt[3]{v_g} - 2640; \text{ at } x_3 = 1.2\% \quad (6)$$

$$K_4 = 1425 \cdot \sqrt[3]{v_g} - 2920; \text{ at } x_4 = 3.75\% \quad (7)$$

To obtain a general equation for the absorption coefficient, the functional relationship between $m = f_1(x)$ and $n = f_2(x)$ had to be established.

The rectilinear functional relationships were recorded on a screen with a reciprocal scale along the x axis and a uniform scale along the m and n axis. This functional relationship is expressed by the formulas:

$$m = a \left(\frac{1}{x} \right) + b$$

$$n = a_1 \left(\frac{1}{x} \right) + b_1$$

Since the modulus of the uniform scale (x) on the basis of which the reciprocal scale was constructed (see Fig. 3) differed from the modulus of the uniform scale for the second variable (a, b), the coefficients a and b can be determined respectively as follows:

$$a = \frac{(m_4 - m_1) \cdot x_1 \cdot x_4}{x_1 - x_4}$$

$$b = m_1 - \frac{a}{x_1}$$

a_1 and b_1 are obtained similarly. Accordingly the following formulas are derived:

$$m = 1490 - 241 \cdot x^{-1}$$

$$n = -(3080 - 590 \cdot x^{-1})$$

The general absorption coefficient $K_g = f(v_g, x)$ can be expressed in the form of the following equation:

$$K_g = (1490 - 241 \cdot x^{-1}) \cdot v_g^{0.333} + (590 \cdot x^{-1} - 3080) \quad (8)$$

This equation holds true for $w = 400$ m³/hour, $v_g = 14 - 30$ m/sec, $x = 0.22 - 3.75\%$, $C_{fl} = 10 - 20$ g/li of Ca nitrite-nitrate, $CaO = 70 - 80$ g/li and $t = 60 - 70^\circ$.

Values of K_g computed according to equation (4) differed from those obtained experimentally by 3 to 4%, indicating a close similarity between the computed and experimentally obtained values.

Volume rate of gas flow effect on the absorption coefficient. The second hydrodynamic factor controlling the rate of the process in the apparatus is the volume rate of gas flow. Assuming that the free cross-section of the absorber was constant, the volume rate of gas flow would determine the linear rate of gas flow and hence, with the increase in the volume rate of gas flow, the linear rate of gas flow would also increase. The experiments disclosed that an initial increase in the volume rate of gas flow markedly increased the absorption rate, since in this case the rate of gas flow increased the fluid turbulence. The absorption rate increased to a definite maximum, after which a further increase in the volume rate of gas flow resulted in a decreased ab-

sorption rate. The experiments revealed that an optimal hydrodynamic condition in absorbers was reached at a linear gas flow rate ranging from 0.8 to 2.5 m/sec.

Linear rates of gas flow exceeding 2.5 m/sec disturbed the effective hydrodynamic conditions by destroying the foam layer and causing the fine droplets to coalesce into coarse aggregates, which fell out of the gaseous phase. This resulted in a decreased surface contact between the phases and in the formation of gas spurts breaking through the apparatus. The volume rate of gas flow determined the contact duration between the phases and the consequent absorption degree. The interaction between these factors determined the apparatus efficiency. For the determination of gas flow volume rate effect upon the degree of absorption, the following constant conditions were selected: v_g of the discs = 22 m/sec, t of the gas = 60 - 70°, CaO = 50 - 75 g/li and nitrite-nitrate salts from 10 to 15 g/li. Separate series of experiments were carried out with each of the following NO + NO₂ concentrations in the gas: 0.15 -

0.3, 0.7 - 0.9, 1.2 - 1.5 and up to 4%.

The volume rates of gas flow equal to 200, 300, 400 and 500 m³/hour were tested for each of the concentrations enumerated. The data derived from these experiments are plotted in Fig. 4. Each point in this diagram was derived as the average of 2 or 3 analyses under the constant conditions of the process.

The same data are listed in Table 2 as averages of computed gas concentrations. Averages of absorption rate (G), motive force absorption (Δp), and absorption coefficient (K_g) were computed for these concentrations. These data were used in constructing the curve shown in Fig. 5 for $K = f(w \cdot x)$, where x is the initial concentration of NO + NO₂ in the gas.

According to Fig. 4 the nitrogen oxides absorption rate decreased gradually

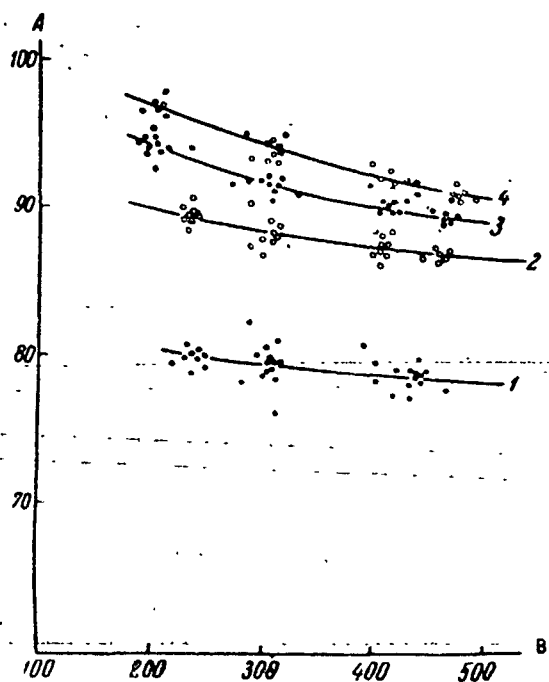


Fig. 4. Degree of nitrogen oxides absorption by Ca(OH)₂ solution in relation to gas volume rate and NO + NO₂ concentration: v_g - 23 m/sec; t gas - 60°; CaO - 50 to 70 g/li; nitrite-nitrate salts 10 - 15 g/li.

A - Absorption in %; B - Gas volume rate in m³/hour.

NO + NO₂ concentration in gas in %: 1 - 0.15 to 0.3; 2 - 0.7 to 0.9; 3 - 1.2 to 1.7; 4 - 3.5 to 4.5.

TABLE 2.

Changes in absorption rates at different gas volume rates and NO + NO₂ concentrations at $v_g = 22$ m/sec; $t = 60$ to 70° ; CaO = 60 to 70 g/li; Ca-nitrite-nitrates 10 to 15 g/li.

Gas volume rate	Average NO + NO ₂ concentrations in percent at		Degree of absorption α	Absorption rate $G/v \cdot \tau$	Absorption motor force A_p	Absorption coefficient K_g
	Inflow	Outflow				
w in m^3/hour	x_1	x_2	In percent	In $kg/m^3/\text{hr}$	In technical at.	$\frac{mg \text{ nitrogen}}{m^3/\text{hr}/atm}$
200	0.225	0.0450	80.1	0.456	0.001120	402
300		0.0460	79.5	0.671	0.001130	595
400		0.0470	79.1	0.890	0.001140	782
500		0.0475	78.9	1.109	0.001142	971
200	0.800	0.0800	90.0	1.800	0.003130	567
300		0.0920	88.5	2.655	0.003280	810
400		0.0960	88.0	3.520	0.003320	1058
500		0.1000	87.5	4.375	0.003370	1298
200	1.450	0.0810	94.4	3.423	0.004750	720
300		0.1120	92.3	5.017	0.005230	959
400		0.1350	90.7	6.575	0.005545	1185
500		0.1460	89.9	8.150	0.005687	1433
200	4.000	0.1200	97.0	9.700	0.011080	876
300		0.2200	94.5	14.175	0.012840	1104
400		0.2800	93.0	18.600	0.014010	1328
500		0.3400	91.5	22.875	0.014800	1540

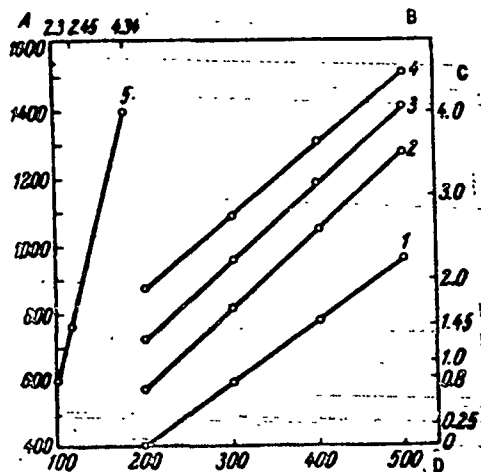


Fig. 5. Determination of coefficient of NO + NO₂ absorption of Ca(OH)₂ solution in relation to gas volume rate and NO + NO₂ concentration.

A - Absorption coefficient in $kg/m^3/\text{hr}/\text{techn. atm.}$; B - Coefficient b at scale $b^{2.5}$; C - NO + NO₂ concentration in gas in %; D - Gas volume rate in m^3/hour .

NO + NO₂ concentration in gas in %: 1 - 0.225; 2 - 0.8; 3 - 1.45; 4 - 4.0; 5 - Changes in b coefficients, at screen scale $x = b^{2.5}$.

with an increase in the volume rate of gas flow for all concentrations of NO + NO₂. Furthermore, the absorption of low NO + NO₂ concentrations may be sufficiently complete at high intensities of the reacting volumes.

The straight lines in Fig. 5 indicate that the absorption coefficients increased with the increase in volume rate of gas flow and with the increase in the NO + NO₂ concentration in the gas. For convenience the absorption coefficients were given in $kg \text{ nitrogen}/m^3 \text{ per hour/atm}$.

In deriving generalizations on the basis of the experimental data it was established that $K = f(w)$ for different concentrations of nitrogen oxides can be expressed as a linear function:

$$K = a \cdot w + b \quad (9)$$

Values of coefficients a and b were determined in Fig. 5 by the graphical analysis method and formulas for the determination of partial values of the absorption coefficients were expressed as:

$$K_1 = 1.896 \cdot w + 23; \text{ at } x_1 = 0.225\% \text{ NO} + \text{NO}_2 \quad (10)$$

$$K_2 = 2.410 \cdot w + 93; \text{ at } x_2 = 0.8\% \text{ NO} + \text{NO}_2 \quad (11)$$

$$K_3 = 2.376 \cdot w + 245; \text{ at } x_3 = 1.45\% \text{ NO} + \text{NO}_2 \quad (12)$$

$$K_4 = 2.213 \cdot w + 434; \text{ at } x_4 = 4.0\% \text{ NO} + \text{NO}_2 \quad (13)$$

A formula for the determination of the general absorption coefficient with the limits $x_1 - x_4$ was derived by rectifying the curve of coefficient b changes on the screen with the scales of x and $b^{2.5}$. The average of coefficient a was assumed to be equal to 2.4. Consequently, the equation for the determination of the general absorption coefficient is as follows:

$$K_g = 2.4 \cdot w + 115 \cdot x \quad (14)$$

This equation holds true for $w = 200 - 500 \text{ m}^3/\text{hour}$, $x = 0.3 - 4\%$, $v_g = 22 - 23 \text{ m/sec}$, $t = 60 - 70^\circ$, concentrations of nitrite-nitrate salts $C_{f1} = 8 - 15 \text{ g/li}$ and $\text{CaO} = 50 - 80 \text{ g/li}$.

For $\text{NO} + \text{NO}_2$ concentrations lower than 0.3% formula (14) shows deviations up to 10 - 12%. For this reason it is better to use the following formula for the determination of partial absorption coefficients in cases of low $\text{NO} + \text{NO}_2$ concentrations:

$$K = 1.9 \cdot w + 23$$

In this case the difference between the experimental and the computed data did not exceed 1.5%.

Optimal amount of liquid. The experiments showed that the ratio of liquid volume to the volume capacity of the absorber was an important factor which affected the absorption rate. When the amount of liquid was small its concentration in the gas decreased, its agitating effect upon the system declined and the contact area between the two phases decreased. Filling the apparatus with liquid above the optimum reduced the free volume of the apparatus, resulted in excessive linear rates of gas flow and intensified strong stream flows which

broke through the apparatus destroying the foam condition and discharging greater quantities of the liquid from the apparatus.

The determination of optimal amounts of liquid which might create most favorable hydrodynamic conditions in the apparatus was attained by a series of experiments conducted under the following constant conditions: $w = 400 \text{ m}^3/\text{hour}$; $v_g = 23 \text{ m/sec}$; $\text{CaO} = 50 - 60 \text{ g/li}$; nitrite-nitrate salts from 10 to 20 g/li. The content of $\text{NO} + \text{NO}_2$ in the gas varied from 1 to 1.32%. The amount of liquid varied between 50 and 200 li, or 6 to 24% of the absorber volume. A measured amount of liquid was poured into the apparatus and the absorber was set into operation. After the predetermined conditions of operation were organized, samples of the gas and of the liquid were taken for analysis at points of inflow and outflow of the absorber. Thereupon the gas was turned off, the apparatus stopped, and the liquid measured.

Note: A constant amount of the liquid in the absorber was maintained at a constant level by natural overflow circulation through a pipe connecting the absorber and the separator.

The next experiment was repeatedly conducted under the same conditions but with different volumes of liquid. The experimental data obtained are plotted in Fig. 6.

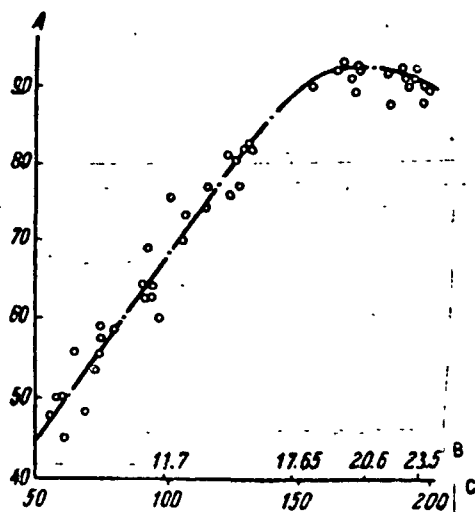


Fig. 6. Degree of nitrogen oxides absorption in relation to volume of fluid in the apparatus.

A - Absorption degree in %; B - Fluid volume in % of absorber capacity; C - Liters of fluid in the apparatus.

The plots show that with an initial increase in the fluid volume, all other conditions remaining constant, the absorption rate increased rapidly; it reached its maximum when the absorber was 19 - 21% filled, thereafter the absorption rate began to decrease.

The total capacity of the absorber used in the present experiments was 850 li and the volume of fluid which assured the best technological performance, varied between 160 and 180 li, or 19 to 21%. Similar data were obtained for absorbers with 55 to 70 li capacity.

In designing apparatuses of larger dimensions and in determining volumes of the fluid and the overflow height at the outflow point of the absorber, the optimum content of the apparatus should be determined on the basis of the

data referred to above. The rate of the horizontal liquid movement had no appreciable effect on the hydrodynamic conditions prevailing in the apparatus, since the flow rate of liquid transported by the discs in direction perpendicular to the gas flow was thousands of times greater than its horizontal movement. The direction of the liquid movement in relation to the gas flow had no appreciable effect on the rate of the process due to the irreversibility of the process. The investigation showed also that the number of discs to be installed on the absorber shaft can be computed with the aid of the following formula:

$$\left(\frac{100}{100 - x}\right)^n = \frac{c_1}{c_2} \quad (15)$$

where n is the number of discs on the absorber shaft and c_1 and c_2 are respective concentrations of nitrogen oxides at the inflow and outflow points of the apparatus.

The highest absorption rate and the least power consumption were obtained with 4 discs, each equipped with 14 to 16 paddles set at 15 to 17°. The distances between the discs were 0.6 - 0.7 of their diameters.

Conclusions.

1. It was established that an increase in the peripheral velocity of the discs up to the optimal value rapidly increased the absorption rate. A peripheral velocity above the optimal decreased the absorption rate. The peripheral velocity of the discs was the basic factor which determined the hydrodynamic conditions in the apparatus and the rate of convection diffusion.

2. The volume rate of gas flow was the second important hydrodynamic factor which determined the rate of the process. Increased volume rates of gas flow to the optimal value rapidly increased the absorption rate; any further increase in the volume rate of gas flow decreased the absorption rate.

3. The optimal liquid volume in the apparatus was 19 to 21% of the volume of the apparatus. The rate and the direction of the horizontal movement of the liquid had no appreciable effect on the absorption rate in irreversible process.

4. It was established that the most rational installation was one in which the absorber shaft was equipped with 4 discs spread at distances equivalent to 0.6 - 0.7 of their diameters.

Bibliography.

- [1] С. Н. Ганз и С. Б. Кравченская, ЖПХ, XXVIII, 2 (1955). —
[2] С. Н. Ганз и М. А. Локшин, Тр. Днепропетр. химико-технолог. инст., 1
(1955). — [3] С. Н. Ганз и С. И. Каптурова, ЖПХ, XXVIII, 6 (1955). —
[4] С. Н. Ганз, М. А. Локшин и С. И. Каптурова, ЖПХ, XXVIII, 8
(1955). — [5] М. Е. Позняк и И. П. Мухленов, Тр. Лен. технолог. инст. им.
Лавского, 26 (1950).

Adsorption of Nitrogen Oxides by Aluminosilicates. Second Report.

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It was previously reported [1] that powdered or granular aluminosilicate effectively adsorbed nitrogen oxides. This paper is a report of a more detailed study of nitrogen oxides adsorption by aluminosilicate at different $\text{NO} + \text{NO}_2$ concentrations in the gas, degree of NO oxidation, volume flow rate and moisture content.

Experimental part. The apparatus used is schematically depicted in Fig. 1. Nitrogen oxide and air were supplied in given ratios into mixer 3, respectively from gas meters 1 and 2. The air and NO volumes were measured by flowmeters 4. Prior to mixing, the gas components were passed either through vessels 5, which were filled with concentrated sulfuric acid, to remove the moisture, or they were run directly into mixer 3 through side tubes 6, depending on the purpose of the experiment. Gases which contained moisture were passed through bottles 5, filled for the purpose with distilled water heated to any required temperature. Mixers were of different sizes, since they also served as volume oxidizers. Approximate NO oxidation degree was determined prior to adsorption on the basis of mixer volume. From the mixer the gas mixture was admitted into the glass adsorber 7, having a porous bottom 3, which supported adsorbent c. Prior to beginning the experiment, the gas in the mixer was analyzed for total nitrogen oxides by the vacuumated flask method, also for the degree of NO oxidation. The

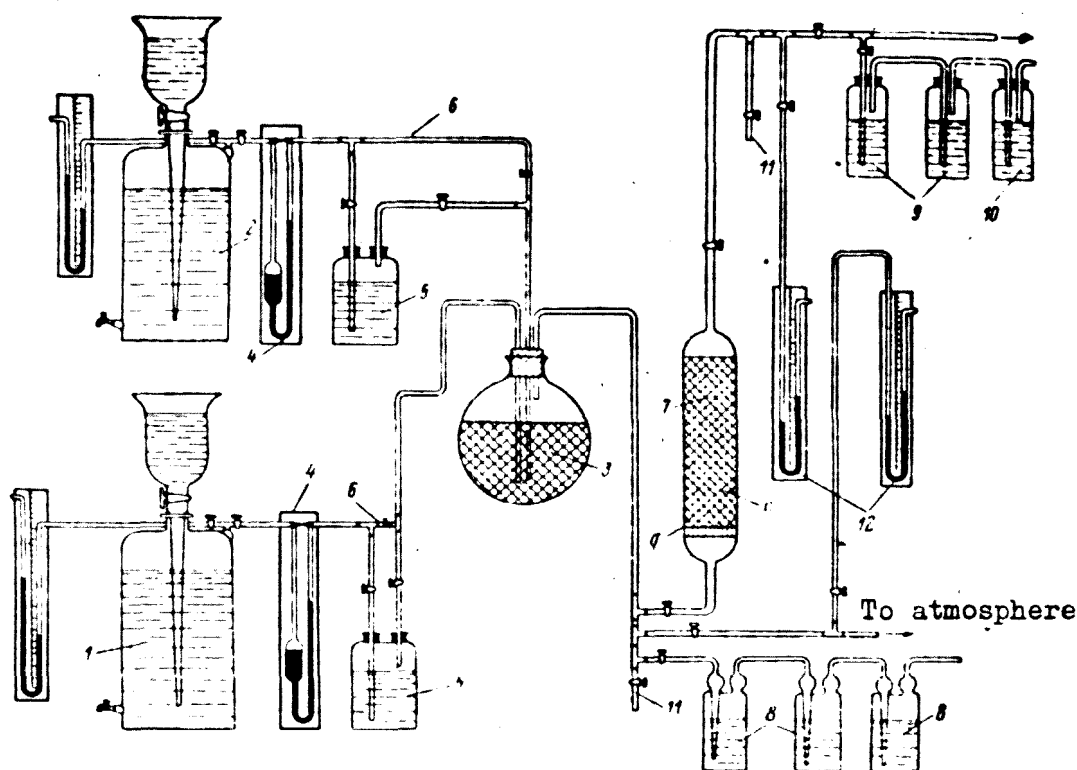


Fig. 1. Plan of the experimental device. (Details in text).

latter was determined by the iodometric method [2], passing the NO_2 through a 5% KI solution contained in absorber flasks 8. After the adsorption, total $\text{NO} + \text{NO}_2$ in the gas was also determined by the vacuumated flask method, and the discharged nitrogen oxides were absorbed by a 1% NaOH solution contained in vessels 9, and FeSO_4 solution in vessel 10. Gas samples for analysis were taken at points 11; the gas pressure at points of entering and leaving the system were recorded manometrically.

Alumosilicate utilized in the experiments consisted of orange or milk-white spherical granules 3 mm in diameter. Uniform size of the granules was obtained by gauge sifting. The adsorbent weighed 0.72 t/m^3 , its free volume was $\approx 0.38 \text{ m}^3/\text{m}^3$, and the mechanical compression strength was 90 kg per granule. The composition and the method of preparing the alumosilicate adsorbent were briefly discussed elsewhere [3, 4].

An identical amount of the aluminum silicate, namely, 50 cm^3 , was placed into the adsorbent container for each of the tests. The adsorbent column was 27.5 cm high, and the initial weight was 35.8 g. The adsorbed nitrogen oxides were computed according to formula:

$$G = \frac{(V_{NO} + V_{NO_2})_{init.} - (V_{NO} + V_{NO_2})_{fin.}}{22400} M_{av} \quad (1)$$

where $(V_{NO} + V_{NO_2})_{init.}$ are separately determined initial amounts of NO and NO_2 at entering, expressed in cubic centimeters at standard pressure and temperature; $(V_{NO} + V_{NO_2})_{fin.}$ same, at exit; M_{av} is the average molecular weight of $NO + NO_2$ in the gas in percent. Volume of adsorbed nitrogen oxides was determined by weighing the adsorbent on an analytical balance before and after adsorption.

To determine the degree to which adsorption of nitrogen oxides depended upon the degree of NO oxidation, and to determine the catalytic effect of the adsorbent upon the rate of NO oxidation, a small (50 cm^3) and large (2270 cm^3) oxidation volumes were used. Averages of data obtained under static adsorption conditions in adsorption column 7 are shown below; in computing, the results were based on averages of experimental data obtained in connection with the larger installation.

Results of investigations. The first series of experiments was devoted to a study of the effect of nitrogen oxides concentration in the gas, the degree of NO oxidation and the volume velocity of the gas on the degree and rate of nitrogen oxides adsorption. Results are plotted in Figs. 2 - 5.

Curves in Fig. 2 show the adsorption degree of nitrogen oxides which passed through the smaller oxidizing volume. As expected, the degree of NO oxidation was reduced with the increase in the volume rate of gas flow, due to the shorter time the gas remained in the oxidizing flask. The following data may apply when volume rate of gas flow $w = 1000 - 1150 \text{ m}^3/\text{m}^3$ of sorbent per hour:

<u>Concentration of nitrogen oxides in percent</u>	<u>Degree of NO oxidation in percent</u>
0.5	5 - 7
1.06	18 - 21
1.52	22 - 25
2.15	30 - 36

Data plotted in Fig. 2 show that with an increase in the nitrogen oxides concentration in the gas, and rise in the degree of their oxidation, the rate of nitrogen oxides adsorption also increased. An increase in the volume gas flow rate in all cases lowered the nitrogen oxides adsorption consequent to the shorter contact time between the gas and the adsorbent. At gas flow vol-

ume rates up to 400 - 500 m³/hour, the adsorption degree fell gradually as the flow rate was reduced. With further increase in volume gas flow rate, the adsorption curves descended more abruptly.

Adsorption rates for nitrogen oxides, computed on the basis of experimental data shown in Fig. 2 are presented in Fig. 3. The data indicate that the unit volume productivity of aluminosilicate adsorbent increased with an increase in

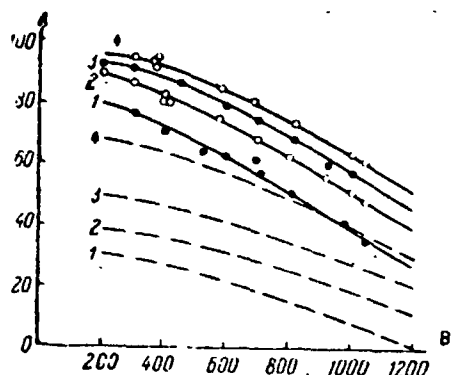


Fig. 2. Degree of nitrogen oxides adsorption in relation to gas flow volume rate, NO + NO₂ concentration in the gas and NO oxidation degree at t = 18 - 20°.

A - Degree of adsorption in %; B - Volume rate gas flow in m³/hour.
Solid lines - Degree of adsorption;
Dotted lines - Degree of NO oxidation.
NO + NO₂ concentration in %: 1 - 0.5;
2 - 1.08; 3 - 1.52; 4 - 2.15.

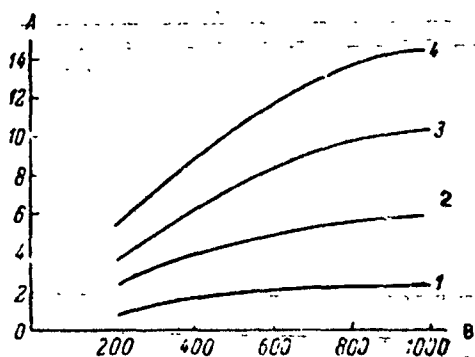


Fig. 3. Rates of nitrogen oxides adsorption with aluminum silicate column migrating against the gas flow in relation to NO + NO₂ concentration and to volume gas rate flow at t = 18 - 20°.

A - Adsorption rate in kg/m³/hour; B - Volume gas flow rate in m³/hour.
NO + NO₂ concentration in %: 1 - 0.5; 2 - 1.08;
3 - 1.52; 4 - 2.15.

the nitrogen oxides concentration in the gas and in the volume gas flow rate. However, the latter holds true only up to w = 600 = 900 m³/hour. Continued increases in the volumetric gas flow rate diminished the adsorption rate, in other words, it lowered the adsorbing unit capacity of the reacting adsorbent per unit time. This holds true for a sorbent which moved toward the flowing gas; under such conditions the degree of adsorbent saturation with nitrogen oxides did not exceed 60 - 65% of the equilibrium saturation. The adsorption coefficients computed on the basis of experimental data are shown in Fig. 4.

In computing the adsorption coefficients, the motive force was assumed equal to the

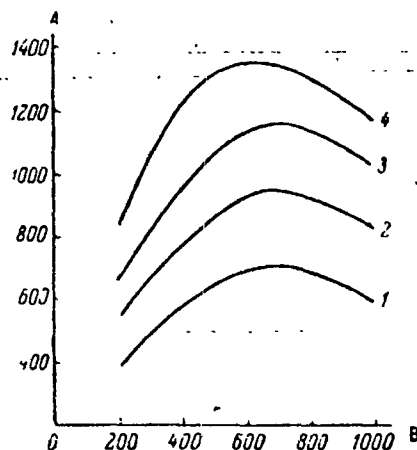


Fig. 4. Coefficients of nitrogen oxides adsorption by aluminosilicate in relation to volume gas flow rate and NO + NO₂ concentration at t = 18 - 20°.

A - Adsorption coefficient in kg/m³/hour/atm;
B - Volume gas flow rate in m³/hour.
NO + NO₂ concentration in %: 1 - 0.5; 2 - 1.08;
3 - 1.52; 4 - 2.15.

mean-logarithmic difference of the partial pressures of $\text{NO} + \text{NO}_2$ respectively upon entering and leaving the apparatus. Fig. 4 indicates that the maximal adsorption coefficient values corresponded to volume velocities of 600 - 700 m^3/hour . Consequently, utilization of gas flow volume velocities greater than 600 - 700 m^3/hour , in this particular case, would be unsuitable because of a lowering in the degree and coefficient of adsorption.

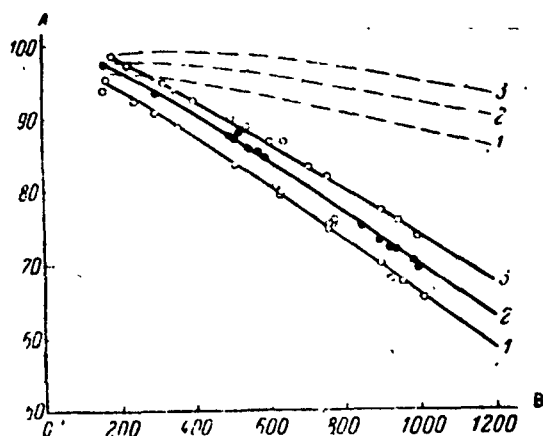


Fig. 5. Adsorption degree in relation to volume gas flow rate, $\text{NO} + \text{NO}_2$ concentration and degree of NO oxidation at $t = 22 - 23^\circ$. A - Degree of adsorption in %; B - Volume gas flow rate in m^3/hour . $\text{NO} + \text{NO}_2$ concentration in %: 1 - 1.1; 2 - 2.08; 3 - 2.94.

data in Fig. 5 indicate that an increase in nitrogen oxides concentration in the gas and in the time of contact between the gas and the sorbent, that is, with a reduction in w , the degree of $\text{NO} + \text{NO}_2$ adsorption increased. A comparative study of the data shown in Figs. 2 and 5 lead to the conclusion that the degree of NO oxidation was of importance in determining the degree and the rate of adsorption. The greater the degree of NO oxidation, the greater is the degree of nitrogen oxides adsorption. The functional dependence between the acceleration of adsorption rate and the degree of NO oxidation can be derived from the general equation of mass transfer:

$$\frac{dx}{d\tau} = k' \cdot x$$

or

$$k \cdot \tau = \lg \frac{x_0}{x \cdot \tau} = \lg \frac{1}{1 - \alpha} \quad (2)$$

where x is the concentration of $\text{NO} + \text{NO}_2$ in the gas, k is the coefficient of adsorption and α is the degree of adsorption, expressed in fractions of unity.

Thus, if $w = 500 \text{ m}^3/\text{hour}$ and $\text{NO} + \text{NO}_2$ concentration in the gas is 1.1%, then the rates of the two adsorbing processes can be expressed as the ratio: $\lg(1 - 0.84) : \lg(1 - 0.78) = 1.27$, where 0.84 is the degree of nitrogen oxides adsorption, with concentration of 1.1% with the degree of NO oxidation 94% (see Fig. 5), and 0.78 is the degree of nitrogen oxides absorption of the same concentration with the degree of NO oxidation equal to 34%.

Accordingly an increase in the degree of NO oxidation by 60% will increase the degree of adsorption by only 6%, and the process of adsorption will be accelerated 1.27 times. From this example, which illustrates the generally regularity of the process, it can be concluded that the aluminosilicate adsorbent not only adsorbed nitrogen oxides, but at the same time acted as a catalyzer of NO oxidation. This phenomenon is substantiated in greater detail in the text below.

The values of the adsorption rates and of the adsorption coefficients for nitrogen oxides were computed on the basis of the experimental data. The values referred to are shown respectively in Figs. 6 and 7.

A comparative study of the data shown in Figs. 6 and 7 with those shown in Figs. 3 and 4 indicates that with an increase in the degree of NO oxidation, as shown in Figs. 6 and 7, the adsorption rate and the adsorption coefficient values exceeded those seen at lower degree of NO oxidation. It can be con-

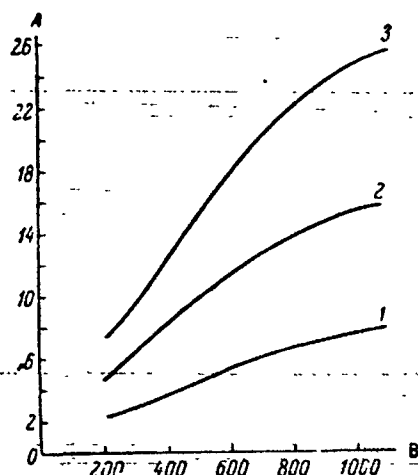


Fig. 6. Adsorption rate in relation to volume gas flow rate and $\text{NO} + \text{NO}_2$ concentration at $t = 22 - 23^\circ$.

A - Adsorption rate in $\text{kg}/\text{m}^3/\text{hour}$; B - Volume gas flow rate in m^3/hour .

$\text{NO} + \text{NO}_2$ concentration in %: 1 - 1.1; 2 - 2.08; 3 - 2.94.

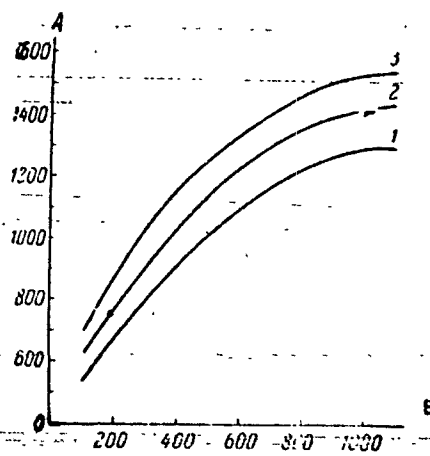


Fig. 7. Adsorption coefficient in relation to volume gas flow rate and $\text{NO} + \text{NO}_2$ concentration.

A - Adsorption coefficients in $\text{kg}/\text{m}^3/\text{hour}/\text{atm}$; B - Volume gas flow rate in m^3/hour .

$\text{NO} + \text{NO}_2$ concentration in %: 1 - 1.1; 2 - 2.08; 3 - 2.94.

cluded from this that the aluminum silicate adsorbed the higher nitrogen oxides.

The above applies to $\text{NO} + \text{NO}_2$ adsorption from a dry gas, i.e., a gas with an approximate 8 g/m^3 water vapor content. However, adsorption of $\text{NO} + \text{NO}_2$ from a moist gas is of great practical interest. Therefore, air and NO entering the mixer were first humidified in their respective flasks, as shown in Fig. 1, at different temperatures, to saturate them with water vapor to a desired degree. The temperature of the gas in this case varied between 23° and 26° ; such variation in the temperature had no pronounced effect on the degree of NO oxidation, which, in this case remained between 93 and 94%. The initial $\text{NO} + \text{NO}_2$ concentration in the gas was maintained within the limits of 1.25 and 1.28%, and the volume velocity of the gas flow $w = 500 \text{ m}^3/\text{hour}$. The results of these experiments are plotted in Fig. 8.

The plots show that the adsorption degree, and consequently the adsorption rate, diminished with the increase in the water vapor content in the gas. The adsorption rate diminished in an analogous manner with the rise in temperature. Within the limits of the temperature under investigation, namely, from 12 to 42° , the constancy of the following factors was maintained: $w = 500 \text{ m}^3/\text{hour}$; gas humidity = 3.1%, $\text{NO} + \text{NO}_2$ content in the gas = 1.35%; and the degree of NO oxidation = 98 to 96%. Under these conditions the adsorption degree diminished from 97 to 73%. The results of this investigation are depicted in Fig. 9.

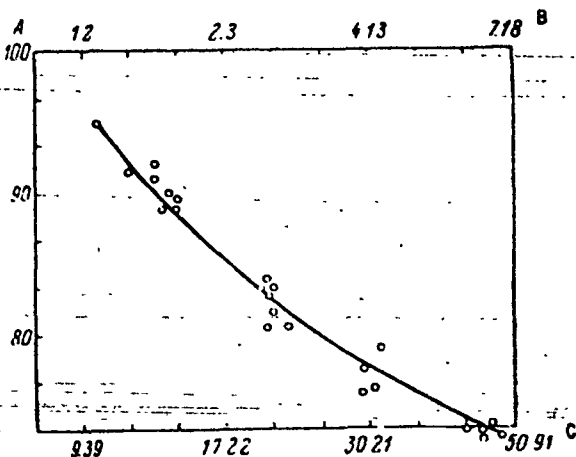


Fig. 8. Degree of nitrogen oxides adsorption in relation to gas moisture content at $\text{NO} + \text{NO}_2$ concentration - 1.25 - 1.28% and $w = 500 \text{ m}^3/\text{hour}$.
A - Degree of adsorption in %; B - Gas moisture content in g; C - Gas moisture in g/m^3 .

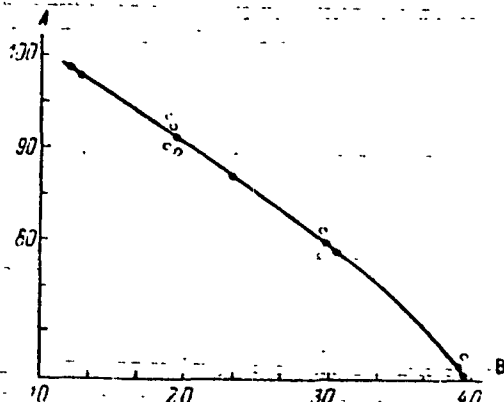


Fig. 9. Degree of nitrogen oxides adsorption in relation to temperature. $\text{NO} + \text{NO}_2$ concentration - 1.35%; NO oxidation - 98%; $w = 500 \text{ m}^3/\text{hour}$.
A - Degree of adsorption in %; B - Temperature in $^\circ\text{C}$.

A comparison of curves shown in Figs. 8 and 9 indicates that an increase in the gas humidity produced a greater negative effect upon the degree of nitrogen oxides adsorption than the effect of temperature raised from 40 to 45°. The adsorption degree fell rapidly when temperature was raised above 55 to 60°.

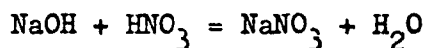
Desorption of nitrogen oxides and regeneration of the adsorbent. Nitrogen oxides were desorbed at 160°, 350° and 500°. The sorbent saturated with nitrogen oxides was placed into a closed quartz tube, which was first filled with nitrogen gas of 99.9% purity. The tube was then placed into an electrical furnace, and the nitrogen gas, preheated in another electrical furnace to a suitable temperature, was forced through the tube.

While passing through the adsorbent, the nitrogen gas became saturated with nitrogen oxides; upon leaving the furnace it was cooled in a condenser, wherefrom it was passed through the absorbing flasks. NO₂ was absorbed by a 5% solution of potassium iodide in the first 3 flasks, and NO was absorbed by a 10% solution of FeSO₄ in the next 2 flasks.

Control analyses were made by absorbing the desorbed nitrogen oxides by a 10% solution of NaOH. The analysis of the absorbent solutions and subsequent computations revealed that the degree of oxidation of the desorbed nitrogen oxides was always higher than that prior to the adsorption.

Computation of the time necessary for NO oxidation with 0.8 - 1.5% concentrations showed that in the presence of aluminosilicate the rate of nitrogen oxides oxidation, the humidity of which reached 18.5 g/m³, increased 2 and 2.5 times respectively.

Results of desorbed gas absorption with NaOH solution at 160°, disclosed that all nitrogen oxides adsorbed by the aluminum silicate were liberated in the form of nitric acid fumes, since they entered into the following reaction with the absorber:



The second series of experiments was devoted to nitrogen oxides desorption with hot nitrose gases, since, in the manufacture of nitric acid the utilized heat required no additional financial outlay in transmitting the heat. The results showed that the nitrose gases could be utilized effectively in the regeneration of the aluminosilicate at a temperature above 300°.

Thus, at $t = 500^\circ$ and an assumed nitrose gas flow rate in the adsorption column equal to 0.7 m/sec, 96 - 98% regeneration of the adsorbent was attained within 10 minutes. The adsorption and regeneration experiments were repeated, using the same adsorbent eight to ten times; it was observed that the adsorbing capacity of the silicate was almost completely restored after regeneration. The physical properties of the adsorbent and its mechanical firmness remained unaffected.

Practical application of the method described and its expediency. The investigation revealed that aluminosilicate possessed considerable adsorbing capacity, as shown by the fact that 1 kg of the adsorbent at 20° adsorbed 0.0306 kg of NO_2 at 2.5% moisture content.

Thus, for 90% purification of 90,000 m^3 /hour of gas, consisting of 0.8% of $\text{NO} + \text{NO}_2$, the required quantity of the adsorbent would be:

$$\frac{90,000 \cdot 0.8 \cdot 46}{100 \cdot 22.4 \cdot 0.0306} = 48,366 \text{ kg}$$

Even with a 100% adsorbent reserve the total quantity required would be less than 100 t per hour. However, taking into account the fact that the adsorbent can be regenerated and used 3 times in one hour the quantity of the adsorbent required for continuous operation can be limited to 35 - 40 t.

The experimental data obtained in the adsorption column were checked in a larger laboratory installation with a moving adsorbent in a triple-zone apparatus. The apparatus was filled with the adsorbent up to 2 li capacity. The regenerating adsorbent was fed through the upper part of the column with the discharged nitrose gas passing in a counterflow direction. After adsorption had been completed, the adsorbent was passed through special pipes to the middle zone, through which a hot nitrose gas was passed coming from adjacent contact apparatuses. In the process of desorption, the nitrose gas becomes enriched with nitrogen oxides; after leaving the desorption zone it is first cooled and again used for adsorption. The regenerated adsorbent is passed through special pipes into the lower zone where it is cooled by circulating cold air. Some of this air containing nitrogen oxides is fed into absorption towers to enrich the gas with oxygen.

For the determination of the technical and economical aspects of the proposed method, the results yielded were compared with the analogous results yielded by installation for the absorption of nitrogen oxides by a solution of $\text{Ca}(\text{OH})_2$. The economy effected by the proposed adsorption method was as follows:

Reaction volumes were reduced to less than 11%.

Capital investment was reduced to less than 15.5%.

Consumption of metal was reduced to less than 8%.

Power consumption was reduced to less than 27%.

Conclusions.

1. Alumosilicate is a highly effective adsorber of nitrogen oxides and can be regenerated to its original capacity. The combination of its great adsorbing capacity with its mechanical firmness, wear and heat resistance make this adsorbent highly suitable for the adsorption of nitrogen oxides.

2. The alumosilicate adsorbent acts as a catalytic agent accelerating the process of NO oxidation to nitric acid.

3. The use of alumosilicate as an adsorbent offers the opportunity for fine purification of gases from nitrogen oxides at lower capital investment and lowered operation cost as compared with other existing methods.

Bibliography.

- [1] С. Н. Г а н з, ЖНХ, XXXI, 1, 138 (1958).— [2] П. М. Ж а в о р о н к о в, ЖХН, 7, 419 (1954).— [3] С. Н. О б р я д ч и к о в, Технология нефти, II. Гостехиздат (1952).— [4] В. П. О б о р и н, Синтетический алюмосиликатный катализатор. Обл. изд. лит. Грозный (1948).

Hydrogen Sulfide Absorption by Sodium Arsenate Solution in a Foam Apparatus.

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The sodium arsenate method for the purification of gases from hydrogen sulfide differs from other scrubber methods in that its ultimate products, elementary sulfur and sodium thiosulfate, are of value industrially. Cycle scrubber methods, such as the potash, soda and ethanolamine methods, produce gaseous hydrogen sulfide, the conversion of which into sulfur or sulfuric

acid incurs additional cost. On the other hand, the technological set-up of the soda-arsenate method of gas purification is more complex and the equipment used is massive. The maintenance and operation of packed scrubbers up to 32 m in height for hydrogen sulfide absorption requires considerable capital investment and high power consumption for pumping the solutions. The use of modern efficient equipment for hydrogen sulfide absorption by soda-arsenate solution should encourage the wide use of this method for freeing gases from sulfur on a more economical basis. In this connection a study of conditions under which such a process of hydrogen sulfide absorption may be made workable in a foam apparatus, usually characterized by high efficiency, is of practical interest [1]. Reports recorded in the literature on investigations related to soda-arsenate gas purification from hydrogen sulfide were concerned primarily with the chemical principles of the processes [2 - 5] and with conditions which caused disturbances in the practical application of this process.

The basic characteristics of scrubbers used in hydrogen sulfide absorption by a soda-arsenate solution were described by Nusinov [6, 7]. In his experiments Nusinov used a solution which contained 10 g/li As_2O_3 and 14 g/li Na_2CO_3 . The initial content of hydrogen sulfide in the gas amounted to 8 g/li or 0.52% by volume. With a spraying rate equal to 5.9 li/m^3 of the gas, or an excess of the reagent equal approximately to 25% over the stoichiometric amount, and the rate of gas flow in the cross-section of the packed section equal to 0.55 m/sec, the total degree of purification was 94.5%, and the absorption coefficient was $136 \text{ kg/m}^3/\text{hr/atm}$. The results of the experiment indicated that the absorption coefficient was independent of the hydrogen sulfide concentration and that the spraying rate was the deciding factor in attaining the high rate and completeness of the absorption. Nusinov also presented data which defined the nature of changes in the degree of H_2S absorption and of the absorption coefficient effected by the linear velocity of the gas flow. An increased gas flow velocity over the open cross-section of the scrubber from 0.5 to 1.3 m/sec lowered the degree of absorption to 52%, and increased the absorption coefficient approximately 1.5 times.

Results of experiments on hydrogen sulfide absorption by soda-arsenate solution conducted on a large industrial scale showed that the absorption coefficient ranged between 80 to $100 \text{ kg/m}^3/\text{hr/atm}$. Krendel' [8] acknowledged on an a priori basis the probability that the absorption coefficient depended upon the hydrogen sulfide concentration in a gas. Other investigators estab-

lished that the rate of hydrogen sulfide absorption depended only on the hydrogen ion concentration in the solution and the hydrogen sulfide concentration in the gas. The hydrogen sulfide absorption by solutions having high pH is very rapid. However, the solution quickly becomes exhausted because of the rapid pH depletion. The presence of arsenic in the solution acted as a buffer, retarding the fall in the pH.

Litvinenko [9] demonstrated that the rate of hydrogen sulfide absorption by a solution of soda or potassium, within the limits of partial pressures equalling 0.02 to 0.03 atm, was expressed by an equation [10], which was applicable to processes, the rates of which were determined by the absorbent concentration in the solution and by the partial pressure of the gas being absorbed. In cases of low hydrogen sulfide pressure, particularly in those below 0.02 - 0.03 atm, the rate of absorption depended upon the partial pressure of hydrogen sulfide, and only to a minor degree upon the concentration of the absorbent in the solution. The characteristics of the process of hydrogen sulfide absorption by a soda-arsenate solution in a scrubber cannot be applied mechanically to H_2S absorption in a foam apparatus, due to the dissimilarity of the hydrodynamic conditions responsible for the technological differences. Results of work conducted for the determination of the degree and of the hydrogen sulfide absorption coefficient by a soda-arsenate solution in a foam apparatus are described below.

Experimental work.

The installation, the experimental methods and the analytical procedures. Fig. 1 is a schematic drawing of the installation used in the study of hydrogen sulfide absorption by soda-arsenate solution in a foam apparatus.

A gas mixture of known composition was prepared in mixer 1. Nitrogen, hydrogen or carbon dioxide coming from gas cylinders and hydrogen sulfide generated in a Kip apparatus were fed into mixer 1 through

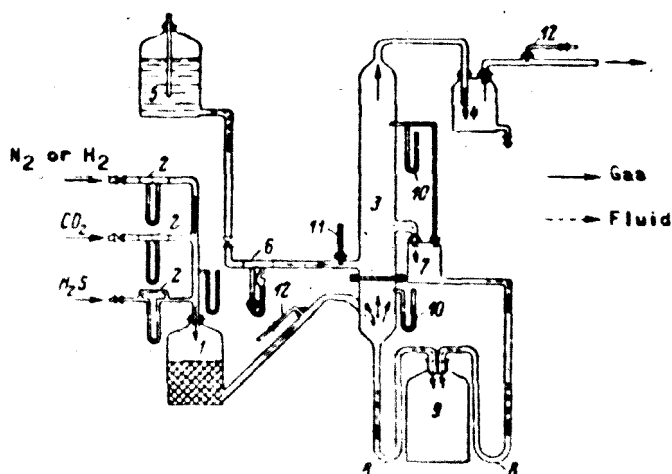


Fig. 1. Plan of installation for hydrogen sulfide absorption in foam apparatus.
1 - Mixer; 2 - Gas flowmeter; 3 - Foam apparatus;
4 - Catcher; 5 - Pressure compartment; 6 - Fluid flowmeter; 7 - Chamber for foam disintegration;
8 - Hydraulic valve; 9 - Receiving flask; 10 - Manometer; 11 - Thermometer; 12 - Gas sampling tubes.

flowmeter 2. From the mixer the gas entered the foam apparatus 3 at a level below the grate, from there it was passed through a spray eliminator and thence into the atmosphere. The absorbent solution, heated to $35 - 38^{\circ}$, was fed into the foam apparatus. The amount of fluid was regulated by means of flowmeter 6. Having passed through the apparatus, the foam fluid first passed through an outflow and entered vessel 7, where the foam disintegrated, and then through hydraulic valves 8 into collecting flask 9.

Several foam apparatus designs have been described previously [1]. A schematic drawing of a laboratory set-up for the study of absorption apparatus performance is shown in Fig. 2, which is self-explanatory.

The overflow elevation above the grate level, equal to 60 mm, determined the height of the weir which retained the foam above the grate. The grate, made of plastic vinyl, was 5 mm thick and had perforations 2 mm in diameter distributed at 5 mm between centers. The area of the perforated part of the

grate 0.0011 m^2 is equal to the cross-section of the apparatus and constituted 15.3% of the area of the grate or screen.

The soda-arsenate solution was prepared by dissolving arsenic trioxide in a solution of calcined soda at $70 - 80^{\circ}$. Then, the solution was diluted with water until it contained $\sim 7 \text{ g/li}$ of As_2O_3 ; hydrogen sulfide at 35° and air at 40° were alternately passed through the solution to convert the sodium arsenate into Na-thioarsenite and Na-thioarsenate. "Ripening" of the solution was determined by the precipitation of sulfur following the alternate passing of air through the solution; sodium thiosulfate was then added according to its content in industrial solutions. In the course of the experiment, the content of arsenic in the solution remained constant at about 6.5 g/li As_2O_3 . The thiosulfate increased from 200

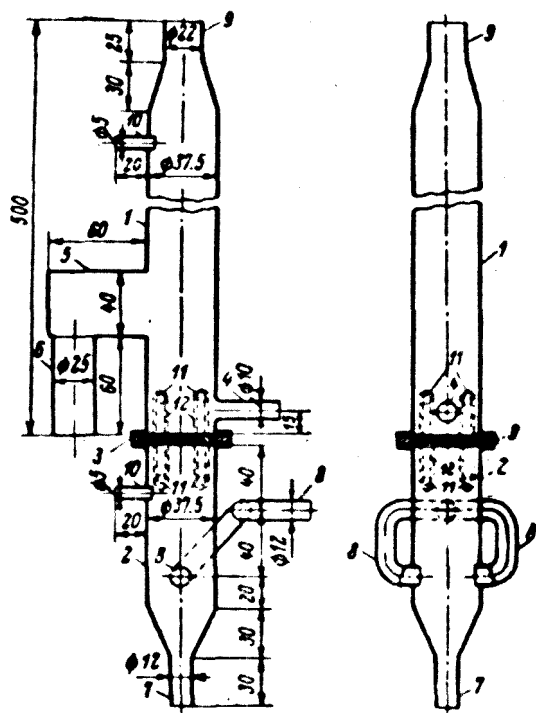


Fig. 2. Laboratory model of a single screen-shelf foam apparatus.
1 - Above screen column sections; 2 - Below screen column sections; 3 - Screens; 4 - Fluid inflow nipple; 5 - Overflow catch box; 6 - Overflow nipple; 7 - Waste fluid outflow; 8 - Fluid inflow tubes; 9 - Gas outflow tube; 10 - Outlet to manometers for pressure recording; 11 - Bearing hooks; 12 - Rubber fastener.

to 210 g/li. The pH value of the solution was approximately 8.0. When the pH value diminished, particularly when the gas contained CO_2 , a corresponding quantity of soda was added to the solution to maintain its pH at 8.0. It should be noted in this connection that after one or two experiments the pH value diminished by 0.1.

The solution used in the experiments was highly reactive; fully saturated with hydrogen sulfide it absorbed nearly all the theoretically computed oxygen; 20 ml of a regenerated solution absorbed not more than 0.3 ml of oxygen. Analysis of the solution and of the gas were made by the usual methods [7, 11]. Gas samples were collected in vacuum flasks. The efficiency coefficient of a single perforated screen-shelf apparatus, i.e., the degree of absorption, and the rate and the absorption coefficient were determined by the hydrogen sulfide content in a gas before and after its passage through the apparatus [12, 13].

Results of the investigation. To determine the basic principles regulating the absorption of hydrogen sulfide by a soda-arsenate solution in a foam

apparatus and to determine the optimal conditions for the process, tests were conducted at different rates of gas flow through the cross-section of the apparatus and at different absorbent fluid flow intensities. By the term "intensity of flow of the fluid" is meant the rate of fluid volume flowing over the apparatus grate (or screen) to the width of the flowing fluid, expressed in $\text{m}^3/\text{m}/\text{hour}$. The rate of gas flow ranged between 0.25 and 2.5 m/sec, which corresponded to variations in the gas volumes from 1.0 to 10.2 m^3/hour . The amount of fluid supplied ranged between 20 and 300 li/hour, which accorded with variations in the fluid flow from 0.67 to 10 $\text{m}^3/\text{m}/\text{hour}$, with the overflow width equal to 0.03 m. Changes in the rate of hydrogen sulfide absorption, depending on mean partial pressure, ranged between 0.0154 and 0.414 volume percent; data are shown in Fig. 3.

Experiments were conducted at linear flow rate $w = 1$ m/sec through a total cross-section, and a liquid

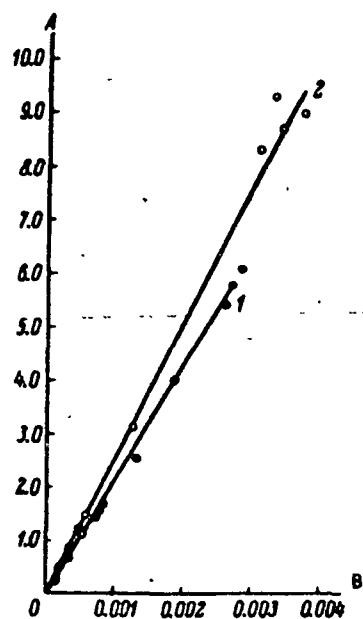


Fig. 3. Rate of hydrogen sulfide absorption in relation to its partial pressure at fluid/gas volume ratio 18.75 g/li. A - Absorption rate in $\text{kg}/\text{m}^2/\text{hr}$; B - Partial H_2S pressure in atm; linear gas flow rate w in m/sec. 1 - 1; 2 - 2.

consumption equal to 75 li/hour, i.e., with an intensity $i = 2.5 \text{ m}^3/\text{m}^2/\text{hour}$, and also with $w = 2 \text{ m/sec}$, and a fluid consumption equal to 150 li/hour, i.e., with $i = 5 \text{ m}^3/\text{m}^2/\text{hour}$. The same ratio of fluid volumes and gas $f = 18.75 \text{ li/m}^3$, was maintained throughout the 2 experimental series. Partial pressure was computed as the arithmetical mean between the partial pressure of hydrogen sulfide before entering and after leaving the apparatus.

It can be seen from Fig. 3 that the hydrogen sulfide absorption rate within the range of the concentrations investigated was directly proportional to its partial pressure p in a gas; this was in agreement with the theoretical and experimental data obtained in absorption tests with other gases and a low concentration of the absorbed component. It follows that the absorption rate of hydrogen sulfide by a soda-arsenate solution per 1 m^2 of the grate (screen) area may be expressed by the following equation:

$$\frac{g}{S \tau} = K \cdot p$$

where g is a quantity of hydrogen sulfide absorbed in kg, S is the area of the grate in m^2 , τ the time of absorption in hours, p the mean partial pressure of hydrogen sulfide in a gas in atm, K the absorption coefficient per 1 m^2 of the surface of the grate in $\text{kg/m}^2/\text{hour}/\text{atm}$. The absorption coefficient K may be computed by the above formula or determined from Fig. 4, since it is equal to the tangent of the angle formed by the plotted straight line and the abscissa. The values of K obtained from the experimental data fall in positions along the straight line parallel to the abscissa in the coordinates $K = C_H$,

where C_H is the initial concentration of H_2S in the gas, expressed in volume percent, thus establishing an independence of K from the partial pressure of hydrogen sulfide in the gas.

The value of the absorption coefficient determined as the tangent of the straight line slope in the coordinate system, the absorption rate of partial pressure, for $f = 18.75 \text{ li/m}^3$ and $w = 1 \text{ m/sec}$, approximated $2150 \text{ kg/m}^2/\text{hour}/\text{atm}$ and for $w = 2 \text{ m/sec} \sim 2500 \text{ kg/m}^2/\text{hr}/\text{atm}$. From this equation, which determined the functional relation of K to the efficiency coefficient of a one-shelf foam apparatus η and the linear rate of gas flow

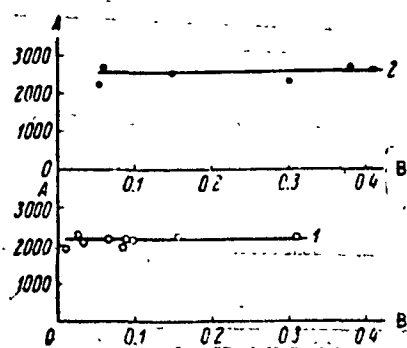


Fig. 4. Values of K at different H_2S concentrations in the gas at $f = 18.75 \text{ li/m}^3$.

A - Absorption coefficient in $\text{kg/m}^2/\text{hr}$; B - H_2S concentration in gas in volume percent; linear gas flow rate w in m/sec .

1 - 1; 2 - 2.

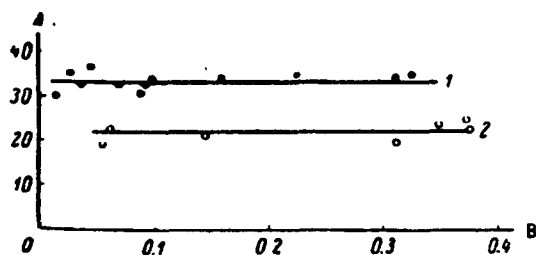


Fig. 5. Screen-shelf efficiency coefficient in relation to H_2S concentration in the gas. A - Efficiency coefficient η in %; B - Initial H_2S concentration in the gas in volume %; Linear gas flow rate w in m/sec: 1 - 1; 2 - 2.

w [12], it follows that if the respective values of K and w remained constant, the value of η also remained constant.

Fig. 5 shows that the efficiency coefficient of a one-shelf foam apparatus did not depend upon the initial concentration of hydrogen sulfide, if the value of w remained constant. This fact makes possible the computation of a multi-shelf apparatus, based on identical values of the

efficiency coefficient for all shelves.

Data on hydrogen sulfide absorption by a soda-arsenate solution in a foam apparatus based on the linear rate of gas flow w , expressed in m/sec, and the intensity of the liquid flow i , expressed in $m^3/m/hour$, are listed in the following Table. Furthermore, the Table also presents data which characterize the absorbing capacity of a soda-arsenate solution: the ratio of liquid K to gas f expressed in li/m^3 , and the excess of chemical reagent over the stoichiometrically required amount U , expressed in percent. Depending upon the ratio of liquid K to gas f , the content of arsenic trioxide in the solution a , expressed in g/li , the content of sulfur in the gas to be purified y_H , expressed in g/m^3 , the excess of the absorber can be computed by the following formula [7]:

$$U = \frac{32 \cdot f \cdot a}{198 \cdot y_H} 100 - 100$$

The functional relations of the efficiency coefficient of a one-shelf apparatus η , to w and i are illustrated in Figs. 6 and 7.

The curves in the following Figs. show that the value of η diminished sharply with the increase in w and increased with the increase in i . Hence, with $i = 1.34 m^3/hour$, equivalent to 40 li/hour of liquid, the efficiency coefficient of the perforated shelf (screen) within 0.25 to 2.5 m/sec range of linear gas flow dropped from ~ 60 to 10%. An increase in the rate of liquid flow up to $5 m^3/m/hour$, equivalent to 150 li/hour somewhat retarded the fall of the efficiency coefficient of the perforated shelf. An increase in w from 0.25 to 2 m/sec resulted in a drop of the efficiency coefficient of the perforated shelf from 62 to 22%. The decrease in the efficiency coefficient of the apparatus screen shelf caused by an increased linear rate of gas flow re-

Experimental results of hydrogen sulfide absorption by soda-arsenate solutions in a one-screen-shelf foam apparatus.
(H_2S concentration in the gas 0.3 volume percent. Height of weir 60 mm).

Rate of gas flow over entire apparatus cross section	Rate of fluid flow in $m^3/m/hr$	Ratio of gas to fluid volume in li/m^3	Absorber fluid excess in % over the theoretical	Efficiency coefficient of the apparatus screen η in %	Absorption rate g/S in $kg/m^2/hr$	Absorption coefficient K in	
						m/hour	kg/m^2 of screen hr/atm
0.25 {	0.67	20.00	420	53.3	2.06	650	985
	1.34	40.00	940	60.8	2.34	783	1185
	2.50	75.00	1850	59.1	2.28	756	1145
	5.00	150.00	3800	62.4	2.40	814	1235
0.50 {	0.67	10.00	160	31.2	2.34	665	1000
	1.34	20.00	420	38.4	3.01	868	1315
	2.50	37.50	860	43.7	3.36	1005	1520
	5.00	75.00	1830	55.3	4.27	1375	2085
0.75 {	0.67	~7.00	80	19.0	2.19	567	860
	1.34	13.30	240	28.7	3.32	805	1375
	2.50	25.00	550	33.7	3.89	1090	1640
	5.00	50.00	1170	40.0	4.62	1350	2045
1.00 {	0.67	5.00	30	16.7	2.56	656	995
	1.34	10.00	160	20.3	3.13	810	1230
	2.50	18.75	380	32.7	5.04	1410	2140
	5.00	37.50	860	38.3	5.90	1700	2580
	7.50	56.25	1330	44.8	6.91	2075	3140
	10.00	75.00	1830	44.6	6.86	2065	3130
1.50 {	1.34	~7.00	80	13.0	3.00	750	1140
	2.50	12.50	210	18.0	4.15	1070	1620
	5.00	25.00	550	27.0	6.22	1680	2550
	7.50	37.50	860	36.2	8.30	2360	3580
2.00 {	1.34	5.00	30	10.8	3.28	822	1250
	2.50	9.38	130	14.5	4.51	1130	1710
	5.00	18.75	380	22.0	6.76	1780	2700

sulted from a shorter contact time between the fluid and gaseous phases [14] and from a lower ratio of liquid and gas volumes. A rise in the value of f at the same solution concentration increased the amount of the chemisorbent reagent, and, according to the law of mass-reaction, should also accelerate the chemical reaction. In experiments conducted at the same time at identical liquid flow rates, the ratio f sharply changed due to increased linear rate of gas flow. Thus, with $i = 0.67 m^3/m/hour$, the value of f , within 0.25 to 2.5 m/sec range of w changed from 20 to 2 li/m^3 . Even at maximum rate of fluid

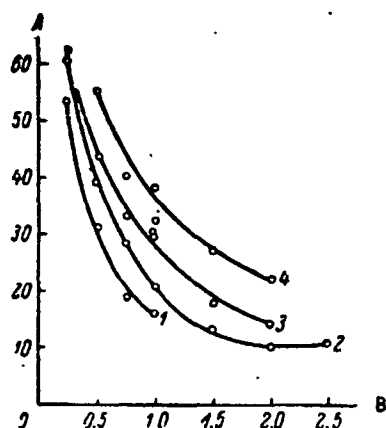


Fig. 6. Efficiency coefficient of apparatus screen-shelf in relation to linear gas flow rate w .
A - Efficiency coefficient η in %; B - Linear gas flow rate w in m/sec.
Intensity i in m^3/hr : 1 - 0.67; 2 - 1.34; 3 - 2.5; 4 - 5.0.

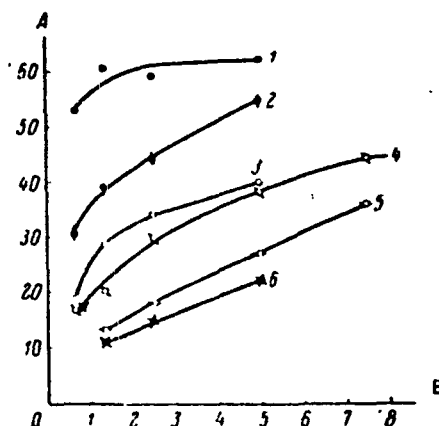


Fig. 7. Efficiency coefficient of apparatus in relation to intensity i of fluid flow.
A - Efficiency coefficient η in %; B - Intensity i in $\text{m}^3/\text{m/hr}$.
Linear gas flow rate w in m/sec: 1 - 0.25; 2 - 0.5; 3 - 0.75; 4 - 1.0; 5 - 1.5; 6 - 2.0.

flow $i = 5 \text{ m}^3/\text{m/hr}$, the ratio of fluid and gas volumes, with $w = 2.5 \text{ m/sec}$, was only 15 li/m^3 , i.e., less than the optimum, which is $\sim 18 - 20 \text{ li/m}^3$. Thus, the results showed that for the same value of the fluid flow velocity the rate of absorption increased with an increase in the linear rate, up to a definite limit, which was approximately 1 m/sec .

An increase in the linear rate of gas flow from 1.0 to 1.5 m/sec lowered the absorption rate for the average velocities of the liquid flow to 1.34 and $2.5 \text{ m}^3/\text{m/hr}$, and retarded the rise in the absorption rate with $i = 5 \text{ m}^3/\text{m/hr}$ as compared with the increase within the interval w up to 1 m/sec . An increase in the absorption rate was observed within the 1.5 to 2.5 m/sec range of w , at $i = 1.34$ and $2.5 \text{ m}^3/\text{m/hr}$, which may have re-

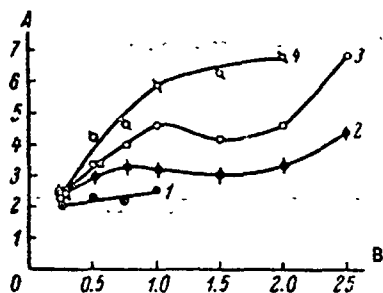


Fig. 8. Rate of hydrogen sulfide absorption in relation to w .
A - Rate of H_2S absorption in kg/m^2 of screen/hour; B - Linear gas flow rate in m/sec.
Intensity i in $\text{m}^3/\text{m/hr}$: 1 - 0.67; 2 - 1.34; 3 - 2.5; 4 - 5.0.

sulted from shifts in the hydrodynamic system, such as increased turbulence in the fluid flow, increased height of the foam layer, etc. The determination of the functional dependence of the absorption rate and of the efficiency coefficient of the perforated shelf (screen) upon the linear rate of gas flow, under conditions of identical liquid and gas volume ratios, is of importance. In the case under consideration changes in the linear rate of gas flow were ac-

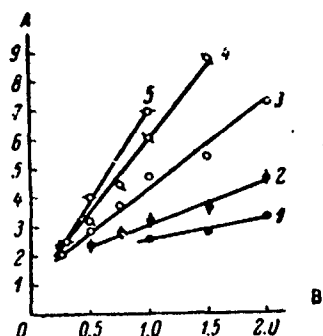


Fig. 9. Rates of hydrogen sulfide absorption in relation to w at different values of f .

A - Rate of H_2S absorption in kg/m^2 of screen/hr; B - Linear gas flow rate w in m/sec .

Values of f in li/min :
1 - 5; 2 - 10; 3 - 20; 4 - 40; 5 - 75.

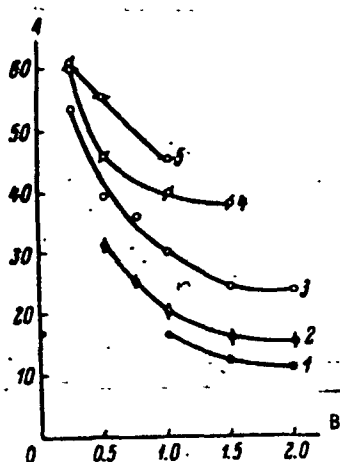


Fig. 10. Efficiency coefficient in relation to w at constant value of f .

A - Efficiency coefficient in %; B - Linear gas flow rate in m/sec .

Value of f in li/m^3 : 1 - 5;
2 - 10; 3 - 20; 4 - 40;
5 - 75.

accompanied by changes in the amount of liquid supplied into the apparatus which caused the rate of liquid flow to change correspondingly.

Curves in Fig. 9 show that the absorption rate for a constant value of f , increased in proportion to the linear rate of gas flow. The straight line curves of this functional relation at different f values are determined by the constancy of the absorbing power of the solution, while their slopes are determined by the absorbing capacity of the solution and by the hydrodynamic conditions prevailing at various fluid and gas volume ratios. The increase in the absorption rate caused by an increase in w was insignificant for low f values, but at $f = 20 li/m^3$ the absorption rate caused by an increase in w rose rapidly. A further increase in f up to 40 and 75 li/m^3 continued to effect an increase in the absorption rate; however, this increase can not compensate for the increased power consumption in pumping the large quantities of liquid and the increased pressure drop of the apparatus.

Changes in the efficiency coefficient of a single perforated shelf of the apparatus in its functional relation to w at different values of f are illustrated in Fig. 10.

A comparison of the data shown in Figs. 6 and 10 indicated that an increasing linear gas flow rate at a constant fluid to gas volume ratio, decreased the efficiency coefficient at a considerably slower rate than at a constant rate of fluid flow. Thus, with w within the 0.5 to 1.5 m/sec range, and $f = 20 li/m^3$, the efficiency coefficient decreased ~ 1.7 times, while with $f = 40 li/m^3$ it decreased ~ 1.2 times. At the same time, with w within the range of 0.05 to 1.5 m/sec , and $i = 1.34 m^3/m/hour$, the efficiency coefficient diminished ~ 3.2 times; with $i = 2.5 m^3/m/hour$, it diminished ~ 3 times. This fact can be ex-

plained by the shift in the absorption rate resulting from the change in the linear gas flow as a function of the constancy of the liquid gas volume ratio, or of the rate of liquid flow. However, the characteristics of the absorption process are best determined by the absorption coefficient and not by the absorption rate.

It was previously shown that the value of the hydrogen sulfide absorption coefficient within the range of its concentration in the gas, with $f = 18.75 \text{ li/m}^3$ and $w = \text{const.}$ was constant. Therefore, to establish optimal conditions for the performance of a foam apparatus it is necessary to determine the values of K within a wider range of the linear rates of gas flow as well as the fluid flow rates.

Curves in Fig. 11 show that with $i = 5 \text{ m}^3/\text{m}/\text{hour}$, K increased rapidly with w within the limits of 0.25 to 1 m/sec, and, thereafter, it remained practically constant. For other f values coefficient K first increased and then decreased. This fact pointed to differences in the importance of the resistance of the gaseous and the liquid phases [15] in the process of hydrogen sulfide absorption in relation to the conditions under which the process was carried out. Thus, the resistance of the liquid phase may be disregarded only at $i = 5 \text{ m}^3/\text{m}/\text{hour}$, and in this case, even though the absorption rate increased slightly with $w > 1 \text{ m}/\text{sec}$, it increased steadily throughout the entire range of linear gas flow rates from 0.25 to 2 m/sec. With the velocity of liquid flow equal to $2.5 \text{ m}^3/\text{m}/\text{hour}$, the resistance of the liquid phase showed a marked effect upon the absorption process and, as a consequence, the absorption co-

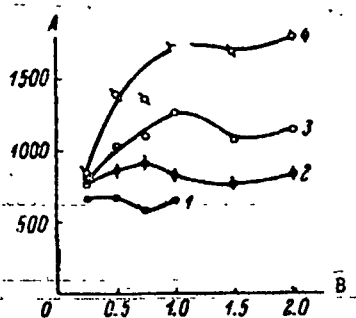


Fig. 11. K in relation to w .
A - K values in m^3/hour ; B -
Linear gas flow rate w in
 m/sec .
Intensity i in $\text{m}^3/\text{m}/\text{hour}$;
1 - 0.67; 2 - 1.34; 3 - 2.50;
4 - 5.0.

efficient increased with the increase in w only up to $\sim 1 \text{ m}/\text{sec}$. When the intensity of the fluid flow decreased to $1.34 \text{ m}^3/\text{m}/\text{hour}$, the absorption rate was determined basically by the liquid phase resistance. In this case, the absorption coefficient increased with the increase in w up to $0.75 - 0.85 \text{ m}/\text{sec}$ only. With constant liquid and gas volume ratios, the absorption coefficient increased steadily with an increase in the linear rate of gas flow, in correspondence with the value of f .

The results showed that the absorption coefficient increased rapidly with the increase in w , and with

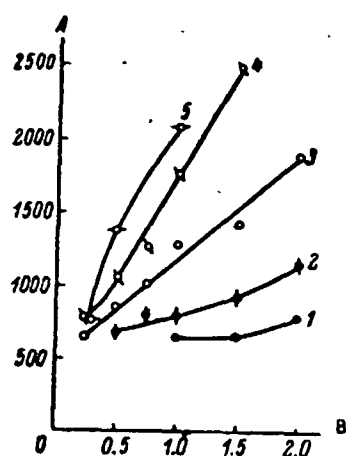


Fig. 12. K in relation to w at constant values of f .
A - Values of K in m/hour;
B - Linear gas flow rate w in m/sec.
Values of f in li/m³: 1 - 5; 2 - 10; 3 - 20; 4 - 50; 5 - 75.

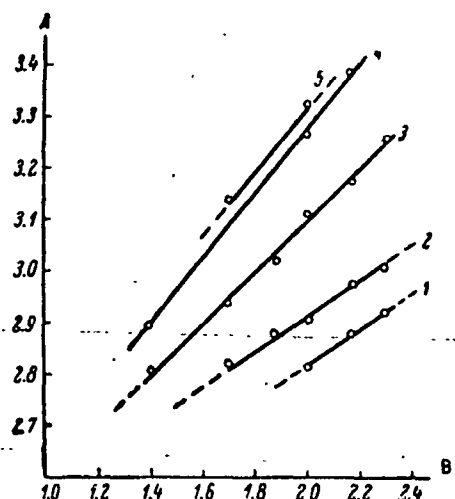


Fig. 13. K in relation to w in logarithmic system of coordinates.
A - Values of $\log K$; B - Values of $\log w$.
Values of f in li/m³: 1 - 5; 2 - 10; 3 - 20; 4 - 40; 5 - 75.

$f = 20 - 75 \text{ li/m}^3$. A decrease in the ratio of f to 10 and 5 li/m^3 resulted in a slower increase in the absorption coefficient with an increased rate of gas flow. This fact can be explained by the dissimilar hydrodynamic complex of conditions prevailing in the gas-liquid system, which, in turn, determined the degree of turbulence in different currents and the contributory resistance of the liquid phase.

Fig. 13 shows K as a function of w in a logarithmic system of coordinates. It also shows that the construction of the function $K = \varphi(w)$ in logarithmic coordinates produced straight line curves of different slopes as functions of the liquid-gas volume ratio. The above points to the fact that, with f being constant, the shift in the absorption coefficient

controlled by the linear rate of gas flow in a foam apparatus can be expressed by the formula $K = a \cdot w^n$. The values of n , determined by the tangent of the straight lines slope in Fig. 13, are equal to:

$$\begin{aligned} 0.33 & \text{ at } f = 5 \text{ and } 10 \text{ li/m}^3 \\ 0.5 & \text{ at } f = 20 \text{ li/m}^3 \\ \text{and } 0.625 & \text{ at } f = 40 \text{ and } 75 \text{ li/m}^3 \end{aligned}$$

The above data show that the resistance of the fluid phase played an important part in the process of hydrogen sulfide absorption by a soda-arsenate solution in a foam apparatus. Furthermore, the resistance of the liquid phase, as a part of the total resistance to absorption, depended upon the liquid and gas volume ratio.

The smaller was the ratio, i.e., the less the

excess of the absorber over the stoichiometric amount, the greater was the resistance of the liquid phase. However, the absorber capacity, especially with $f = 20 \text{ li/m}^3$, was high, and under the study conditions, i.e., under low partial hydrogen sulfide pressures, the absorption intensity was practically

determined only by the partial gas pressure. At the same time, the rate and the absorption coefficient depended considerably upon the hydrodynamic conditions prevailing in the foam apparatus.

The absorption coefficient in a foam apparatus was several times 10 greater than in a scrubber. It was previously stated that the coefficient of H_2S absorption in a scrubber apparatus did not exceed $100 \text{ kg/m}^3/\text{hour/atm}$. under conditions of industrial production. The respective values for the coefficient of hydrogen sulfide absorption obtained in a foam apparatus with $f = 18.75 \text{ li/m}^3$ were:

$2150 \text{ kg/m}^2/\text{hour/atm}$, at $w = 1 \text{ m/sec}$, and

$2500 \text{ to } 2700 \text{ kg/m}^2/\text{hour/atm}$, at $w = 2 \text{ m/sec}$.

Even at $f = 20 \text{ li/m}^2$ and $w = 0.5 \text{ m/sec}$, $K = 868 \text{ kg/m}^2/\text{hour/atm}$.

A distance of 0.5 m between the perforated shelves of the foam apparatus assured its normal operation. The results showed that gas purification from hydrogen sulfide by means of soda-arsenate solution can be accomplished in a foam apparatus much more efficiently than in a scrubber apparatus, as shown below:

with $w = 0.5 \text{ m/sec}$ - 17 times more efficient

$w = 1 \text{ m/sec}$ - 40 times more efficient

$w = 2 \text{ m/sec}$ = 50 times more efficient

Conclusions.

1. During the study of hydrogen sulfide absorption by a soda-arsenate solution in a foam apparatus, it was established that within the investigated range of H_2S concentration in a gas, i.e., up to approximately 4% by volume, and with constant liquid-gas volume ratios and constant linear rates of gas flow, the absorption coefficient and the efficiency coefficient of a single perforated shelf (screen) of the apparatus were independent of the hydrogen sulfide concentration in the gas.

2. Depending on the rate of liquid flow the efficiency coefficient of a single perforated shelf (screen) of the apparatus dropped by 55 to 65% at gas flow rate of 0.25 m/sec , and by 10 to 20% at gas flow rate equal to 2 m/sec .

3. With a constant liquid-gas volume ratio the rate and the absorption coefficient changed in proportion to the change in the linear rate of gas flow.

4. With low liquid-gas volume ratios, such as $f = 5 - 10 \text{ li/m}^3$, and within the $1 \text{ to } 2 \text{ m/hour}$ range, the absorption coefficient increased 1.2 to

1.4 times at a progression proportional to the 0.33 power of the rate of gas flow.

5. With high liquid-gas volume ratios the absorption coefficient, within the range of 0.5 to 1.5 m/sec, increased 2 times at $f = 20 \text{ li/m}^3$, and 2.5 times at $f = 40 \text{ li/m}^3$, or progressions proportional to the 0.5 power and 0.66 power of the rate of gas flow.

6. The values of the absorption coefficient obtained for hydrogen sulfide absorption in a foam apparatus (for example at $f = 18$ to 20 li/m^3) were many times greater than the values obtained for absorption in a scrubber apparatus.

7. Installation of foam apparatus requires several times less space than scrubber installation.

Bibliography.

- [1] М. Е. Позин, И. П. Мухленов, Е. С. Тумаркина, Э. Я. Тарат. Певный способ обработки газов и жидкостей. Госхимиздат (1955). — [2] С. Г. Аронов. Сера. Извлечение из промышленных отбросных газов. Metallurgizdat (1940). — [3] Н. И. Егоров, М. М. Дмитриев, Д. Д. Зыков. Очистка от серы коксового и других горючих газов. Metallurgizdat (1950). — [4] К. Н. Шабалин, Э. М. Михельсон, ЖХП, 9, 13 (1932). — [5] H. A. Golmer, Ind. Eng. Ch., 26, 2, 130 (1934). — [6] Г. О. Нусинов, ЖХП, 23, 1420 (1936). — [7] Г. О. Нусинов и А. П. Андрианов. Мышьяковый процесс газоочистки. ОНТИ (1937). — [8] А. С. Крендель, ЖХП, 4, 288 (1937). — [9] М. С. Литвиненко, ЖПХ, XXV, 7, 696 (1952). — [10] М. Е. Позин, ЖПХ, X/X, 1201, 1319 (1946); XXV, 802 (1948). — [11] С. М. Голлянд, А. Е. Страхова, ЗЛ, 4—5, 503 (1946). — [12] М. Е. Позин, ЖПХ, XXV, 10, 1032 (1952). — [13] М. Е. Позин, Б. А. Копылев, Г. В. Бельченко, Тр. ЛТИ им. Ленсовета, 36, Госхимиздат (1956). — [14] М. Е. Позин, Б. А. Копылев, ЖПХ, XXX, 3, 362 (1957). — [15] М. Е. Позин, Б. А. Копылев, ЖПХ, XXXI, 3, 387 (1958).

Rate of Hydrogen Sulfide Absorption by Sodium Arsenate Solutions.

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Zhurn. Prikl. Khim., Vol. 31, No. 11, 1624-1627, 1958.

The purpose of this study was to determine the mechanism of hydrogen sulfide absorption by sodium arsenate solutions under conditions simulating those in industry. The following series of experiments were conducted to determine the effect of different factors on the absorption rate. The technique of the experiment and the synthesis of the oxy-arsenate solutions were described in previous publications [1, 2].

Experimental part. Absorption of hydrogen sulfide by a solution containing a mixture of $\text{Na}_2\text{HAsS}_3\text{O}$ and $\text{Na}_2\text{HAsS}_2\text{O}_2$. The atomic ratio of sulfur to arsenic in industrial sodium arsenate solutions after regeneration is approximately 2.5. Therefore, a mixture of $\text{Na}_2\text{HAsS}_3\text{O}$ and $\text{Na}_2\text{HAsS}_2\text{O}_2$ was prepared having a 2.48 ratio of S to As. The experimental data of hydrogen sulfide absorption by such a solution are shown in Table 1.

T A B L E 1.

Effect of solution pH on hydrogen sulfide absorption rate by a solution of $\text{Na}_2\text{HAsS}_2\text{O}$ and $\text{Na}_2\text{HAsS}_2\text{O}_2$. Ratio of S:As in g at 2.48; temperature 40° ; As concentration = 0.05 g/li.

Solution composition	Per cent hydrogen sulfide in the gas	Solution pH		Ml of absorber in 3 min	Time in minutes during which S:As ratio increased by 0.5
		Initial	After 3 min		
$\text{Na}_2\text{HAsS}_{2.48}^{\text{O}}_{1.52} + \text{NaOH}$	4.80	10.5	—	68.3	70
$\text{Na}_2\text{HAsS}_{2.48}^{\text{O}}_{1.52}$	4.45	8.2	7.05	26.3	16
$\text{Na}_2\text{HAsS}_{2.48}^{\text{O}}_{1.52} + \text{H}_2\text{SO}_4$	4.65	7.2	6.55	30.9	18

As was mentioned in the preceding report [2], the addition of alkali retarded the rate of oxygen substitution by sulfur. However, the addition of sulfuric acid had practically no effect upon the rate of absorption under

study. This may be explained by the fact that a lowering in the pH value accelerated the reaction rate; it must be remembered, however, that there are other factors which lower the concentration of HS ions in the solution, and, as a consequence, retard the absorption rate. It is also possible that a lower degree of hydrolysis of $\text{Na}_2\text{HAS}_3\text{O}$ salt, as compared with that of $\text{Na}_2\text{HAS}_2\text{O}_2$ may be such a factor. Investigation of hydrogen sulfide absorption by $\text{Na}_2\text{HAS}_3\text{O}$ solutions was conducted along 2 lines: the partial pressure of hydrogen sulfide was varied in one series of experiments, while the concentration of sodium oxythioarsenate was varied in the other series. The experiments were conducted at 20° .

T A B L E 2.

Rate of hydrogen sulfide absorption by the $\text{Na}_2\text{HAS}_3\text{O} + \text{H}_2\text{SO}_4$ solution in relation to partial hydrogen sulfide pressures in the gas at 20° .
Concentration of As in solution = 0.05 g/li.

Percent of hydrogen sulfide in the gas	Solution pH		Ml of hydrogen sulfide absorbed in 3 minutes			Time in minutes during which S:As ratio rose by 0.5
	Initial	After 3 minutes	In physical solution	As the result of rapid chemical reaction	Total	
2.1	7.30	7.20	5.4	3.3	8.7	242
5.0	7.25	6.85	12.9	11.0	23.9	138
10.0	7.30	6.60	25.8	21.3	47.1	115
15.0	7.30	6.45	38.7	36.7	75.4	-

T A B L E 3.

Rate of hydrogen sulfide absorption by $\text{Na}_2\text{HAS}_3\text{O} + \text{H}_2\text{SO}_4$ solution at 20° in relation to solution concentration.

Solution concentration in mol/li	Percent of hydrogen sulfide in gas	Solution pH		Hydrogen sulfide absorbed in 3 minutes in standardized ml			Time in minutes during which S:As ratio rose by 0.5
		Initial	After 3 minutes	In physical solution	As the result of rapid chemical reaction	Total	
0.026	5.0	7.30	6.55	12.9	5.5	18.4	93
0.051	5.0	7.25	6.85	12.9	11.0	23.9	138
0.079	5.0	7.30	6.90	12.9	15.5	28.4	119
0.105	5.0	7.25	7.20	12.9	21.5	34.4	135

The results obtained, shown in Tables 2 and 3, indicated that the rate of hydrogen sulfide absorption by 0.05 mol. solution of $\text{Na}_2\text{HAS}_3\text{O}$ in the first and second stages of the process was directly proportional to the concentration of hydrogen sulfide in the gaseous phase and also to the concentration of the sorbent. The temperature effect upon the absorption rate is shown in Table 4.

T A B L E 4.

Effect of temperature on rate of hydrogen sulfide absorption
by solution of $\text{Na}_2\text{HASO}_4 + \text{H}_2\text{SO}_4$.
As concentration in solution = 0.045 g/li.

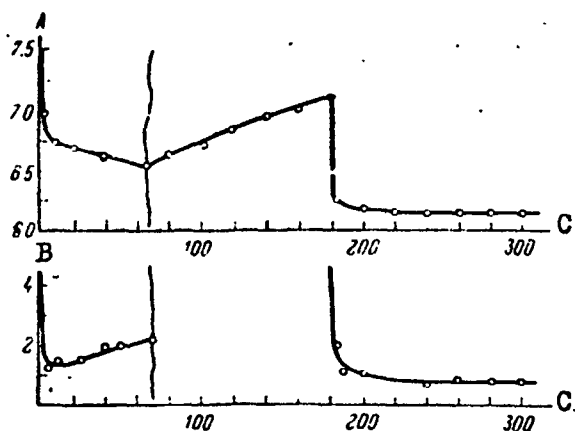
Temperature in $^{\circ}\text{C}$	Percent of hydrogen sulfide	Solution pH		Hydrogen sulfide absorbed in 3 minutes in ml	Time in minutes during which S:As ratio rose by 0.5
		Initial	After 3 minutes		
20	15.6	6.9	6.35	58.0	55
40	16.8	6.9	6.35	40.7	24
50	15.5	6.9	-	44.5	14

Results of the experimental hydrogen sulfide absorption by Na_2HASO_4 solution at various temperatures, recorded in Table 4, indicate that the rate of oxygen substitution by sulfur greatly depended upon temperature. For instance, the time required for saturation of Na_2HASO_4 with hydrogen sulfide to the point at which the ratio of sulfur to arsenic equalled 0.5 was twice as long at 20° as it was at 40° .

Hydrogen sulfide absorption by Na_2HASO_4 with intermittent feeding of hydrogen sulfide into the reaction vat. The mechanism of hydrogen sulfide absorption by a solution of sodium oxythioarsenate was described in a previous publication [2]. The conclusions arrived at were verified by the following experiments: continuous determinations of pH values of the solution were made during the experiment, while the hydrogen sulfide feeding into the reaction vat was temporarily discontinued. The experiment was conducted in the following manner:

Hydrogen sulfide absorption by 0.05 mol Na_2HASO_4 solution was investigated at pH = 8.5 and 17% of hydrogen sulfide content in the gas. The pH was determined in the course of hydrogen sulfide absorption. The pH value of the solutions fell in the course of time as in the case of preceding experiments.

After a certain lapse of time, hydrogen sulfide feeding was discontinued and the vat was brought to rest, but the pH determinations were continued. The results showed that the pH was gradually increasing. Thereupon, the hydrogen sulfide feeding was resumed, the vessel again set into motion and the experiment was continued. Curves for this experiment are presented in the following Graph.



Rate of hydrogen sulfide absorption and pH value in relation to experiment duration at periodic addition of H₂S into the reaction chamber. A - pH values; B - H₂S content in ml H₂S/min; C - Time in minutes.

The curves indicate that at the time the experiment was discontinued and the feeding of hydrogen sulfide into the solution was stopped, a low level reaction persisted between the hydrosulfide and the sodium oxythioarsenate, as revealed by a continually increasing pH of the solution. Hydrogen sulfide was gradually absorbed from the gaseous phase, causing a degree of rarification within the vessel. After the motor was started again and the flow of hydrogen sulfide was resumed, the dissolution of hydrogen sulfide and the formation of sodium hypo-

sulfite commenced anew, and the process continued, accompanied by immediate high rate hydrogen sulfide absorption.

The results of the experiment strengthened the previous assumption regarding the chemical reactions which took place in the process of hydrogen sulfide absorption by the solutions under investigation. Furthermore, the results of the experiment demonstrated the expediency of prolonging the contact between the sodium arsenate solution and the absorber, since, under such conditions the alkaline capacity of the absorber and its chemical reactive capacity for arsenic were utilized more effectively.

Conclusions.

1. The reaction rate of sulfur substitution for oxygen in sodium oxythioarsenate, i.e., the third stage, depends on the partial pressure of hydrogen sulfide in a gas, on the pH of the solution, and on its temperature.
2. The expediency of prolonging the presence of sodium arsenate solution in the absorber has been experimentally proved.

Effect of Foam Layer Thickness over Screen Shelf on Carbon Dioxide Absorption by Alkaline Solution.

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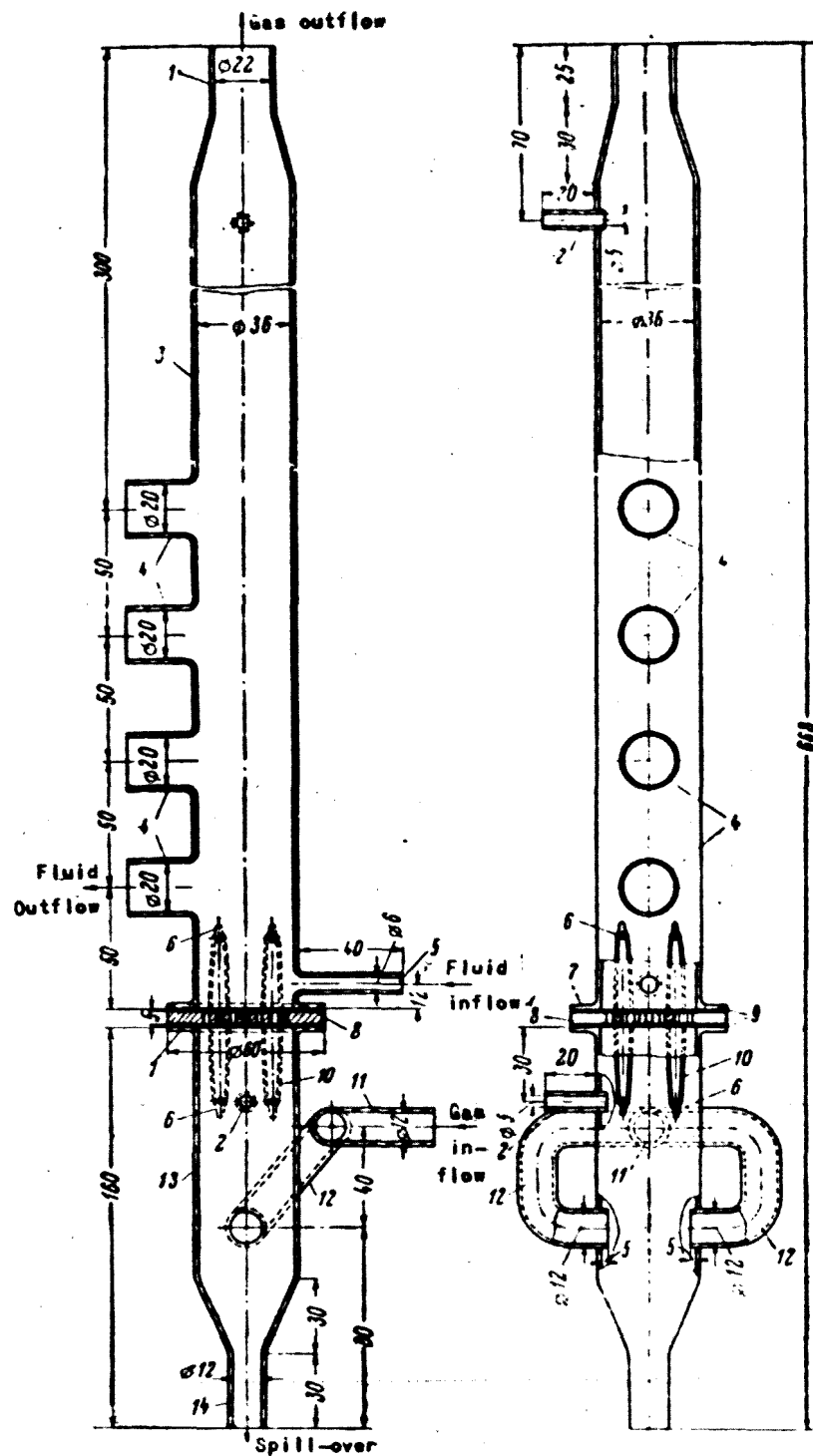
Zhurnal Prikladnoi Khimii, Vol. 32, No. 5, 1004-1010, 1959.

Hydrodynamic conditions which develop in the treatment of a gas-fluid system in a screen-shelf type absorption apparatus are determined by linear rate of the gas flow, the quantity of fluid over the screen, the total area of the screen perforations, and the physical properties of the system components. In its turn, the hydrodynamic regime (the complex of hydrodynamic conditions) determines the degree of flow turbulence, and, hence, the intensity of heat and mass (volume) transfer. The combination of hydrodynamic conditions, which produce complete foaming of the layer of absorber fluid passing over the supporting screen are analyzed below.

The assumption prevailed in the past [1] that the height of foam layer H and the hydraulic resistance Δp of the foam over the supporting screen characterized the hydrodynamic behavior of the absorber apparatus. The functional dependence of H and Δp on such determining parameters as rate of gas flow w , intensity or force of the fluid current i , height of the weir overflow h_w , specific gravity of the fluid γ_{fl} and viscosity μ has been discussed in previously published reports [2 - 5]. The influence of H on the rate of heat transfer as well as mass transfer in different gas fluid systems, predominantly for easily soluble gases [2, 6, 7], was thoroughly analyzed in those reports. Below are given values for H and Δp when air of different CO_2 content was passed through NaOH solution; the resulting rate of CO_2 absorption was then compared with these values.

Experimental procedure. ^{1/} Experiments on carbon dioxide absorption by a foam layer of sodium hydroxide solution were conducted using an apparatus schematically illustrated in Fig. 1. It consisted of a glass column with $d = 36$ mm, divided into 2 parts by a horizontal vinyl plastic screen: the total area of the screen perforations was 0.001 m^2 , which was the equivalent of the apparatus cross-section.

^{1/} L. Ya. Tereshchenko and P. M. Karaseva participated in the experimental work.



The diameter of the screen openings was 2 mm wide and the distance between centers was 5 mm; accordingly, the area of the perforation equalled 17% of the total screen area, or $S_o = 17\%$. Four overflow boxes were installed above the screen 50 mm apart, beginning with the screen level for foam diversion. During the experiment one box was connected with the foam disintegrator, while the others were stoppered. Thus, by changing the weir level h_w and feeding different quantities of fluid into the glass column, i.e., changing the flow rate, the height of foam H was changed from 100 to 400 mm at a given rate w of gas flow in the apparatus. The flow intensity was taken with reference to the diameter of the overflow box; it was expressed in m^3/hour . With an overflow box diameter of 20 mm, the fluid supply $Q = 20 \text{ li/hr}$ which corresponded to fluid flow intensity of $i = 1 m^3/m$ per hour. This apparatus was used in previous laboratory installations for carbonization of soda solutions, as described in reference [8]; it was equipped with an additional gas and sodium hydroxide solution heater. Absorption of carbonic acid from air samples was conducted with 3 N NaOH solution; the CO_2 concentration was 6%, and the gas and absorber fluid temperature was approximately 60° . The analytical procedure was the same as described elsewhere [8].

In measuring the height (thickness) of the foam layer H , the spray above the upper level of gas-fluid system was not taken into account. The Δp value was determined by subtracting the resistance of the dry or non-active section of the screen from the total hydraulic resistance (pressure drop) of the apparatus screen shelf. Averages of several tests were used in evaluating the experimental results. CO_2 absorption indicators, absorption coefficient K in relation to $1 m^2$ of the screen, and efficiency coefficient of one shelf η were computed with the aid of analytical data of a gaseous phase using formulas presented elsewhere [9]. K was computed assuming that the pressure balance of CO_2 over solution NaOH was zero.

Experimental results. Preliminary tests established that conditions of foam formation in an apparatus of small diameter were the same as in the standard model of 75 cm^2 cross section area (Fig. 2) [2], and that the change in CO_2 concentration in the purified gas up to 15% did not affect the foam formation. NaOH solution foaming was studied while air was passed through 3 N NaOH at 18 to 80° . The tests were conducted with gas flow rates w between 0.5 and 3.5 m/sec and height of initial fluid layer h_o between 20 and 100 mm.

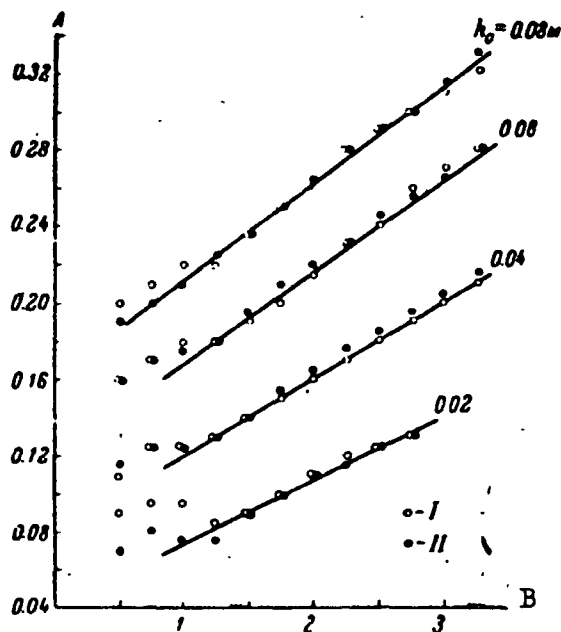


Fig. 2. Foam formation in air-water system at 18°.

A - Foam height H in m; B - Gas flow rate w through entire apparatus section in m/sec.

I - Experimental data in standard model screen 5/2 at $S_0 = 12.8\%$; II - Experimental data in model d = 36 mm and screen 5/2 at $S_0 = 17.0\%$.

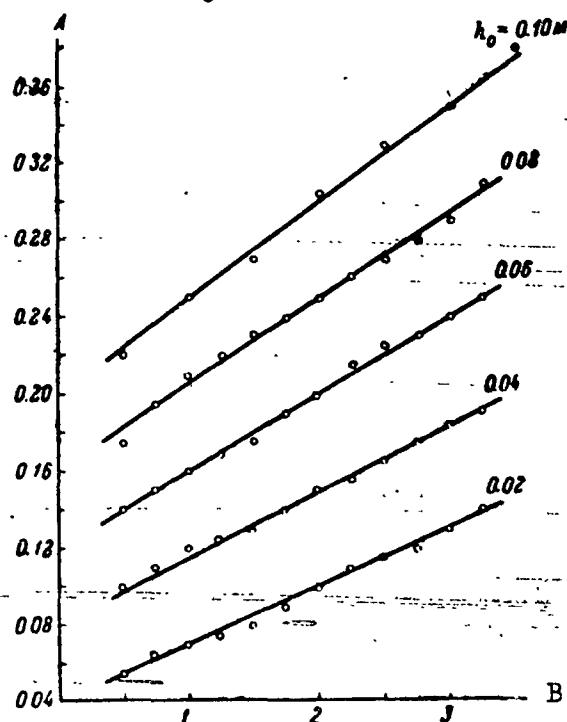


Fig. 3. Foam formation in system air, 3 N NaOH at 60° and with screen 5/2.

A - Foam height H in m; B - Rate of gas flow w through entire apparatus section in m/sec.

Foam formation in NaOH solution.

Fig. 3 indicates that the plot of relation between foam layer thickness H and w at different values of h_0 assumed the form of a series of straight lines according to equation (1):

$$H = 0.25w(h_0 + 0.1) + 2h_0 \quad (1)$$

It was found that equation (1) applied within a sufficiently wide range for w from 0.5 to 3.5 m/sec, and for h_0 from 0.02 to 0.1 m. H slightly increased (Fig. 4) as the temperature rose.

Curves in Fig. 5 indicate that with a constant rate of gas the hydraulic resistance of the foam layer increased in proportion to its thickness, which behaved as a direct function of h_0 . The straight lines in Fig. 5 run parallel to one another. The "specific gravity" of the foam and its hydraulic resistance were inversely proportional to the rate of gas flow in the apparatus; with an increased rate of gas flow, a foam layer of equal depth (height) was produced from a smaller volume of fluid, that is, a lower h_0 , than would be the case with lower gas flow rate.

Therefore, the curves indicating the functional relation between Δp and H show by their positions

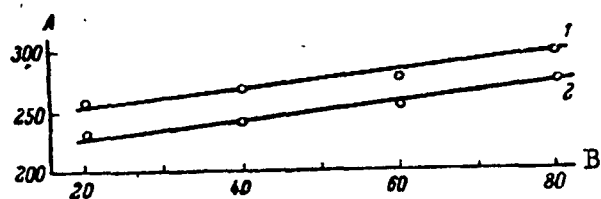


Fig. 4. Foam height in relation to temperature with screen 5/2; $w = 2.0$ m/sec; $i = 5$ m³/m/hr; $h_w = 100$ mm. A - Foam height H in mm; B - Temperature in °C.

NaOH solution concentration in g equiv/li: 1 - 1.0; 2 - 3.0.

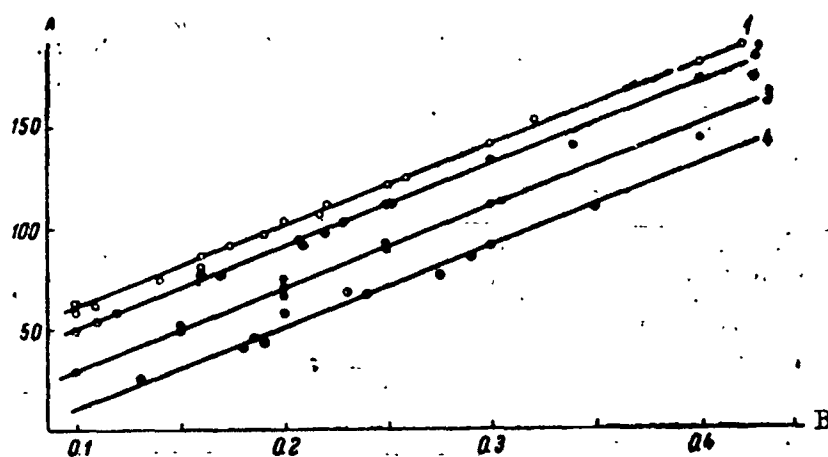


Fig. 5. Hydraulic resistance (pressure drop) of foam in relation to its height at 60°, screen 5/2 and 3 N NaOH.

A - Foam resistance Δp in mm water; B - Foam height H in mm.

Gas flow rate in apparatus w in m/sec:
1 - 0.5; 2 - 1.0; 3 - 2.0; 4 - 3.0.

between absorption coefficient K as applied to 1 m² of the apparatus screen and the value of H at different values of w . Change in H when $w = \text{const.}$ was attained by changing the weir height and the amount of fluid fed into the apparatus. As can be seen from Fig. 6, coefficient of CO₂ absorption with a solution of NaOH at the given rate of gas flow was proportional to the foam layer height within the experimental limits of variation. The equation for the computation of K in relation to H and w is presented below:

$$K = 200w(H + 2) + 2400H \quad (3)$$

The degree of the foam layer turbulence can be evaluated to some extent by its hydraulic resistance Δp . In its turn this value can serve as an orientation

that an increase in the linear velocity of the gas lowered the position of the curves. The general empirical equation for the computation of Δp in the system examined is as follows:

$$\Delta p = 400H - 20w + 30(\text{mm water}) \quad (2)$$

The functional relationship between the absorption coefficient and also the efficiency coefficient of the apparatus

screen on the foam layer thickness (height). It is known [1, 2] that the foam layer height H created over the screen of the apparatus was one of the basic indicators of the foam system which determined the value of the absorption coefficient and the efficiency of the absorption process, i.e., the coefficient of the screen efficiency, or performance.

Curves in Fig. 6 present the functional relation

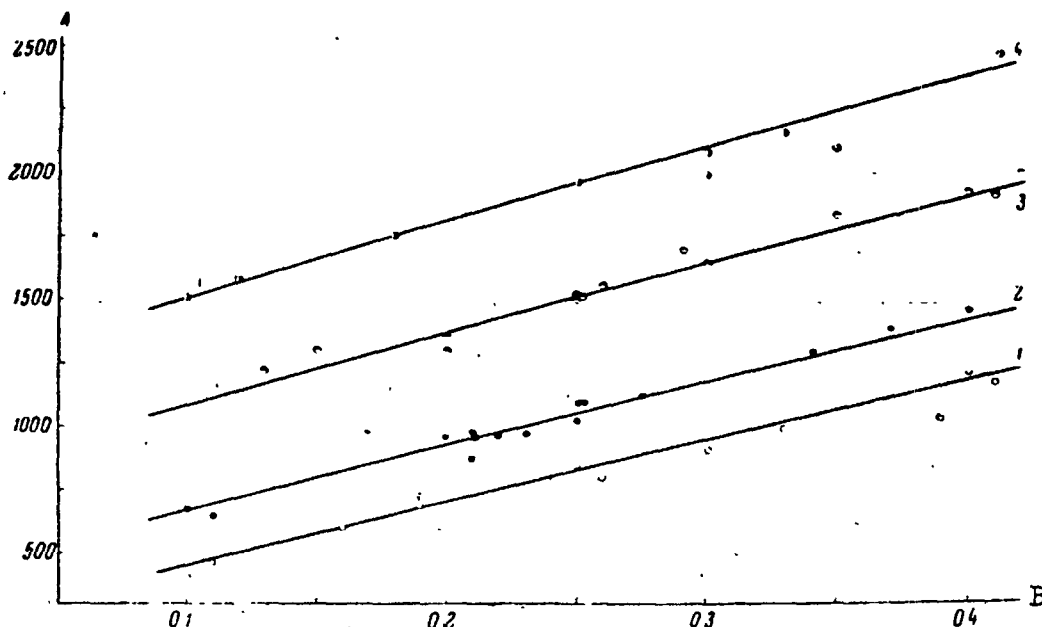


Fig. 6. Coefficient of carbon dioxide absorption in relation to foam height at 60°, screen 5/2, 3 N NaOH solution, 6% carbon dioxide in gas.
A - Absorption coefficient K in kg/m²/hour/m³; B - Foam height H in m.
Ratio of gas flow w in apparatus in m/sec: 1 - 0.5; 2 - 1.0; 3 - 2.0; 4 - 3.0.

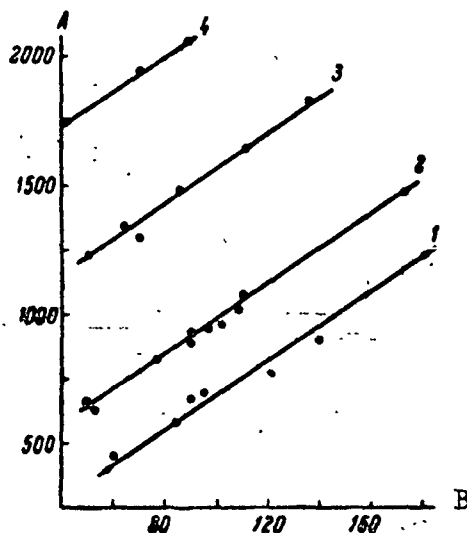


Fig. 7. Coefficient of carbon dioxide absorption in relation to hydraulic foam resistance at 60°, 3 N NaOH solution, 6% carbon dioxide in gas.
A - Absorption coefficient K in mg/m²/hr x kg/m³; B - Foam resistance Δp in mm water.
Rate of gas flow w in apparatus in m/sec: 1 - 0.5; 2 - 1.0; 3 - 2.0; 4 - 3.0.

criterion for the estimation of the intensity of apparatus performance.

Curves in Fig. 7 present comparative values of K and of Δp at different foam heights above the screen. The connection between them at different w values form straight line curves, and

$$K = 6.75\Delta p + 580w - 260 \quad (4)$$

This indicates that the absorption rate in the foam apparatus was directly proportional to the amount of energy consumed in the formation of the foam system.

An equation for the determination of the efficiency coefficient of CO₂ absorption with an alkaline solution and given height of absorber foam layer can be derived [9] with the aid of the following generality:

$$\eta = \frac{2K}{2v + K} \quad (5)$$

where v is the velocity of the inert (unabsorbed) gas in m/hour.

For gas containing 6% CO_2 :

$$v = 3600 w(1 - 0.06) \approx 3400w \quad (6)$$

from which:

$$\eta = \frac{2K}{6800w + K} \quad (7)$$

By substituting in equation (7) value K from equation shown in (3) we obtain:

$$\eta = \frac{12H + w(H + 2)}{12H + w(H + 36)} \quad (8)$$

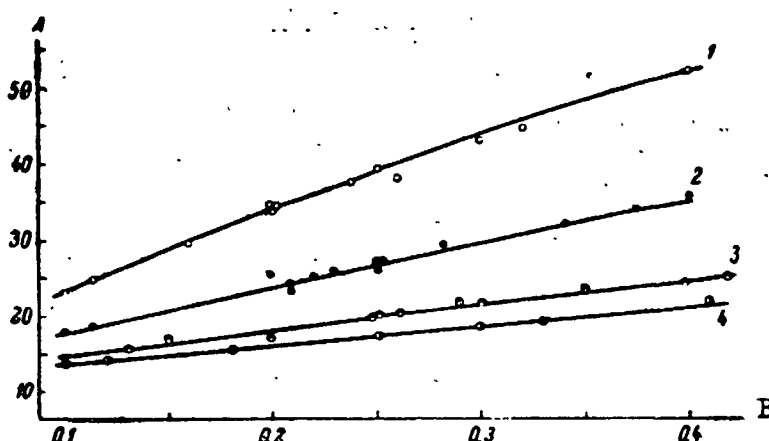


Fig. 8. Degree of carbon dioxide absorption (efficiency coefficient) in relation to foam height at 60° , 3 N NaOH solution, 6% carbon dioxide in gas.

A - Degree of absorption (efficiency coefficient) η in %; B - Foam height H in m. Rate of gas flow w in apparatus: 1 - 0.5; 2 - 1.0; 3 - 2.0; 4 - 3.0.

Curves in Fig. 8 present the function of K in relation to H calculated according to equation (8) for different rates of gas flow in the apparatus. Experimental data, that is points on the curve, closely coincide with the theoretically derived curves.

Equation (3) is an empirical one, and its application as well as the application of equation (8) can be resorted to only under conditions analogous to those described above.

Conclusions.

1. The efficiency coefficient of one screen of a foam absorber apparatus during absorption of carbon dioxide with 3 N NaOH solution at 60° varied within the limits of 0.15 - 0.5 for rates of gas flow between 0.5 and 3.0 m/sec.

2. The carbon dioxide absorption coefficient fluctuated within the limits of 500 - 2500 depending on the rate of gas flow and the quantity of fluid flowing over the screen.

3. Under the conditions of the present experiments, that is with 3 N solution of NaOH, 6% concentration of CO_2 in the gas, temperature of 60° , the absorption coefficient varied in proportion to the foam layer height, which

fluctuated with the given linear gas flow rate and the correlated fluid volume flowing over the screen of the apparatus.

4. Use of the foam system of carbon dioxide absorption from gases by sodium hydroxide solutions proved to be effective; it resulted in a highly intensive process of absorption and consequently, it can be employed effectively in connection with small size absorbers.

Bibliography.

- [1] М. Е. Позин, И. П. Мухленов и Э. Я. Тарат, ЖПХ, XXX, 1, 45 (1957). — [2] М. Е. Позин, И. П. Мухленов, Е. С. Тумаркина, Э. Я. Тарат. Новый способ обработки газов и жидкостей. Госхимиздат (1955). — [3] М. Е. Позин, И. П. Мухленов, Е. С. Тумаркина и Э. Я. Тарат, ЖПХ, XXVII, 1, 13 (1954). — [4] М. Е. Позин, И. П. Мухленов, ДАН СССР, Новая серия, 2, 2, 393 (1953). — [5] М. Е. Позин, Е. С. Тумаркина, ЖПХ, XXVII, 11, 1170, 1180 (1954). — [6] М. Е. Позин, И. П. Мухленов и Э. Я. Тарат, ЖПХ, XXX, 2, 293 (1957). — [7] М. Е. Позин и Э. Я. Тарат, ЖПХ, XXXI, 9, 1332 (1958). — [8] М. Е. Позин, Б. А. Копылов и Э. Я. Тарат, ЖПХ, XXX, 5, 674 (1957). — [9] М. Е. Позин, ЖПХ, XXV, 10, 1032 (1952).

Calculating the Phase Balance of Multi-Component Gas Mixtures.

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No records have been found in the literature presenting experimental data on the subject of multi-component mixture system balance. This is the reason why performance analysis of industrial installations used in processing carbohydrate gas mixtures is accomplished in most instances by the calculation method. In such calculations extensive use is made of the so-called phase balance constants; with the aid of such constants simple determinations are made of the dewpoint, boiling point, quantity and composition of condensates formed in the processes of uniflow and counterflow gaseous mixture condensation. Phase balance constants have been used also in determining the size of condensation stripping and rectification columns [1]. The calculation is based on the well-known laws of Raul ($p_A = x_A \times P_A^0$) and of Dalton ($p_A = y_A \times P$) from

which, in the case of ideal mixtures, the following equation can be derived which coordinates (connects) the phase compositions:

$$y_A = \frac{P_A^0}{P} \cdot x_A = K \cdot x_A \quad (1)$$

in which K is the balance of the phase; in the case of ideal mixtures such balance depends upon the temperature and the total mixture pressure.

In the case of actual (practical) mixtures the pressure of saturated vapor of component A over a solution (P_A^0) is determined not only by the temperature, but also by the correction for the deviation from ideal gas laws, which is the coefficient of compressibility. The opinion has also been expressed [2] that with an increased total pressure over the liquid mixture mirror (surface), the pressure of the saturated component vapor depended also upon the total pressure. The factors mentioned are taken into account in the following equation [2]:

$$K = \frac{f_{f1}}{f_p}$$

in which f_{f1} is the volatility of the pure fluid at temperature and total pressure at balance, f_p is the volatility of the vapor.

Taking into consideration the complexity and difficulty of f_{f1} and f_p determination for many substances under practical computation conditions, it appeared more convenient to determine the constants of phase balance by the established practical procedure, or in extreme cases, by the method of highly qualified calculation taking the volatility correction into consideration.

Numerical values of such constants can be found in special references [3] in the form of corresponding curves in relation to temperature and total pressure. However, it is known that in most cases such curves did not cover all possible values of temperature and pressure, not even those which occurred in processing mixtures of gaseous hydrocarbons. Such a situation limits to a considerable degree the calculation possibilities and creates the need for the systematization and coordination of the existing experimental and calculation data for the purpose of deriving general regularity trends connected with phase balance constants.

The pressure of a pure component saturated vapor over a liquid (P_A^0) practically covers the effect of 2 factors of the phase constant, namely, temperature and the nature of the substance. Where the process temperature is con-

stant, the effect of the substance nature in this relationship can probably be expressed not only through corresponding changes in the saturated vapor pressure, but by any other physical parameter.

From the viewpoint of possible generalizations of the results for the purpose at hand, it is more convenient to use, for example, the critical pressure of the substance (P_{cr}) and substituting for P_A^0 its equivalent P_{cr} , as shown by the following equation:

$$K_{lt} = \text{const} = \frac{P_A^0}{P} = f\left(\frac{P_{cr}}{P}\right)$$

Furthermore, considering that the pressure ratio P/P_{cr} can be assumed to be identical with actual pressure P' , the functional interrelation can be expressed by the following formula:

$$K_{lt} = \text{const} = f\left(\frac{1}{P'}\right)$$

in which the effect of the substance nature and of the total gas mixture pressure at $t = \text{const.}$ is determined by the value of P' . It is known that the reduced pressure represents a generalized parameter, accordingly the above expressed functional relationship is of a universal nature. For the checking and final determination of the function character a curve is constructed expressing the functional relationship between the phase balance constant and the reduced pressure P' at constant temperature in all instances cited in the literature (θ). In connection with the above, use is made of all the available practical data for such hydrocarbons as methane, ethylene, propylene, ethane, propane and butane. Such a curve is presented in Fig. 1, in which values of the constants at $\theta = 1$ are plotted along the coordinate and actual reduced pressure is plotted along the abscissa.

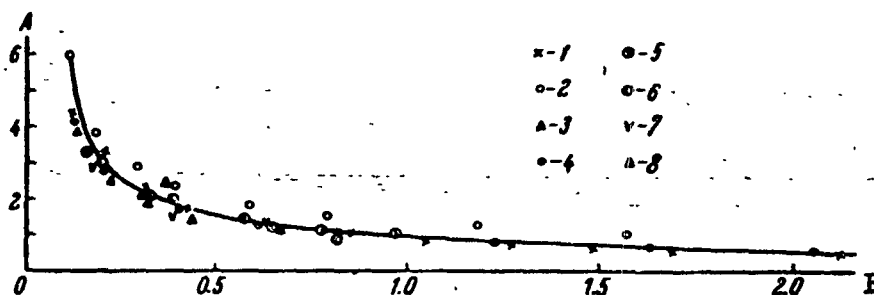


Fig. 1. Functional relationship between phase equilibrium constants (A) and artificially reduced pressure (B) at reduced temperature (θ) equal 1.
1 - Methane; 2 - Ethylene; 3 - Propylene; 4 - Ethane; 5 - Propane;
6 - Butane; 7 - Carbon Monoxide; 8 - Nitrogen.

The curve in Fig. 1 confirms the actual existence of universal functional relationships between K and P' , in other words, the phase balance constants for different hydrocarbons at different reduced parameters have identical values. Deviations at isolated points from the universal regularity are insignificant and accidental.

Data found in the literature related to nitrogen and carbon monoxide constants were also processed. However, due to the lack at wide intervals of reliable pressure and temperature data, only a few points could be determined; such points were in close agreement with points of observation for all hydrocarbons, insofar as basic regularity was concerned at $\Delta = 1$.

Less gratifying results were obtained with carbon monoxide at reduced temperature and with θ less than 0.8, and for nitrogen with θ greater than 1.2, despite the fact that at other sections of the curve the coincidence of the results was a satisfactory one. This seems to confirm the fact that the accuracy of values found in the literature for the above-mentioned constants [4] was not sufficiently high at all intervals of study.

Figs. 2 and 3 present curves of functional K and P' relationships at different reduced temperatures for a number of approved substances. All confirm the fact that for all values of θ the K and P' functional relationship was a monotypical one; this in turn, makes possible the bringing out of certain

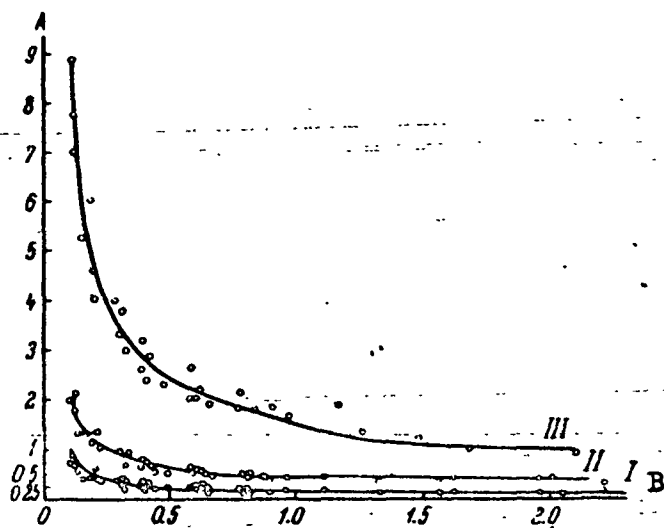


Fig. 2. Functional relationship between phase equilibrium constants (A) and artificially reduced pressure (B). Reduced temperature (θ): I - 0.7; II - 0.8; III - 1.2.

general regularity characteristics of phase balance constants. It can be seen that at P' greater than 2 or at general gas mixture pressure P greater than $2P_{cr}$ the phase balance constant is practically independent of the reduced pressure and that with the rise in the pressure it remained constant. Therefore, the utilization of the pressure factor for the intensification of the condensation process was limited by a maximum, and the application of pressures exceeding $2P_{cr}$ would serve no beneficial purpose. Under such conditions a

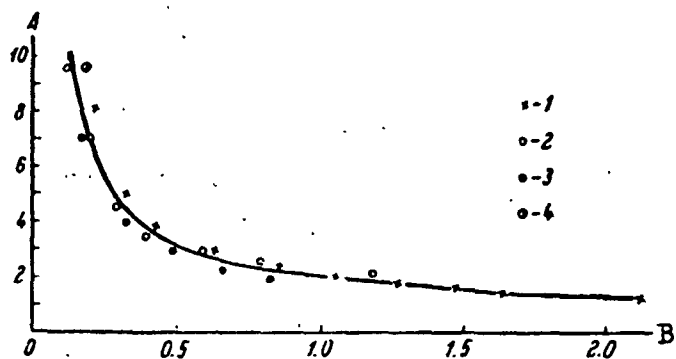


Fig. 3. Functional relationship between phase equilibrium constants (A) and artificially reduced pressure (B) at reduced temperature (θ) equal 1.3.
1 - Methane; 2 - Ethylene; 3 - Propane; 4 - Carbon monoxide.

The described characteristics (properties) are only qualitative. For the quantitative expression of such changes it is necessary to resort to certain analytical equations which can be derived by taking into consideration certain general functional interrelations. By the method of logarithmic curve plotting, that is, by the straight-line method of plotting the following equation is obtained:

$$\lg K = \lg a - 0.785 \lg P'$$

in which a is the coefficient, the value of which depends upon the reduced temperature and with $\theta = 1$, and $a = 0.95$. In order to bring out the nature of function $a = f(\theta)$, curves were constructed, as shown in Fig. 4, on the basis of data taken from Figs. 1 - 3, representing functional relationships between phase balance constants and reduced temperature at different assumed pressures. The logarithmic or straight-line presentation of the curves established that $a = 0.95 \times \theta^{2.85}$, and consequently and finally:

$$\lg K = \lg 0.95 + 2.85 \lg \theta - 0.785 \lg P' \quad (2)$$

Fig. 4. Functional relationship between phase equilibrium constant (A) and reduced temperature (θ) Artificially reduced pressure P' : 1 - 0.15; 2 - 0.2; 3 - 0.5; 4 - 1.0; 5 - 2.0.

Equation (2) is a universal or generalized one and can be used in the preliminary or orientation determination of phase balance constants at different conditions of actual processes and for different practically encountered gas phase mixtures.

reduction in the phase balance constant can be obtained only by lowering the temperature.

The general picture is much the same in the region where P' is either equal to or less than 0.1. Here the constant value practically tends to approach infinity and an increase in the process efficiency can be obtained by lowering considerably the condensation temperature.

Experimental Utilization of Manganese Dioxide in Purifying Gases from Hydrogen Sulfide and Recovery of Elemental Sulfur.

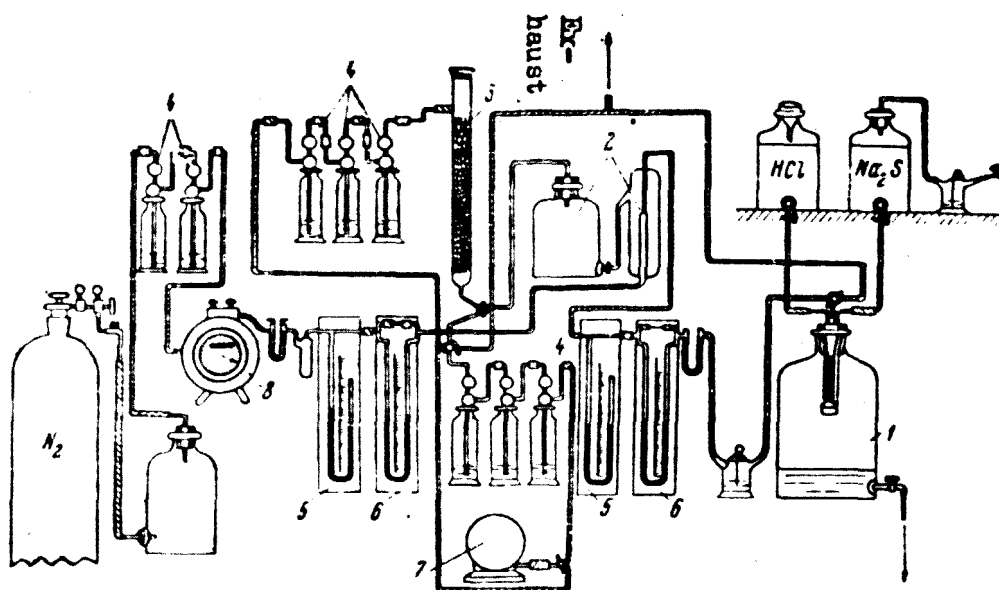
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Many methods for the purification of gases from hydrogen sulfide have been described in the literature. The most widely used are based either on the oxidation of hydrogen sulfide to elemental sulfur [1 - 6], or on the neutralization of hydrogen sulfide by substances possessing basic properties [2, 3, 7 - 9]. The use of manganese dioxide in the purification of gases from hydrogen sulfide was first proposed in 1931 [10]. However, the proposed method apparently passed unnoticed, since no evidence was found in the literature of any progressive work along this line. Studies made by Chagunav in purification of gases from sulfur by manganese compounds [11], were made without any reference to the regeneration and repeated use of the manganese substances.

These authors developed a method for the utilization of manganese dioxide in the purification of gases of hydrogen sulfide, accompanied by recovery of elemental sulfur in a continuous process. Experiments were performed with manganese dioxide which contained less than 0.95% of MnO, less than 5.78% of Mn_2O_3 , and less than 80.07% of MnO_2 . The quantity of MnO_2 , calculated on the basis of "active oxygen", ranged between 74.70 and 87.02%. The set-up used is shown schematically in the following Figure; it consists of a generator which received hydrogen sulfide from a 10% solution of sodium sulfide and hydrochloric acid (1), a mixer of hydrogen sulfide and nitrogen or other gas (2), a reaction column with MnO_2 (3), Drexel containers with solutions of cadmium acetate (4), manometers (5), flowmeters (6), air blower (7) and a gasmeter (8). In studying the process of hydrogen sulfide oxidation with pure MnO_2 the latter was placed into the reaction column in experiments Nos. 1 - 7; the MnO_2 was applied to the carrier (vehicle) in tests Nos. 8 and 9; it was used in water suspension in tests Nos. 10 and 11. In the cases of the latter use was made of 2 bubbling apparatuses instead of the reaction column. The finely ground MnO_2 water suspension was placed into bubblers equipped with magnetic mixers. Results of the tests are listed in Table 1. The data in Table 1 indicate that the outcome of the reaction $MnO_2 + 2 H_2S \rightleftharpoons MnS + 2H_2O + S$



Schematic drawing of the apparatus used in hydrogen sulfide oxidation by manganese dioxide. Explanation in text.

T A B L E 1.

Results of hydrogen sulfide oxidation by manganese dioxide.

Test No.	Absorber mass composition				Rate of gas flow in ml/min	H ₂ S content in original gas	Time of gas flow in min.	MnO ₂ oxidized H ₂ S in g		Oxidation in %
	MnO ₂	H ₂ O	Slaked lime	Vehicle				Theoretical	Experimental	
1	35.0	-	-	-	31.4	0.30	2110	20.44	19.96	97.85
2	10.0	-	-	-	36.2	0.52	314	6.40	5.88	91.90
3	30.0	-	-	-	34.4	0.38	1896	19.20	19.20	100.00
8	4.0	12.0	0.1	125.6 of chamotte	50.0	0.32	180	2.72	2.72	100.00
9	4.0	12.0	0.1	125.6 of chamotte	12.0	0.34	930	2.72	2.60	95.58
10	35.0	350.0	5.0	-	21.0	0.11	931	20.44	2.29	11.20
11	4.0	340.0	0.1	-	10.7	0.46	112	2.72	0.55	20.22

differed with each of the methods used. Lowest percent of hydrogen sulfide oxidation occurred in the experiments performed with the MnO₂ suspension in water.

Lowering the thickness of the absorber layer and increasing the gas passage rate and the content of hydrogen sulfide in the final gas, reduced the percent of gas oxidation to a slight degree only. On the other hand, the use of carriers or vehicles produced positive effects on the process of gas purification from hydrogen sulfide. The formed manganese sulfide was oxidized by the air oxygen

according to the following reaction: $\text{MnS} + 1/2 \text{O}_2 + \text{H}_2\text{O} = \text{Mn(OH)}_2 + \text{S}$. The sulfur was extracted with dichlorethane or trichlorethylene by the Soxlet method; the solvent was then distilled off using superheated steam; for this purpose a particular set-up was used which consisted of a steam producer, steam superheater, a reaction column and a sulfur receiver provided with a cooling apparatus. The results are presented in Table 2. Data in this Table show that both methods produced complete sulfur separation. Tests indicated that the sulfur thus obtained was of adequate purity.

T A B L E 2.

Results of sulfur separation from products of manganese sulfide oxidation by air oxygen.

Test No.	Initial substance	Extraction method	Theoretically computed amount of free sulfur in g on the basis of hydrogen sulfide	Amount of separated sulfur	
				In g	In %
1	Manganese dioxide	Dichlorethane	2.20	2.13	96.82
2		Trichlorethylene	5.02	5.05	100.50
3		Steam	18.79	18.57	98.83
4	Manganese dioxide in refractory clay	Steam	4.67	4.35	93.14

It was now necessary to determine the economic practicability of manganese dioxide utilization in practice by the so-called "dry" method of hydrogen sulfide purification. Hence, a study was made of the most economical process of manganese dioxide regeneration, in connection with the continuous method of gas purification. Regeneration of manganese dioxide by air oxygen progressed at a slow rate and with considerable difficulty. The products obtained from such oxidation possessed low hydrogen sulfide oxidizing properties, as shown by the fact that activity of manganese dioxide thus regenerated did not exceed 32 - 36%. However, further studies of manganese dioxide regeneration showed that the simultaneous introduction of chlorine gas and steam hastened the process of manganese oxidation and increased its value as an active oxidizer. Slaked lime was added to the solution to create a state of alkalinity for the purpose of reducing loss of manganese by washing out water-soluble divalent manganese salts. Experiments for the purification of gases from

hydrogen sulfide and succeeding regeneration of the spent manganese dioxide and its repeated utilization in the continuous cycle were performed as follows: a known weight of manganese dioxide was introduced into the set-up shown in the schematic drawing; the gas containing the hydrogen sulfide was then passed through it until the manganese dioxide was completely reduced. After complete oxidation by the atmospheric air, the sulfur was extracted with trichlorethylene. Before starting cycle II, a mixture was prepared consisting of 30% slaked lime and 70% of the products resulting from manganese sulfide air oxidation which was arbitrarily designated as "manganese dioxide". The final product was then chlorine treated by the steam heat process. The latter treatment raised the potency of the manganese dioxide (activity) from 30.81 to 81.53%. Similar chlorine steam heat treatment was applied to the products in cycles II and III for the re-utilization of manganese dioxide in gas purification from hydrogen sulfide. Oxidizing agents other than chlorine were tested in a similar manner, but yielded no positive results.

The summary results obtained by the use of manganese dioxide in the purification of gases from H_2S are presented in Table 3. The data in that Table lead to the conclusion that the introduction of 30% by weight of slaked lime completely eliminated the loss of manganese; the reaction between H_2S and MnO_2 in experimental cycles I, II and III proceeded to completion, as was shown by the fact that 100% of the sulfur was regained; the steam-chlorine heat treatment resulted in an increase in the potency of the manganese dioxide "activity" to 75 - 85% of utilization.

Conclusions.

1. Studies of the process of gas purification from hydrogen sulfide by means of manganese dioxide showed that the oxidation-reduction reaction between hydrogen sulfide and manganese dioxide proceeded to completion. The reaction product, sulfur, was extracted by chloro-organic solvents with the aid of superheated steam; 1 kg of manganese dioxide having an MnO_2 "activity" of 83.11% per cycle oxidized 760.9 g of hydrogen sulfide and produced 737.7 g of elemental sulfur.

2. Conditions were established for practically complete regeneration of manganese dioxide. It was shown that steam-chlorine heat treatment enhanced the oxidizing potency of manganese dioxide after it had reacted with

T A B L E 3.

Total yield from the use of manganese dioxide in the purification
of gas from hydrogen sulfide.

Absorber mass composition	Content of "active" MnO ₂ in percent	Cycle I		Oxidizing agent	Treatment I	
		Sulfur yield % of theo- retically calcu- lated	"Active" MnO ₂ con- tent at end of cycle		Percent of "active" MnO ₂	Percent of lost MnO ₂
Original MnO ₂	83.11	-	-	Chlo- rine	99.47	1.25
MnO ₂	83.11	100	30.91		87.72	35.22
80% MnO ₂ + 20% Ca(OH) ₂	83.11	100	33.96		76.25	9.31
70% MnO ₂ + 30% Ca(OH) ₂	83.11	100	38.70		81.53	0.00
50% MnO ₂ + 50% Ca(OH) ₂	83.11	100	36.05		74.03	2.23
70% MnO ₂ + 30% Ca(OH) ₂	83.11	100	38.70	Air	81.53	0.00
70% MnO ₂ + 30% Ca(OH) ₂	83.11	100	37.27		40.25	5.40
70% MnO ₂ + 30% Ca(OH) ₂	83.11	100	37.27		42.67	4.17
				Oxygen		

Absorber mass composition	Cycle II		Treatment II		Cycle III	
	Sulfur yield % of theo- retically calcu- lated	Sulfur yield in %; loss not ac- counted for	"Active" MnO ₂ con- tent in percent	Mn loss in percent	Sulfur yield % of theo- retically calcu- lated	Sulfur yield in %; loss not ac- counted for
Original MnO ₂	-	-	-	-	-	-
MnO ₂	100	64.78	85.62	53.40	100	46.60
80% MnO ₂ + 20% Ca(OH) ₂	-	-	-	-	-	-
70% MnO ₂ + 30% Ca(OH) ₂	-	-	-	-	-	-
50% MnO ₂ + 50% Ca(OH) ₂	-	-	-	-	-	-
70% MnO ₂ + 30% Ca(OH) ₂	100	100.00	74.23	1.55	100	98.45
70% MnO ₂ + 30% Ca(OH) ₂	-	-	-	-	-	-
70% MnO ₂ + 30% Ca(OH) ₂	-	-	-	-	-	-

hydrogen sulfide and air oxygen. The addition of slaked lime was instrumental in totally preventing the loss of manganese.

Bibliography.

- [1] Г. О. Нусинов. Методы извлечения серы из промышленных газов. Госхимтехиздат, М.—Л. (1933). — [2] Н. И. Егоров и др. Очистка от серы коксоваль-
ного и других горючих газов. ГНТИ, М. (1950). — [3] А. С. Смирнов. Тран-
спорт и хранение газов. Госхимтехиздат, М.—Л. (1950). — [4] Y. Norton, Gas J.,
254, 4428, 111 и 4429, 158 (1948). — [5] Ф. И. Ивановский, В. А. Довцова,
Т. А. Семенова, Хим. пром., 4, 28 (1955). — [6] Г. О. Нусинов, А. П. Анд-
рианов. Мышьяковый процесс газоочистки. ОНТИ, М.—Л. (1937). —
[7] М. В. Гофман и др., Тр. Харьковского научно-исслед. углехим. инст., 20
(1941). — [8] М. С. Литвиненко. Коксохимическая промышленность США.
Металлургиздат (1947). — [9] Очистка газа от сероводорода и производство серной
кислоты, Центральный институт информации Министерства Черной металлургии
СССР, Бюлл. 23 (283), (1955). — [10] Stephan Hunyady, Rakosfalota
und Karl Koller, Герм. пат. 529698, kl. 26, vom 2/9 1928, ausg 16/7, 1931;
Ch. Zbl., 2, 1801 (1931). — [11] В. Т. Чагунава. Автореферат докторской дис-
сертации. Тбилиси (1954).

Abstract.

Effect of Low SO_2 Concentrations on the Organism of Animals. E. K. Lobova.
In book: Vopr. Gigeny Atmosf. Vozdukha. L., 14-24 (1959). Experiments were
performed with white rats. Exposure of 24 rats for a period of 4 hours to
 SO_2 concentration of 20 mg/m^3 lowered the activity of spleen tissue dehydrase
by 28.6 - 63.7%, as compared with the controls; activity of cholinesterase in
the tissues of the spleen, kidneys, blood, brain, and small intestine mucosa
was reduced by 29.0 - 41.7%. Exposure of white rats to SO_2 concentrations
of 0.48 mg/m^3 for 4 hours daily over a period of 144 days caused some animals
to lose weight, lowered the spleen dehydrase activity by 50 - 56% and the same
of the liver, lung, heart, and kidney tissues. Activity of cholinesterase
of tissues of the spleen, liver, intestinal mucosa, lungs, heart, and brain
were also reduced. No determinations were made for the effect of SO_2 on the
blood. There was a tendency to lowered vitamin C content in the kidney,
liver tissues and in the intestinal mucosa. At 0.1 mg/m^3 concentration of—
 SO_2 animal exposure for 5 hours daily over 165 days there was a slight ten-
dency on the part of carbonhydrase to fall below normal activity. Such shifts
were of short duration and reversible. Recommendations: complete absorption

of SO_2 from flue gases before they are discharged into the atmospheric air, so that the SO_2 concentration in the atmospheric air should not exceed 0.03 mg/l^3 as in the case of H_2S .

Wetting Agents Property to Catch Dust in a Dust Chamber.

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Zhurn. Prikl. Khim., Vol. 32, No. 4, 797-800, 1959.

Measures to prevent silicosis and anthracosis, i.e., the pathologic effects of quartz and coal mining, consist in the main of a wide use of water, such as drilling blast holes with washing, sprinkling, water "curtains", and similar methods. The dust catching capacity of water can be increased by adding certain wetting agents which increase the capacity of water to engulf particulates. Substances with lower surface tension, such as sulfonol (a Russian trade name), OP-7, OP-10, DB and others [1] belong to the group of wetting agents. Addition of such substances in practice indicated that residual air dustiness in mines may be reduced to one-half or one-third; in many instances [2] it was actually reduced to the level required by sanitary regulations. Therefore, physical and chemical analyses and comparative evaluations of the effectiveness of various wetting agents are of importance.

Taubman and Nikitina [3] made a thorough study of many wetting agents by the "drop method" to determine the capacity of individual drops to entrap particles of suspended dust. They were able to interrelate the dust capacity of wetting agents with their composition, chemical structure, degree of dust dispersion and many other pertinent factors [4].

The present report describes experimental tests made with wetting agent solutions using a laboratory dust chamber of 1 m^3 capacity, which is schematically presented in Fig. 1.

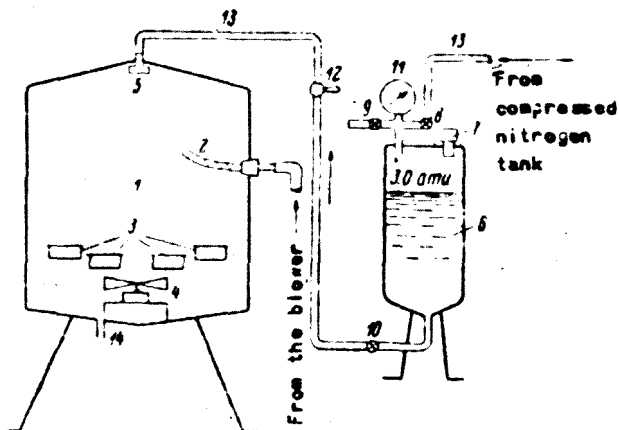


Fig. 1. Plan of installation used in the determination of dust catching property of wetting agent solutions in a dust chamber.

1 - Dust chamber; 2 - Dust disperser; 3 - Receivers; 4 - Blower; 5 - Forced spray nozzle; 6 - Tank containing water or wetting agent solution; 7 - Opening to tank filling; 8, 9, 10 - Valves; 11 - Manometer; 12 - Faucet; 13 - Hose; 14 - Drain.

These tests are of particular value, since they were performed under conditions similar to those prevailing in industrial dust catching by means of water spray, especially of dust suspended in mine air. The results should be of greater practical value than those obtained by the laboratory drop apparatus used by Taubman and Nikitina.

Where solutions of wetting agents were used instead of plain water [5], harmless silico-organic particles were formed in the spray-

containing air through the evaporation of the wetting agent solutions which distorted counts made for the evaluation of dustiness, yielding misleading information regarding the dust-catching capacity of the solutions tested. Furthermore, the gravimetric count cannot be used when tests are made in a chamber, since an air sample containing a sufficient amount of dust would cause a considerable decrease of the dust concentration in the chamber. Therefore, a special method was developed for the determination of the dust catching capacity of water and of wetting agent solutions, based on turbidity caused by the suspension of the dust collected in the process of liquid spraying. The relative effective dust catching capacity (E) was determined from the ratio between the turbidity of the dust collected by the solution of a wetting agent M_{wa} and the turbidity of dust suspension collected by water M_{wt} [3].

$$E = \frac{M_{wa}}{M_{wt}}$$

The dust concentration in the chamber changes continually during the experiment due to settling of coarse dust particles; therefore, measurements were begun after 7 to 8 minutes, when the heavy particle settling stopped and the concentration of suspended particles could be considered constant for purposes of study.

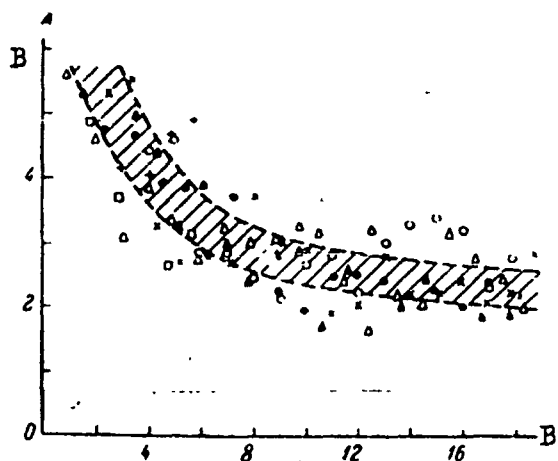


Fig. 2. Curves of quartz dust settling in dust chamber. A - Dust density in $n \cdot 10^{-4}$ particles per m^3 ; B - Time τ in min.

Curves shown in Fig. 2 represent rate of quartz dust settling and indicate that the initial concentration under the experimental conditions was $2.5 - 3.0 \times 10^4$ of particles per cm^3 . Determinations of the initial dustiness in the dust chamber were made by the count method using an electron ultramicroscope VDK [6]. Samples were taken approximately at mid height of the chamber. Spraying was done under pressure of 3 atmospheres; water droplets distribution according to diameters was as follows: 30 - 50 μ - 67.3%; 50 - 100 μ - 12.1%; 100 -

200 μ - 10.7%, and > 200 μ - 9.9%.

Substances under investigation were dust from the Baleiskii deposit, which contained approximately 60% of SiO_2 , and coal dust from the Yasinovka Donbass mine, the particle sizes of this dust were approximately 10 μ or less.

One g of quartz dust or 3 g of coal dust were placed into a dust diffuser, built for this study. Approximately one minute before the experiment was initiated, a fan was started in the chamber to maintain uniform dust distribution. The dust under study was then gradually forced out of the diffuser by the operating blower. The diffuser was then removed from the chamber, its opening was plugged, and the fan was turned off. The dust was allowed to settle undisturbed for about 7 minutes; then, either water or a wetting agent solution was sprayed in under pressure of 3 atmospheres. As the sprayer was set into operation, the receptacle lids were opened by means of an outside attachment, and an air sample was taken over a period of one minute. The suspension collected in 4 receptacles was transferred into a volumetric flask. In the experiments with pure water spray, a stabilizer, which was the wetting agent being tested, was introduced into the suspension. Parallel control experiments were conducted to determine the correction factor accounting for freely settling dust. The turbidities of the suspension obtained were measured with an "NMF" nephelometer.

The following Table shows the results obtained with quartz dust and with coal dust in determining the dust catching capacity of solutions of a

Dust catching capacity of wetting agent RAS-Na in relation to concentration.

Wetting agent concentration in percent	$E = \frac{M_{wa}}{M_{wt}}$	Dust type
0 (water)	1.00	Quartz
0.25	1.37	
0.50	1.67	
1.00	1.85	
1.00	2.22	Coal

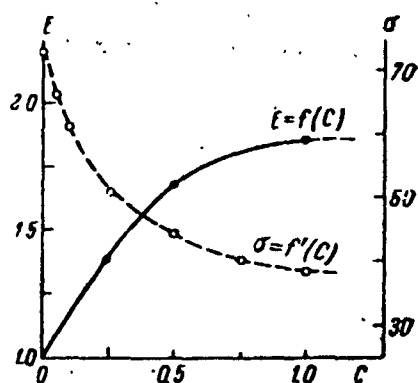


Fig. 3. Dust catching capacity of RAS-Na wetting agent solution in relation to concentration.

E - Dust catching capacity;
C - Wetting agent concentration in %; σ - Surface tension in erg/cm^2 .

particularly in their application to the abatement of deleterious silicon and anthracite dusts.

2. The value of a new synthetic wetting agent known as RAS-Na in catching silicosis and anthracosis producing dusts has been established by this method.

new wetting agent known as "RAS-Na", synthesized in the Oil Institute, Academy of Sciences, U.S.S.R. [7].

The curve in Fig. 3 represents the functional relation of the dust catching capacity (E) of RAS-Na solutions to the concentrations of the wetting agent using quartz dust. The dash line represents the isotherm of the dynamic surface tension for same solutions corresponding to the time of droplet (τ) formation equal to 2 seconds [8].

The results agree with data obtained by the trickling apparatus and lead to the conclusion that the procedure described herein and the use of a dust chamber for the evaluation of the dust collecting capacity of wetting agent solutions which lower surface tension constitute a convenient semi-industrial method for use in selecting effective wetting agents.

Conclusions.

1. A special method was developed based on the use of a laboratory dust chamber for the evaluation of dust catching capacity of wetting agent solutions with a lower surface tension,

Bibliography.

- [1] Л. И. Барон. Профилактика силикоза и антракоза при горных работах. Углетехиздат (1954). — [2] Л. И. Барон. Борьба с силикозом, 2. Изд. АН СССР, 71 (1955). — [3] А. Б. Таубман и С. А. Никитина. Борьба с силикозом, 2. Изд. АН СССР (1955). — [4] А. Б. Таубман и С. А. Никитина. ДАН СССР, 170, 600, 816 (1956). — [5] С. А. Никитина, А. Б. Таубман и С. Х. Зайцева. Борьба с силикозом, 3. Изд. АН СССР (1957). — [6] Б. В. Дерягин и Г. Я. Власенко. Борьба с силикозом, 2. Изд. АН СССР, 223 (1955). — [7] А. Я. Ларин, Промышленная кооперация, 1, 25 (1957); М. А. Гейман, А. Я. Ларин, В. Б. Шнейерсон и Р. А. Фридман, Тр. инст./нефти АН СССР, 6, 159 (1954). — [8] С. А. Никитина и А. Б. Таубман, ДАН СССР, 176, 113 (1957).

Basic Data for the Determination of Sanitary Clearance Zone Widths Around
Peat Burning Electric Heat and Power Stations.

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and Hygiene, Ministry of Health of the U.S.S.R.).

Gigiena i Sanitariya, Vol. 24, No. 9, 6-10, 1959.

It has been estimated that 60% of the world's peat supply was within the boundaries of the U.S.S.R. Some of the largest U.S.S.R. electric heat and power stations burned peat. It has also been estimated that at the end of the fifth Five-Year Plan the U.S.S.R. will generate 25% of the world's electric energy. The effect of such an amount of peat burned by electric heat and power plants will be seriously reflected in increased atmospheric air pollution with fly ash and other pollutants resulting from burning the anticipated quantities of peat. Peat as a fuel is characterized by low ash content. Top-layer peat contains 2 - 4% of ash, the intermediate layers contain 4 - 6% of ash, and the lower layers of peat contain 6 - 18% of ash. Sulfur content of peat varies between 0.1 and 0.2% in the top layer variety and between 0.3 and 0.5% and rarely up to 1.0% in the lower layered peat. K. G. Beryushev was the first to study atmospheric air pollution by discharges coming from peat burning electric heat and power stations. Using the sedimentation method Beryushev established signs of atmospheric air pollution within a 2 km area from the source of the discharge.

The purpose of the present study was to secure data for the revision of the sanitary clearance zone regulation GOST N 101-54, applicable to electric heat and power stations which used peat as fuel. Studies were conducted in the environs of four separately located electricity generating stations: 3 stations were located in the Moscow and one in the Ivanovsk regions. The stations burned 50, 90, 200 and 250 tons of peat per hour; they were equipped with jalousie ash catchers and with cyclone ash abaters which operated at 50 - 65% effectiveness, with the smokestacks ranging between 30 - 60 m height. The study was limited to the estimation of atmospheric air pollution with dust and with SO_2 . Five-hundred and twenty-three air samples were collected by the aspiration method in the path of the smoke flume at distances between 100 to 2500 meters from the point of discharge. Simultaneously studies were made of

the amounts of ash and SO_2 actually emitted into the atmosphere by the electric stations. The procedure was as follows: at the time the aspiration air samples were collected, records were made of the number of operating boilers, their charge or loading capacity, the rate of fuel consumption, the fuel composition and the ash catcher operation. Supplemental study results and other pertinent data are listed in Table 1. It should be added at this point that the methods of fuel combustion used by the electric heat and power stations under investigation were different. Electric heat and power stations Nos. A and B burned a mixture consisting of 60% milled and 40% lump peat, station C burned milled peat exclusively, and station D burned lump peat exclusively. Atmospheric air pollution data (dust and SO_2) are listed in Table 2.

T A B L E 1.

Properties of the fuel and of the emissions into atmospheric air.

Indexes	Electric heat and power plants			
	A	B	C	D
Peat consumption in tons per hour	250	200	90	50
Peat ash content in percent	8	9	9	10
Efficiency coefficient of flue gases purification in percent	62	4 boilers 50 5 boilers no purification	60	65
Ash emission in tons per hour	5.3	8	3	0.5
Sulfur content in percent	0.3	0.3	0.3	0.3
SO_2 emission in tons per hour	1.5	1.1	0.5	0.3
Smokestack height in m	40	7 stacks 40 2 stacks 60	30	30

The hygienic evaluation of data related to atmospheric air pollution and to width of sanitary clearance zones was based on a comparison of the actual maximal single concentrations with the limits of allowable concentrations adopted in the U.S.S.R. for dust (0.5 mg/m^3) and SO_2 (0.5 mg/m^3). Of equal weight and importance were the answers to a list of questions given to local residents which in this case were in close correspondence with the results of the analytical laboratory findings. Answers given by residents at a radial distance of 1500 m from electric stations A and B presented a suitable example

T A B L E 2.

Maximal dust and sulfur dioxide concentrations in mg/m^3 in atmospheric air in the surroundings of the electric heat and power plants.

Meters from plant	Electric heat and power stations							
	A		B		C		D	
	Dust	SO ₂	Dust	SO ₂	Dust	SO ₂	Dust	SO ₂
100	-	-	-	-	-	-	1.70	0.8
300	-	-	17.0	1.6	3.26	2.60	0.40	0.6
500	9.55	2.1	12.3	1.6	2.89	0.45	0.18	None found
1,000	3.31	1.8	4.0	1.2	1.00	0.39	None found	None found
1,500	1.47	1.5	2.0	0.8	0.68	0.32	-	-

T A B L E S 3 A N D 4.

Answers to questions by residents in surroundings of plants A and B in percent.

Meters from electric power plant	No. of persons	Air smokiness noted						Soiled linens and clothes	Smoky and dusty windows	Damaged vegetation
		Generally	Frequently	Infrequently	None	Strong	Weak			

Plant A

200-300	101	100.0	71.0	18.0	-	93.0	7.0	100.0	98.0	99.0
500-600	100	100.0	-	-	-	100.0	-	100.0	100.0	100.0
1,200-1,500	92	92.0	-	1.1	-	19.8	80.2	99.8	100.0	99.8

Plant B

200-300	99	100.0	100.0	-	-	100.0	-	100.0	100.0	100.0
500-600	95	100.0	96.8	2.1	-	66.4	33.6	100.0	100.0	95.0
1,200-1,500	94	91.5	8.5	91.5	8.5	1.1	89.3	36.2	72.3	1.1

of the above mentioned correspondence; the answers are listed in Tables 3 and 4. The answers given by the residents indicated that the smokestack discharges seriously affected the general living conditions of the population residing 1500 meters from electric stations A and B. This was basically due to the fact that the flue gas purification equipment operated at low efficiency, and the smokestacks were of insufficient height on the one hand, and on the other hand the sanitary clearance zones between the stations and the populated areas were of insufficient width.

Electric station A burned 250 tons of peat per hour; the peat contained 8% of ash; the ash catching installations operated at 62% efficiency, and the height of the smokestack was 40 meters. Accordingly, the smokestack discharged into the atmospheric air 5.3 tons of ash every hour. According to the data listed in Table 2 the sanitary clearance zone should have been more than 2500 m wide, since even at a distance of 2500 m from station A the SO_2 concentration in the atmospheric air was 3 times the required limit of its allowable concentration. Examination disclosed that the actual width of the existing clearance zones was approximately 200 m and that it was not possible to increase its width under the prevailing localization of populated areas; the only way in which this particular sanitary problem could be solved, would be by raising the ash-removing efficiency of the gas purifying equipment to 97 - 98%.

Electric station B burned 200 tons of peat per hour; the ash content of the peat was 9%; the station operated on 9 boilers, of which only 4 were equipped with ash-catching installations. As a result, this station emitted through its smokestacks of 40 - 60 m high 8 tons of ash per hour. At 2500 m from this station the maximal dust concentration exceeded by 4 times the maximal single allowable concentration; the SO_2 concentration at 2500 m from the station exceeded by 1.6 times the maximal single allowable atmospheric air concentration. Accordingly, the width of the sanitary clearance zone surrounding station B should be 2500 m. Here, again, the existence of populated areas makes widening of the present sanitary clearance zone practically impossible, and, as in the case of station A, the sanitary problem could be solved only by raising the total flue gas purification to 97%.

Station C burned 90 tons of peat per hour; the ash content of the fuel was 9%; ash catchers took care of only 60% of the ash, so that the smokestacks of 30 m in height discharged into the atmospheric air 3 tons of dust per hour. Accordingly, in this case, the width of the sanitary clearance zone should also be 2500 m. In fact, however, the existing sanitary clearance zone was only 100 m wide. In this case sanitary problems could be resolved by increasing the ash catching to 93%.

Electric station D burned 50 tons of peat every hour; the ash content of the peat was 10%; total ash removal amounted to 65%, and the station discharged into the atmospheric air through the smokestacks of 30 m high 0.5 tons of ash hourly. Residential homes were built in close proximity to the station grounds.

Simple calculation indicated that flue gas purification from ash in this instance should be increased to not less than 90%.

The electric heat and power stations under present study had ash abating facilities which removed not more than 50 - 65% of flue gas ashes, and their smokestacks were of insufficient height (30 - 60 m). Regulation N 101-54 contains no specifications for sanitary clearance zones for plants similar to the above. For the comparative evaluation of the results obtained calculations were made for the determination of dust concentrations which would remain if 75 - 90% of the ash were removed, and if the smokestacks were 100 - 120 m high; and which would accord with requirements stipulated in regulation N 101-54. The calculation formula was based on actual dust concentrations found in the atmospheric air surrounding the investigated stations. In Table 5 data are presented related to dust concentrations calculated on the basis of degree of discharge purification, with the aid of the following formula:

$$K = \frac{K_{\phi}(1 - \eta_p)}{1 - \eta}$$

where K is the sought concentration; K_{ϕ} is the actual determined concentration; η is the actual coefficient of effective performance; η_p is the computed coefficient of efficiency.

TABLE 5.

Computed dust concentration in mg/m^3 .

Meters from electric plant	At 75% dust catching				At 90% dust catching			
	Electric heat and power stations							
	B	C	D	A	B	C	D	
300	6.8	2.0	0.28	-	2.4	0.8	0.11	
500	4.9	1.8	0.12	2.5	1.7	0.7	0.05	
1,000	1.6	0.6	-	0.9	0.7	0.3	-	
2,500	0.8	0.4	-	0.4	0.3	0.2	-	

In studying conditions prevailing in electric heat and power stations with 30 - 40 m smokestacks (low smokestacks), and of 100 - 120 m (high smokestacks) and identical gas purification equipment, B. P. Gurinov and N. Ya. Yanysheva obtained data on the effect of smokestack height on the intensity of atmospheric air pollution with dust. Results of such investigations were instrumental in determining the correction coefficients to be used in calculating dust concen-

trations at different distances from smokestacks of different heights. Such data are presented in Table 6.

T A B L E 6.

Computed dust concentrations in mg/m^3 with smokestacks 100 - 120 m high.

Meters from power plant	Correction coefficient	At 75% dust catching :				At 90% dust catching			
		Electric heat and power stations							
		B	C	D	A	B	C	D	
300	9.5	0.71	0.21	0.29	-	0.25	0.08	0.011	
500	2.5	1.95	0.72	0.05	1.00	0.68	0.28	0.020	
1,000	1.5	1.07	0.40	-	0.60	0.47	0.20	-	
2,500	1.2	0.67	0.34	-	0.33	0.25	0.16	-	

Conclusions.

1. An electric heat and power station which burned hourly 250 tons of peat containing 10% of ash, and which was equipped with 90% ash abating installations and had smokestacks 100 - 120 m high, discharged into the atmospheric air 1.4 tons of ash. In such cases the calculated width of sanitary clearance zones should be not less than 1000 m, indicating that the officially adopted width of 500 m was inadequate; this was verified by the fact that at 500 m from the smokestacks the maximal dust concentration was in excess of the allowable maximal concentration.

2. An electric heat and power station which burned hourly 200 tons of peat containing 10% of ash, and which was equipped with 75% ash abating installations and had smokestacks of 100 - 120 m high, discharged into the atmospheric air 2.7 tons of ash hourly. According to regulation N 101-54 such a plant should be separated from populated localities by a sanitary clearance zone 500 m wide. However, results of calculations indicated that the width of the sanitary clearance zone should be more than 2500 m. Under similar conditions and with flue gas purification amounting to 90% of ash removal the volume of ash discharged into the atmospheric air would amount to 1.1 tons per hour. Here again, the required 500 m wide sanitary clearance zone prescribed by N 101-54 was inadequate and should be revised to 1000 m.

3. An electric heat and power station which burned hourly 90 tons of peat containing 10% of ash, and which was equipped with 75% ash-removing equipment, discharged into the atmospheric air 1.7 tons of ash hourly through high smoke-

stacks; according to the results of the proposed computation the sanitary clearance zone in such cases should be not less than 1000 m wide, instead of 500 m as recommended by regulation N 101-54. At 90% ash removal such a station will still discharge into the atmospheric air 0.7 tons of ash hourly; here, again, the 300 m clearance zone prescribed by regulation N 101-54 is sadly inadequate.

4. An electric heat and power station which burned hourly 50 tons of peat containing 10% of ash, and which was equipped with 75% ash-removing equipment discharged into the atmospheric air 0.5 tons of ash per hour. Calculation by the method previously outlined indicated that the 300 m wide sanitary clearance zone prescribed by regulation N 101-54 was inadequate.

Bibliography.

Берюшев К. И. В кн.: Сборник трудов Научно-исслед. ин-та коммунальной санитарии и гигиены. М., 1949, т. 3, стр. 133. — Гуринов Б. П., Янышева Н. Я.; Гордон А. В. Информационный бюллетень Московск. научно-исслед. ин-та санитарии и гиг. М., 1958, № 14--15, стр. 35. — Дергачев Н. В., Гуринов Б. П. В кн.: Очистка промышленных выбросов в атмосферу. М., 1953, в. 1, стр. 54. — Золотин Н. Г., Шухер С. М. Очистка дымовых газов. М.—Л., 1948. — Справочник по торфу. М.—Л., 1954.

Hygienic Basis for the Determination of Standard Sanitary Clearance Zone Widths Around Gasoline Filling Stations.

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In accordance with the decision of the XXI Conference of the KPSS (Communist Party of the U.S.S.R.) freight autotransport is to be increased to 1.9 times its present capacity, and passenger autotransport is to be increased to 3 times its present capacity during the 1959 - 1965 Seven-Year Plan. This brings into sharp focus the problems of air pollution with auto discharge gases and of automobile discharge noise as threats to the health and comfort of city dwellers. In this connection the gasoline supply stations will become more

potent points of congregation of freight and passenger automobiles, of concentrated air pollution with gasoline vapor and of exhaust explosion noises. This places into the forefront the urgent problem of creating sanitary clearance zones between gasoline filling stations and living quarters.

The purpose of the present investigation was to determine the degree and extent of atmospheric air pollution and of noise around gasoline supply stations which could yield a rational and scientific basis for the adoption of sanitary-hygienic clearance zones. For this purpose 1038 air samples were collected, 591 of which were analyzed for carbon monoxide content, and 447 for content of gasoline vapor. By means of noise recorder 634 determinations were made of intensity and distribution of noise in the proximity of gas supply stations. A specially prepared questionnaire was distributed among 223 persons. Analyses were made of the blood of 50 gasoline station women attendants; the photometric method of Ezheneeskii was used for the determination of hemoglobin percent and number of erythrocytes. The survey extended through the summer and winter months of 1957 - 1958. Points of investigation were Lenin-grad gasoline filling stations of different tank capacity and of different locations. Carbon monoxide was determined in air samples collected at 6 such gasoline stations, and gasoline vapor content in air samples collected at 5 gasoline stations; noise intensity was determined at 4 gasoline stations. Until August of 1957 all gasoline stations under investigation, with the exception of station No. 9, supplied ethylated gasoline; after August 1957, as a rule, all stations supplied second-grade gasoline coming from Eastern crude oil distilleries. For the determination of carbon monoxide content and gasoline vapor, air samples were collected in direct proximity of the gasoline pumps and at 25, 50, 75 and 100 m away; the same was true of noise intensity determinations; samples of air were also collected and noise determinations were made in the working premises of the women gasoline station attendants and in residences located 21 - 90 m from the gasoline filling stations.

Results of air sample analyses showed that the intensity of atmospheric air pollution with carbon monoxide and with gasoline vapor varied directly with the number of automotive vehicles being serviced, and also with the amount of gasoline being dispensed; it was inversely proportional to the distance from the gasoline pumps. Data in Table 1 show that at a distance of 50 m from gasoline filling stations Nos. 7, 10, 16 and 23 the highest carbon monoxide

concentration exceeded the limit of allowable CO concentration (6 mg/m^3) in atmospheric air. At a distance of 75 m from the largest gasoline station No. 23 the highest CO concentration was 9 mg/m^3 and the lowest 4 mg/m^3 . Lowest concentrations of CO in the air in the proximity of gasoline station No. 10 was observed at a time when the number of automobiles were comparatively few. Carbon monoxide concentrations in the air at all points of observation were 1.5 as high during the cold of winter months as during the warm summer months, probably due to slower spread of the exhaust gases at low temperatures.

In the working premises of the women gasoline station attendants CO concentration in the air ranged between $4 - 34 \text{ mg/m}^3$, with an average of 12 mg/m^3 . The CO concentration exceeded the limit of allowable concentration for air of working premises (30 mg/m^3) in only 2 of 35 samples. The content of CO in the air of residences automatically equipped with (natural) gas supply, and which were located 21 - 69 m from a gasoline supply station, ranged between $4 - 29 \text{ mg/m}^3$. When natural gas was being burned in the kitchen the CO in the air rose to $60 - 158 \text{ mg/m}^3$. Conditions of this type interfered with the reliable determination of the effect of gasoline supply stations on indoor residential air. Concentrations of gasoline vapor in the air in proximity of gasoline stations are listed in Table 2.

The data in Table 2 show that at 50 m from gasoline stations Nos. 7, 10, 22 and 23 the highest gasoline vapor concentration exceeded the maximal allowable concentration of 5 mg/m^3 adopted for stations which distribute gasoline distilled from Eastern crude oil (S. N. Kosourov). In the vicinity of the largest gasoline station No. 23 the concentration of gasoline vapor in the air was 5 mg/m^3 , or the equivalent of the allowable limit of concentration, in samples collected 75 m from the gasoline pump. In this vicinity the concentration of gasoline vapor in the air was at all points greater in the summer months than in the winter months. This may have been due to the more intensive evaporation of the gasoline at the higher summer temperatures. The intensity of gasoline odor at the gasoline pumps could be designated as strong, at 25 - 50 meters from the pump and in the direction of the prevailing wind the odor, on a comparative basis, was designated as weak; it was barely perceptible at 50 m, and in the case of the larger stations occasionally even at 75 m from the pump (stations 7 and 23).

T A B L E S 1 A N D 2.

Distribution of carbon monoxide and of gasoline vapor in the atmospheric air of gasoline stations surroundings.

Gasoline station No.	No. of samples	Concentration of carbon monoxide or gasoline vapor in mg/m ³									Average number of automobiles per hour.
		Directly at gasoline pump			At a distance of						
					25 meters			50 meters			
		Mini-mal	Maxi-mal	Average	Mini-mal	Maxi-mal	Average	Mini-mal	Maxi-mal	Average	

Carbon monoxide

No. 23	97	4.0	178	24.3	4	204	39.3	4	32	10.0	50
No. 7	97	4.0	158	25.5	4	146	30.7	4	12	6.9	31
No. 22	92	4.0	141	31.3	4	136	40.7	4	6	5.0	34
No. 9	52	4.0	142	32.1	4	260	53.2	4	6	4.7	41
No. 10	77	4.0	114	20.9	4	152	26.7	4	9	6.3	25
No. 16	19	6.0	78	33.0	6	186	53.9	7	8	7.5	-

Gasoline vapor

No. 23	80	5.0	89	26.7	3	19	8.1	3	12	5.6	3,272
No. 7	72	13.0	129	52.9	3	21	7.5	3	11	5.4	2,050
No. 22	95	5.0	49	18.1	3	31	7.9	4	10	5.4	2,123
No. 9	33	4.0	96	31.6	5	18	9.2	3	4	3.5	2,688
No. 10	48	5.5	49	17.4	3	9	6.1	4	8	5.3	1,654

Gasoline concentrations in the air of the working premises of the women station attendants ranged between 11 - 94 mg/m³ with an average of 36.8 mg/m³. Thus, the maximal concentration of 94 mg/m³ did not exceed the 100 mg/m³ maximal allowable concentration for the indoor air of working premises (R. L. Shur). Concentrations of gasoline vapor in the air of residences located in the vicinity of the gasoline stations ranged between 13 - 32 mg/m³, 21 to 60 m from the gasoline pump.

The noise intensity in the proximities of gasoline filling stations ranged between 42 - 52 noise units (phones) mostly caused by the auto transport and tramway movement in the neighboring streets. Results of noise measurements listed in Table 3, show that the noise produced by the automotive traffic spread over considerable distances from the gasoline stations. The noise penetrated into residences located 69 m from gasoline station No. 7, where its intensity measured 35 noise units.

Carboxyhemoglobin in the blood of the women station attendants ranged between 0.94 and 10.07%; the carboxyhemoglobin average before beginning work.

T A B L E 3.

Zone of noise distribution around gasoline stations.

Gasoline station No.	Number of determinations	Sound loudness in "phones"								
		Directly at gasoline pump			At a distance of					
					50 meters			100 meters		
		Mini-mal	Maxi-mal	Average	Mini-mal	Maxi-mal	Average	Mini-mal	Maxi-mal	Average
No. 23	88	71	88	78	55	74	63	48	63	56
No. 7	55	70	89	76	52	69	60	42	46	44
No. 10	48	79	88	81	50	75	61	-	-	-
No. 22	20	71	84	75	52	65	54	-	-	-

was 3.39% and at the end of work 3.23%, as compared with control persons residing in non-gas equipped homes beyond the city limits of 0.92 to 4.58 with an average of 2.46%. It must be noted in this connection that all women gasoline station attendants lived in gas equipped homes; in evaluating the data on a comparative basis this fact must be taken into consideration. No cases of polyglobinemia were found among the women filling station attendants. The hemoglobin content ranged between 67 - 76%; erythrocytes ranged between 3,400,000 and 5,540,000 per mm³, with an average before beginning work of 4,420,000 and after work of 4,460,000 per mm³. Replies to questionnaires distributed among the women gasoline station attendants came from 50 persons. The answers indicated that 39 had no complaints to register and 11 complained of headaches, vertigo, tachycardia, restless sleep, general malaise, weakness in the lower extremities, etc. Replies from nearby residents indicated that the basic mass of population residing 20 - 90 m from the gasoline pumps and occupying dwellings, the windows of which faced the gasoline stations, strenuously complained of noise annoyance, headaches, restless sleep, inability to relax and perception of the unpleasant odor of gasoline. On the basis of the replies coming from the general population, it can be admitted that atmospheric air pollution with gasoline vapor, auto exhaust gases and, in addition, the prevailing noise, extended over a radial distance of 70 - 90 m from the gasoline stations.

Conclusions.

1. Gasoline supply stations are foci of noise creation and distribution and of atmospheric air pollution with gasoline vapor and automobile exhaust

gases. The degree of atmospheric air pollution and the noise intensity in the proximity of gasoline stations depend upon the number of automobiles served, the volume of gasoline dispensed and, consequently, with the number of gasoline pumping installations.

2. Carbon monoxide pollution of the air extended over 75 m from the gasoline stations; its concentration in the atmospheric air at such points reached 9 mg/m^3 .

3. Gasoline vapor air pollution extended over a distance of 75 m from the gasoline stations; its concentration at such points reached a maximum of 5 mg/m^3 .

4. Noise generated by the automotive transport extended over a distance of 100 m from the gasoline station; its intensity at such distant points exceeded the noise intensity determined in close proximity of the gasoline stations.

5. Based on the observations, analyses and other data above recorded the following is proposed: that the width of sanitary clearance zones be adopted in accordance with the size of the station and the amount of gasoline dispensed; larger gasoline stations with 3 pumps and 50 m^3 gasoline tanks and dispensing over 3000 li/hour of gasoline should be surrounded by a sanitary clearance zone of not less than 100 m wide; stations having 2 pumps and 50 m^3 gasoline tanks and dispensing 1500 - 3000 li/hour of gasoline should have a sanitary clearance zone of not less than 75 meters wide; smaller gasoline stations, such as have one pump and a storage tank of 15 m^3 capacity and dispensing less than 1500 li/hour of gasoline should have a sanitary clearance zone of not less than 50 m wide.

Bibliography.

Вольфсон З. Г. Борьба с выхлопными газами автотранспорта. М., 1937. — Измеров Н. Ф. Гиг. и сан., 1958, № 2, стр. 8. — Косоуров С. Н. В кн.: Предельно допустимые концентрации атмосферных загрязнений. М., 1955, в. 2, стр. 92. — Лыкова А. С. Загрязнение воздуха городских улиц окисью углерода и ее вредное влияние, Дисс. канд. Л., 1953. — Навянжский Г. Л. Учение о шуме. Л., 1948. — Рязанов В. А. Санитарная охрана атмосферного воздуха. М., 1954. — Шапшев К. Н. Вопросы городского шума и борьбы с ним Л., 1939.

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I. Field of application.

1. The present "Norms" (standards) apply to planning of new, improving and rebuilding of existing industrial enterprises.

In the instances of special enterprises characterized by inherent factors of harm to health (chemical and the like), supplemental sanitary requirements are effectuated by means of special norms (standards) according to the nature of the industrial enterprises, which were developed by appropriate ministries in coordination with the All-Union State Sanitary Inspectorate.

With the approval of the appropriate organs of the All-Union State Sanitary Inspectorate certain deviations from the present standards of sanitary requirements may be granted in special instances of rebuilding industrial enterprises as well as in planning new, small industrial enterprises.

II. Basic requirements for general planning.

2. The site of the industrial enterprise, of the nearby residential settlement, the water supply source and manner of sewage disposal must accord with the regulations of the organs of the All-Union State Sanitary Inspectorate and organs of other pertinent State Regulating Organizations.

3. The conditions prevailing in the territory of the planned industrial enterprise must accord with the sanitary requirements as regards atmospheric precipitation, drainage, direct sunshine, natural ventilation, level of ground water and possibility to institute effective anti-malarial measures.

4. In assigning sites for different industrial enterprises in any given locality, production plants must be grouped in such a manner as to obviate

the possibility of unfavorable effects of one production plant on another.

5. Plans for the erection of industrial enterprises (production plants) must include provision for the protection of the health of inhabitants through the installation of such devices as dust catchers and dust abatons, gas purifiers, noise absorbers, conduit and other equipment hermatization, by-product recovery, etc.

6. The site of industrial enterprises, or industrial production complexes, which produce such harmful effects as deleterious gases, smoke, soot, dust, unpleasant odors, noise, etc., must be selected by taking into consideration the location of the nearest leeward residential settlement with regard to prevailing winds, and to separate the plant or the complex from the boundary of such settlement by appropriate sanitary clearance zones.

Note 1. Prevailing direction of winds is determined by a several-years average of wind "rosette" (pattern) during the warm season of the year.

Note 2. The sanitary protection (clearance) zone is defined as a territory (belt) between the industrial plant buildings, storage houses and other installations which emitted or discharged industrially produced nuisances and deleterious substances, and residential, therapeutic and prophylactic stations, recreational institutes or buildings housing other similar organizations.

7. Based on the industrial discharges created and emitted by industrial plants, and taking into consideration technological measures adopted for the purification of deleterious emissions into the atmospheric air, industrial production and processing enterprises have been classed into five groups according to Supplement 1:

Class I requiring a sanitary clearance zone 1000 m wide.

Class II requiring a sanitary clearance zone 500 m wide.

Class III requiring a sanitary clearance zone 300 m wide.

Class IV requiring a sanitary clearance zone 100 m wide.

Class V requiring a sanitary clearance zone 50 m wide.

Note 1. The sanitary clearance zone can be widened at the demand or by order of the All-Union State Sanitary Inspectorate to not more than twice the stipulated width in the following special cases: a) where it was not feasible or possible to reduce the harmful discharged substances into the atmospheric air by any of the presently developed technical means to a concentration compatible with the protection of the health of surrounding population; b) in the case of residential foci located leeward in relation to the

production plant or combine which emitted the deleterious substances into the atmospheric air.

Note 2. The width of sanitary clearance zones next to production plants not specifically mentioned in the supplement must be the same as for production and processing plants most closely related to them.

Note 3. The sanitary clearance zone regulation does not apply to production and processing plants which are free from any type of harmful emissions or discharges.

8. Organs of the All-Union State Sanitary Inspectorate can authorize a reduction in the width of sanitary clearance zones as specified under item 7, if in their opinion the emission-purifying installations of any plant, combine or complex are of high purifying efficiency, are operated and maintained properly so that the concentrations of atmospherically emitted harmful substances did not exceed prescribed maxima, thereby protecting the health and well-being of the population of the surrounding residential area.

9. In modernizing and reconstructing such commercial enterprises, as means of transport-communications or heat and power electric stations, located within the boundaries of populated settlements, the width of sanitary clearance zones should be determined by the consent of and in agreement with the appropriate organs of the All-Union State Sanitary Inspectorate.

10. Location of the following is permitted on the grounds of sanitary clearance zones between residential settlements and industrial manufacturing and processing enterprises which emit into the atmosphere deleterious substances: production and industrial processing plants of lower degree of harmful discharges, provided that the distance between them and the nearest residential settlement was in compliance with the prescribed classification.

The following may also be located within a sanitary clearance zone: fire departments, bath houses, public laundries, guard houses, public garages, certain storage facilities, service and administration buildings, trade houses, dining rooms, polyclinics, etc., dwellings for emergency and general servicing personnel.

The general plan of the industrial production and processing enterprises must include a well-considered plan for execution and maintenance of the required sanitary clearance zone, the adequate planting of appropriate trees, shrubs and other green plants, and any anticipated legally permissible utilization of the proposed required clearance zone.

11. The erection of residence buildings on the site or within the grounds of a commercial production plant is forbidden. This applies to proposed as well as to presently existing plants.

12. In making general or basic plans for new commercial production or processing plants the following regulations must be taken into consideration as basic and mandatory:

a) Buildings must be erected with due regard to direction of most effective light and direction of prevailing wind (as defined in item 6), so as to assure most favorable conditions of natural light and ventilation;

b) Such buildings of the general production or processing combine or complex, which house departments which emit into the atmospheric air harmful substances, must be located in relation to buildings which house other production departments in such a way as to enable the prevailing winds to carry the emission away from them and not towards them.

c) In line with regulation (b) buildings housing production departments which emit harmful gases, dust, or other deleterious substances should be located in groups observing the principle expressed in (b).

d) Ample and appropriate provision should be made beforehand for the removal of waste products, such as slag, ash, etc. from the plant grounds; where the volume of such end products is not voluminous temporary storage on the plant grounds may be permitted at an appropriately chosen section of the plant grounds.

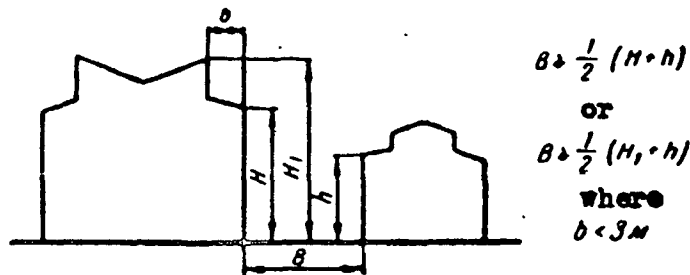
e) Sewage and industrial-effluent purification buildings may be located on the production or processing plants' grounds.

f) Clearances between buildings which house unusually noisy production departments of the level of 90 decibels, and living quarters of emergency and other service personnel should be not less than 100 m.

13. Breaks or clearances between different sections of a production or processing industrial building can be best attained by resorting to the Π (π -shaped) or $\Pi\Pi$ (comb-shaped) type of building, in which case the following regulations must be observed:

a) The longitudinal axes of the space breaks must be built in conformity with certain stipulations in relation to the prevailing winds.

b) The width of the space breaks or clearances must be not less than one-half of the height of the building walls, and in no case should it be less than 15 m, as is shown in the following drawing; in cases where



deleterious or harmful emissions are involved the minimum width of the space or clearance between the wings of the building may be reduced to 12 m.

14. Where it is technologically expedient or desirable to erect the production or processing plant in the shape of a closed rectangle, the following regulations must be observed:

- a) The shortest side of the inside clearance-space rectangle must measure not less than, or it must exceed twice the height of the highest point of the inclosing walls.
- b) The inclosed air space must be subject to adequate ventilation.

S U P P L E M E N T 1.

SANITARY CLASSIFICATION OF PRODUCTION AND PROCESSING PLANTS IN RELATION TO SANITARY CLEARANCE ZONES.

Chemical Industry Plants.

Class I requiring a sanitary clearance zone 1000 meters wide.

1. Production of bound nitrogen and nitrogenous mineral fertilizers.
2. Production of nitric and other acids, the manufacture of which is accompanied by the discharge of oxides of nitrogen.
3. Production of intermediate products of aniline dyes industry, e.g., aniline, nitrobenzene, nitroaniline, chlorobenzene, phenol, with total production exceeding 1000 tons per year.
4. Production of intermediate products of naphthalene and anthracene series (β -naphthol, peracid, anthraquinone, phthalic anhydride, etc.), exceeding 2000 tons per year.
5. Production of iron bromide.
6. Production of sulfite paper and cellulose sulfate (pulp).
7. Production of illuminating, water and generator gas in amounts exceeding 5000 cubic meters.
8. Production of sodium hydroxide by the electrolytic method.

9. Production of calcium carbide.
10. Production of artificial viscose fibers and cellophane.
11. Production of concentrated mineral fertilizers.
12. Production of oils and solvents (benzene, toluene, xylene, naphthol, phenol, cresol, anthracene, phenanthrene, acridine, carbazole).
13. Production of arsenic and its inorganic compounds.
14. Production of natural gas in excess of 5000 cubic meters per hour.
15. Production of processed petroleum containing more than 0.5% by weight of sulfur of high content of volatile hydrocarbons.
16. Production of picric acid.
17. Production of hydrofluoric acid and cryolite.
18. Production of coal concentrates.
19. Production of bituminous shale.
20. Production of mercury.
21. Production of soot.
22. Production of sulfuric acid, oleum and sulfur dioxide.
23. Production of carbon bisulfide.
24. Production of hydrochloric acid.
25. Production of superphosphates, in sulfuric acid plants.
26. Production of nitrogenous fertilizers, such as aminophosphates.
27. Production of yellow and white phosphorus.
28. Production of chlorine.
29. Production of chlorinated and hydrochlorinated hydrocarbons, in excess of 1 ton of chlorine in 24 hours.

Class II requiring a sanitary clearance zone 500 meters wide.

30. Production of ammonia.
31. Production of natural gas.
32. Production of organic sulfur dyes, such as sulfur black.
33. Production of hydrocyanic acid.
34. Production of synthetic camphor, oils, cellulose, etc.
35. Production of beryllium, thallium and niobium.
36. Production of generator gas from coal or peat in quantities of 25,000 to 50,000 cubic meters per hour.
37. Production of processed natural tars and their residues.
38. Production of calcined soda by the ammonia process in excess of 400,000 tons per year.
39. Production of synthetic rubber.

40. Production of organic reagents.
41. Production of plastics, plastic masses, cellulose esters, etc.
42. Production of rare metals by the chlorination process.
43. Production of barium chloride by the hydrogen sulfide method.
44. Production of superphosphate without the aid of sulfuric acid, and with the aid of volatile fluorides.
45. Production of saturated technical fats by non-electrolytic hydrogen.
46. Production of fluorides, hydrofluoric acid excepted.
47. Production of synthetic drugs and pharmaceuticals.
48. Production of chlorine, not exceeding 1 ton per day.
49. Production of distilled petroleum, containing less than 0.5% by weight of sulfur and of low content of volatile hydrocarbons.
50. Production of peat processed chemicals.
51. Production of chromic anhydride and chromic acid salts.
52. Production of leather substitutes requiring the use of highly volatile solvents.
53. Production of essential oils (complex).
54. Production of organic solvents for synthetic products, such as alcohol, ether, etc. and crude oil gases in excess of 5000 m³ per hour.
55. Production of aniline dyes intermediates, such as aniline, nitrobenzene, nitroaniline, chlorobenzene, nitrochlorobenzene, phenol, etc., not exceeding 1000 tons per year.
56. Production of naphthalene and anthracene intermediates, such as β -naphthol, peracids, anthraquinone, phthalic anhydride, etc., not in excess of 2000 tons per year.
57. Production of sulfur dyes not to exceed 4000 tons per year.
58. Production of all indigo dyes.
59. Production of experimental aniline dyes not to exceed 2000 tons per year and other allied manufacturing processes not to exceed 1000 tons per year.
60. Production of processed asbestos fibers.

Class III requiring a sanitary clearance zone 300 meters wide.

61. Production of bitumen and other chemical materials prepared from coal tar, petroleum and conifers (petroleum asphalt and the like).
62. Production of tar, methanol, acetic acid, turpentine, oils, etc. from wood by destructive distillation.
63. Production of fats by the contact process.
64. Production of calcined soda by ammonia process not exceeding 400,000 tons per year.

65. Production of sodium hydroxide according to Lewis by the caustic lime process.
66. Production of salts of inorganic acids (salts of arsenic, phosphorus and chromium excepted).
67. Production of petroleum gas in volumes of 1000 to 5000 cubic meters per hour, and generator gas in quantities of 5000 to 25,000 cubic meters per hour.
68. Production of nicotine.
69. Production of plastic material and plastics, celluloid, bakelite, chlorovinyl, etc.
70. Production of textile and paper products by impregnation and pressure and/or rolling in with resins, not exceeding 100 tons per year.
71. Production of mineral dyes.
72. Production of regenerated rubber and gum.
73. Production of gum and ebonite.
74. Production of phenolic aldehyde and other artificial resins not exceeding 300 tons per year.
75. Production of chemically processed ores for the production of salts of antimony, bismuth, lithium, etc.
76. Production of synthetic camphor by process of isomerization.
77. Production of synthetic rubber by the alcohol method.
78. Production of mineral fertilizer mixtures.
79. Production of coal products for electric industries, e.g., brushes, electrodes.
80. Production of phenol aldehyde and other artificial resins, less than 300 tons per year.
81. Production of vulcanized rubber with carbon bisulfide.

Class IV requiring a sanitary clearance zone 100 meters wide.

82. Production of paper from treated cellulose and rags.
83. Production of galalith and other protein resins, aminoplasts, etc.
84. Production of glycerol.
85. Production of generator gas from coal and peat not exceeding 5000 cubic meters per hour.
86. Production of synthetic fibers by acetate-ammonia process.
87. Production of lead pencils.
88. Production of soaps on a large scale.
89. Production of resins, alcohol, typographical lacquers for rubber industry, insulation material, etc.
90. Production of oil varnish.

91. Production of organic preparations.
92. Processing ores of rare metals (molybdenum, tungsten and cobalt salts).
93. Production of products from paper and textiles by pressure rolling with resins, not exceeding 100 tons per year.
94. Production of hydrogenated fats electrolytically.
95. Production of salt (NaCl).
96. Production of potassium salts for pharmaceutical purposes, such as potassium chloride, sulfate, potash.
97. Natural rubber processing.
98. Production of liquid mineral fertilizers.
99. Production of saccharin and vanillin.
100. Production of petroleum gas not exceeding 1000 cubic meters per hour.

Class V requiring a sanitary clearance zone 50 meters wide.

101. Production of alkaloid and galenic preparations.
102. Production of natural mineral dyes (chalk, ocher, red ocher, etc.).
103. Production of inorganic reagents without use of chlorine.
104. Production of paper from waste materials as well as from finished cellulose and rags, not bleached.
105. Production of vulcanized rubber without use of carbon disulfide.
106. Production of carbon dioxide and dry ice.
107. Production of artificial pearls.
108. Mechanical working up of compressed masses (compositions).
109. Production of perfumes and perfumed goods.
110. Production of hydrogen and oxygen in pressure tanks.
111. Production of photochemical materials (films and plates).
112. Production of carbonic acid-containing mineral fertilizers.
113. Production of tannin extracts.
114. Places (localities) where cisterns are cleaned.
115. Production of matches.

Metal Processing and Machine-Construction Industry.

Class I requiring a sanitary clearance zone 1000 meters wide.

116. Production of magnesium by the chlorination process.
117. Secondary processing of non-ferrous metals (in amounts over 3000 tons per year).
118. Production of coke.

- 119. Production of pig iron in blast furnaces having over 1500 cubic meters capacity.
- 120. Production of non-ferrous metals (smelting) directly from ores or concentrates (zinc, lead, tin, nickel).
- 121. Production of aluminum by electrolysis of fused aluminum salts (oxides).

Class II requiring a sanitary clearance zone 500 meters wide.

- 122. Production of agglomerated iron or processing non-ferrous metal ores.
- 123. Production of magnesium (except by chlorination process, compare 116).
- 124. Production of non-ferrous metals in quantities 1000 - 3000 tons per year.
- 125. Production of non-ferrous metals (secondary processing) in quantities up to 3000 tons per year.
- 126. Production of pig iron in blast furnaces of over 500 to 1500 cubic meters capacity.
- 127. Production of steel by Martin and converter process in quantities over 1,000,000 tons per year.
- 128. Production of ground Thomas slag.
- 129. Production of pig iron in quantities over 20,000 tons per year.
- 130. Production of antimony by the pyrometallic process.
- 131. Production of zinc, copper, nickel and cobalt by electrolysis of water solutions.
- 132. Production of iron alloys.

Class III requiring a sanitary clearance zone 300 meters wide.

- 133. Production of supply depots for airplanes whose motors are equipped with mufflers which produce in the protective zone no more than 70 tons.
- 134. Metal enrichment without using high temperatures.
- 135. Production of storage batteries (larger works) on a large scale.
- 136. Production of non-ferrous metals (secondary processing) in quantities up to 1000 tons per year.
- 137. Production of pig iron in blast furnaces of less than 500 cubic meters capacity.
- 138. Production of steel by Martin and converter process in quantities under 1,000,000 tons per year.
- 139. Production of pig iron in foundries for quantities of 5,000 to 20,000 tons per year.
- 140. Production of non-ferrous metals in quantities of 100 to 2000 tons per year.
- 141. Production of lead-coated or rubber-insulated cables.

Class IV requiring a sanitary clearance zone 100 meters wide.

- 142. Production of non-insulated cables.
- 143. Production of boilers.
- 144. Production of engines and equipment for electric industries (dynamos, transformers, etc.) having small foundries and other heat emanating installations.
- 145. Production of processed pig iron and steel up to 10,000 tons per year and of ferrcus casting up to 100 tons per year.
- 146. Production of mercury-containing apparatus (mercury rectifiers, thermometers, lamps, etc.).
- 147. Production of electro-steel.
- 148. Production of antimony by electrolysis.

Class V requiring a sanitary clearance zone 50 meters wide.

- 149. Thermal working up of metals except foundries.
- 150. Production of storage batteries on a small scale.
- 151. Production of implements for electrotechnical industry, as electro-lamps, searchlights (spotlights), etc.
- 152. Production of hard alloys and difficult fusible metals.

Production of Ores and Minerals.

Class I requiring a sanitary clearance zone 1000 meters wide.

- 153. Production of petroleum (crude oil) containing more than 0.5% by weight of sulfur or with high content of volatile hydrocarbons.

Class II requiring a sanitary clearance zone 500 meters wide.

- 154. Production of bituminous shale.
- 155. Production of coal, anthracite and brown coal (lignite).
- 156. Production of iron ores, and quarrying stones by blasting.
- 157. Production of phosphorite, apatites and quartz without chemical processing.
- 158. Production of lead, arsenic and manganese ores.

Class III requiring a sanitary clearance zone 300 meters wide.

- 159. Production of petroleum (crude oil) containing less than 0.5% of sulfur and with low content of volatile hydrocarbons.
- 160. Production of dolomite, magnesite, asbestos, gondron (soft asphalt) and asphalt.

- 161. Production of metal and metalloid (non metallic) ores in the open, except lead, arsenic and manganese ores.
- 162. Production of briquettes from coal and peat.

Class IV requiring a sanitary clearance zone 100 meters wide.

- 163. Production of metal and metalloid (non metallic) ores underground, except lead, arsenic and manganese ores.
- 164. Production of peat by the milling process.
- 165. Production of rock salt.

Building (Construction) Industry.

Class I requiring a sanitary clearance zone 1000 meters wide.

- 166. Production of Portland and Pozzuolana blast furnace cement over 150,000 tons per year.

Class II requiring a sanitary clearance zone 500 meters wide.

- 167. Production of Portland and Pozzuolana cement up to 150,000 tons per year (blast furnace).
- 168. Production of lime, magnesite and dolomite by burning in shaft furnaces.

Class III requiring a sanitary clearance zone 300 meters wide.

- 169. Production of local cements (roman, gypsum, slag cement, etc.) in quantities up to 5000 tons per year.
- 170. Production of alabaster and asphalt concrete.
- 171. Production of glass wool.
- 172. Production of tar board and rubberoids.

Class IV requiring a sanitary clearance zone 100 meters wide.

- 173. Production of asbestos cement and slate.
- 174. Production of artificial stones and concrete products.
- 175. Stone foundries.
- 176. Production of bricks (red and silicate).
- 177. Production of hard tile, ceramic and other firewood products.
- 178. Production of glass.
- 179. Production of building materials (from electric heat and power station end products).
- 180. Production of cement elevators and other equipment used in handling dust producing materials.
- 181. Production of porcelain and fine pottery products.

Class V requiring a sanitary clearance zone 50 meters wide.

- 182. Production of rocks without blasting and of products resulting from processing of natural stones.
- 183. Production of gypsum products.
- 184. Production of hard fiber plates (kamyshite, solomite, differentas, fibrolite, etc.).
- 185. Production of clay products.

Wood Processing Industry.

Class II requiring a sanitary clearance zone 500 meters wide.

- 186. Production of wood charcoal (retort process excepted).

Class III requiring a sanitary clearance zone 300 meters wide.

- 187. Wood preservation by impregnation.

Class IV requiring a sanitary clearance zone 100 meters wide.

- 188. Production of wood wool (fibers).
- 189. Production of wood charcoal by retort process.
- 190. Sawmills, production of building framework, moulding and standardized house parts.
- 191. Production of ships (large wooden ships).
- 192. Production of cartwrights.

Class V requiring a sanitary clearance zone 50 meters wide.

- 193. Production of products from wood wool (fibers).
- 194. Production of products from bast fibers.
- 195. Production of wooden rafts, furniture, inlaid floors (parquetry), wooden boxes, etc.
- 196. Production of cooper's tools from stave wood.
- 197. Preserving wood by impregnation or coating with solutions (arsenic solutions excluded).
- 198. Ship building (smaller wooden ships).

Textile Industry.

Class II requiring a sanitary clearance zone 500 meters wide.

- 199. Production of textile fabrics, impregnating with chemicals or carbon disulfide.

Class III requiring a sanitary clearance zone 300 meters wide.

- 200. Plants performing continuous impregnation of textiles, paper with lacquers made of asphalt rosins, bakelite or other rosins for use in the electro-industry, with a yearly production over 300 tons.
- 201. Establishments undertaking preliminary processing of natural fibers (linen, cotton, hemp, etc.).
- 202. Plants performing continuous impregnation of textiles or paper with lacquers made of rosins, asphalt rosins, bakelite and other rosins up to 300 tons per year.
- 203. Plants impregnating and processing textile fabrics by chemical means, except carbon disulfide, e.g., by dermatite, granitol, etc.

Class IV requiring a sanitary clearance zone 100 meters wide.

- 204. Production of coto bark articles.
- 205. Boiling and unwinding silk cocoons.
- 206. Production of silk and cord lace.
- 207. Production of mixed textile fabrics.
- 208. Bleaching, dyeing and finishing establishments.
- 209. Production of cotton, linen and wool, yarn spinning, bleaching and dyeing.

Class V requiring a sanitary clearance zone 50 meters wide.

- 210. Production of cotton, linen and wool yarn (spinning) (no bleaching or dyeing).
- 211. Production of jersey wearing apparel and stockings.
- 212. Production of carpets and artificial fur goods.

Plants Processing Animal Products.

Class I requiring a sanitary clearance zone 1000 meters wide.

- 213. Production of glue, stock processing including hides, wastes, ground bones, etc.
- 214. Production of technical grade gelatin from bones, glue, hides, leather scraps, etc., stored out of doors.
- 215. Plants utilizing animal carcasses, fish, etc. for the production of fat, animal fodder, fertilizer, etc.

Class II requiring a sanitary clearance zone 500 meters wide.

- 216. Plants for charring and grinding of bones.

Class III requiring a sanitary clearance zone 300 meters wide.

- 217. Plants processing and dyeing raw animal skins and pelts, sheepskins, furs, preparation of raw and morocco leather, etc.
- 218. Production of raw hides (tanneries, manufacture of sole leather, calf leather, etc.).
- 219. Wool-washing plants.
- 220. Production of technical grade fats in quantities over 30 tons per year.
- 221. Plants for storage of wet preserved raw hides (over 200 items).

Class IV requiring a sanitary clearance zone 100 meters wide.

- 222. Plants which prepare animal fodder from food wastes.
- 223. Felting plants.
- 224. Production of quality grade gelatin from fresh bones, stored only for a short time in refrigerators.
- 225. Production of artificial leather.
- 226. Production of technical grade fats in quantities up to 30 tons per year.
- 227. Production of skeletons and instruction material from animal carcasses.
- 228. Plants processing hair, bristles, feathers, hoofs, etc.

Class V requiring a sanitary clearance zone 50 meters wide.

- 229. Production of shoes.
- 230. Production of patent leather.
- 231. Production of objects from bones.
- 232. Production of brushes from hair and bristles.
- 233. Felting workshops.
- 234. Plants for storage of wet preserved raw hides (under 200 items).
- 235. Production of gut-strings (cat gut).

Plants Producing Foods and Flavoring Materials.

Class II requiring a sanitary clearance zone 500 meters wide.

- 236. Cattle stockyards for more than 1000 head.
- 237. Slaughter houses.
- 238. Fat rendering (sea animal fat).
- 239. Intestine cleaning (gut preparation).
- 240. Railroad cattle car yards.

Class III requiring a sanitary clearance zone 300 meters wide.

- 241. Production of beet sugar.
- 242. Stockyards for cattle up to 1000 head.
- 243. Slaughter houses for small cattle and poultry.
- 244. Fish processing.

Class IV requiring a sanitary clearance zone 100 meters wide.

- 245. Production of albumin.
- 246. Production of alcohol.
- 247. Mills, grain peeling (husking) and various food factories.
- 248. Meat combines and meat refrigerators (three-day supply of living cattle).
- 249. Coffee roasting plants.
- 250. Processing vegetable oils.
- 251. Production of margarine.
- 252. Fruits and vegetables processing (drying, salting, fermenting, etc.).
- 253. Production of dextrin, glucose and syrup.
- 254. Production of cheese.
- 255. Production of fish fillets and preserved fish.
- 256. Production of starch and potato flour.
- 257. Tobacco processing (sweating).

Class V requiring a sanitary clearance zone 50 meters wide.

- 258. Breweries.
- 259. Canneries.
- 260. Granaries.
- 261. Sugar refineries.
- 262. Macaroni factories.
- 263. Fish smoking plants.
- 264. Dairies (milk, butter and other dairy products).
- 265. Sausage factories producing more than 3 tons a shift.
- 266. Confectionary goods, large plants.
- 267. Bakeries.
- 268. Food and provision production.
- 269. Vinegar distilleries.
- 270. Refrigeration plants over 600 tons.

Sanitary-Technical Equipment and Installations for Community Use.

Class I requiring a sanitary clearance zone 1000 meters wide.

- 271. Unassorted garbage dumps for liquid and solid household waste.
- 272. Areas fertilized with night-soil.
- 273. Ground sewage filters.

Class II requiring a sanitary clearance zone 500 meters wide.

- 274. Public rubbish dumping and burning places.
- 275. Sewage filtration stations (up to 5000 cubic meters per hour).
- 276. Supervised assorted rubbish and garbage dumps.
- 277. Animal burial places.

Class III requiring a sanitary clearance zone 300 meters wide.

- 278. Compost fields.
- 279. Garbage sterilization and processing (rendered safe).
- 280. Sewage irrigated fields for agricultural use.
- 281. Septic tanks, air filter, sedimentation tanks, etc.
- 282. Temporary garbage and trash unloading centers.
- 283. Purification plants.
- 284. Cemeteries.
- 285. Main depots for commercial raw materials.
- 286. Thermal hatching installations.

Class IV requiring a sanitary clearance zone 100 meters wide.

- 287. Places for temporary storage of commercial raw materials not to be processed.

Table to go with Supplement 1.

Sanitary Protection Zones in Meters for Regional and Factory Electric Heat, Light and Power Stations and for Boiler Operated Industrial Plants Having a Fuel Consumption of Three Tons or More per Hour.

Fuel ash content percent on the as fired basis	Boiler operated industrial plants having 50% ash abaters		Electric heat, light and power stations											
			At 75% ash abatement						At 90% ash abatement					
			Rate of coal consumption in tons per hour											
			Over 3 - 12.5 up to 25	Over 12.5 up to 25	Over 25 up to 50	Over 50 up to 100	Over 100 up to 200	Over 200 up to 300	Over 3 - 12.5 up to 25	Over 12.5 up to 25	Over 25 up to 50	Over 50 up to 100	Over 100 up to 200	Over 200 up to 300
	Up to 10	Over 10 up to 15	Over 15 up to 20	Over 20 up to 25	Over 25 up to 30	Over 30 up to 45	Up to 10	Over 10 up to 15	Over 15 up to 20	Over 20 up to 25	Over 25 up to 30	Over 30 up to 45		
Up to 10	100	300	100	100	300	500	500	500	100	100	100	300	500	500
Over 10 up to 15	100	300	100	300	500	500	500	1,000	100	100	300	300	500	500
Over 15 up to 20	100	500	100	300	500	500	1,000	1,000	100	100	300	300	500	1,000
Over 20 up to 25	300	500	100	300	500	1,000	1,000	VGSI	100	100	300	300	500	1,000
Over 25 up to 30	300	500	100	300	500	1,000	1,000	VGSI	100	300	300	500	1,000	1,000
Over 30 up to 45	500	1,000	300	500	1,000	1,000	VGSI	VGSI	100	300	300	500	1,000	1,000

Note 1. VGSI (All-Union State Sanitary Inspectorate).

Note 2. Electric heat, light and power stations must make provision for reliable and uninterrupted removal of the ash from the ash catchers and of the boiler slag.

Height of smokestacks.

Average daily fuel consumption in tons per hour	Smokestack height in meters	Supplemental instructions
Up to 5	30	a) For fuel of low ash content (reduced ash content less than 5% per 1000 large cal/kg) the smokestack height should be as follows: at fuel consumption from 5 to 100 tons per hour the smokestack height should be 60 meters; at fuel consumption of 100 to 200 tons per hour the smokestack height should be 80 meters.
From 5 up to 15	45	
From 15 up to 50	60	If located within a radius of 200 meters from nearby boiler operated plant building rising to a height of 15 meters the minimal height of the smokestack must be 45 meters.
From 50 up to 100	80	
From 100 up to 200	100	
Over 200	120	

Notes: Electric heat, power and light stations burning fuel of high sulfur content (such as lower Moscow coal) at the rate of 100 or more tons per hour and which are located in an area of populated sections must have installations for the purification of flue gases from oxides of sulfur which in each case must be agreed upon and approved by the All-Union State Sanitary Inspectorate. Sanitary clearance zones for electric heat, power and light stations must accord with paragraph 9 of the present standards ("Norms").

The instructions listed in this table do not apply to boiler operated plants which use wood and gas for fuel; widths of sanitary clearance zones for such plants are determined by the type and nature of the industrial manufacturing or processing procedures.

(Supplement 2 deals with sanitary regulations pertaining to industrial sewage disposal and will be presented in full in one of the forthcoming volumes).

SUPPLEMENT 3.

Limits of Allowable Concentrations of Poisonous Gases, Vapors and Dust in the Air of Working Zones in Industrial Premises.

Substance	mg/li
Acrolein.....	0.002
Ammonia.....	0.02
Acetone.....	0.2
Aniline, toluidine, xylidine.....	0.005
Benzidine, dianizilene, α - and β -naphthalamine.....	0.001
Gasoline, white spirits, ligroine, kerosene, crude oil in terms of C.....	0.3
Benzene.....	0.1
Decaline, tetraline.....	0.1
Divinyl, pseudobutylene.....	0.1
Di- and trinitro compounds of benzene and its homologues (dinitrobenzene, trinitrotoluol, etc.....)	0.001
Xylol.....	0.1
Manganese and its compounds, on the basis of MnO_2	0.0003
Hydrogen arsenide.....	0.0003
Arsenical and arsenious anhydrides.....	0.0003
Unsaturated alcohol of fatty acids (allylic, crotylic, etc.).....	0.002
Nitro- and dinitrochloro compounds of benzene (nitrochlorobenzene, dinitrochlorobenzene, etc.).....	0.001
Nitro- compounds of benzene and their homologues, nitrobenzene, nitrotoluol, etc.....	0.005
Oxides of nitrogen, in terms of N_2O_3	0.005
Zinc oxide.....	0.005
Carbon monoxide ^{1/}	0.03
Metallic mercury.....	0.00001
Lead and its inorganic compounds, lead sulfide excluded.....	0.00001
Lead sulfate.....	0.0005
Selenium anhydride.....	0.0003
Sulfuric acid and sulfuric anhydride.....	0.002
Sulfurous anhydride (SO_2).....	0.02
Hydrogen sulfide.....	0.01
Carbon bisulfide.....	0.01

^{1/} Where work time in an atmosphere containing this pollutant does not extend beyond one hour the limit of allowable concentration of carbon monoxide may be raised to 0.05 mg/li; where such work time does not exceed one-half hour, the carbon monoxide concentration in the air may be 0.1 mg/li; where work under such conditions does not extend beyond 15 - 20 minutes the CO concentration of the air may be raised to 0.2 mg/li. Rest periods of not less than 2 hours must be enforced where workers must be repeatedly subjected to high CO air concentrations.

Substance	mg/li
Turpentine.....	0.3
Solvent naphtha.....	0.1
Alcohols:	
Amyl.....	0.1
Butyl.....	0.2
Methyl.....	0.05
Propyl.....	0.2
Ethyl.....	1.0
Bichloride of mercury.....	0.0001
Tobacco and tea dust.....	0.003
Toluol.....	0.1
Phenol.....	0.005
Formaldehyde.....	0.005
Phosphoric anhydride.....	0.001
Phosphorus, yellow.....	0.00003
Hydrogen phosphide.....	0.0003
Hydrogen fluoride.....	0.001
Salts of hydrophosphoric acid.....	0.001
Chlorobenzene.....	0.05
Chlorinated hydrocarbons:	
Dichlorethane.....	0.05
Trichlorethylene.....	0.05
Carbon tetrachloride.....	0.05
Hydrogen chloride and hydrochloric acid.....	0.01
Chromic anhydride, chromates and bichromates.....	0.0001
Chloronapthalene and chlorophenyl.....	0.001
Chlorine.....	0.001
Hydrogen cyanide and salts of hydrocyanic acid, on the basis of HCN.....	0.0003
Ethyl (diethyl) ether.....	0.3
Acetic acid esters (acetates):	
Methyl acetate.....	0.1
Ethyl acetate.....	0.2
Propyl acetate.....	0.2
Butyl acetate.....	0.2
Amyl acetate.....	0.1

Note 1. The standards (norms) for limits of allowable concentrations of deleterious vapors, gases and dust are obligatory (compulsory) only for actual working locations. By the term actual working locations is meant points of uninterrupted or intermittent presence of workers who perform functions of observation or of actual production processes. Where industrial production processes occur at different points of the work premises all such points fall under the above designation of actual working locations, which includes the entirety of the work premises.

Note 2. Where work under conditions of polluted air in the work premises is of short duration, and in isolated instances, where the norm of the pollutant concentrations indicated in the table can not be attained, the responsible authority (Minister) of the appropriate Ministry, having previously secured the consent of the All-Union State Sanitary Inspectorate, may allow certain deviations from the required concentration norms.

Note 3. Where vapors of several solvents, such as benzene and its homologues, alcohols, esters of acetic acid, etc. are emitted into the air simultaneously, especially in the case of sulfuric and sulfurous anhydrides (SO_3 and SO_2), hydrochlorides, hydrogen fluoride, etc., which cause eye irritation, or oxides of nitrogen and CO, the total ventilation turnover must be calculated on the basis of the volume summation required for the dilution of each of the solvent vapors, each of the irritating gases and of the CO individually to the required standard concentration in the air. This regulation applies to instances of simultaneous presence in the air of several gases or vapors other than those above enumerated, in order that maximum permissible air ventilation may be secured.

Note 4. In the case of poisonous substances not specifically mentioned in Supplement 3, and in instances of combined effect of such poisonous pollutants, limits of allowable concentrations of such substances in the air must be prescribed by the All-Union State Sanitary Inspectorate.

SUPPLEMENT 4.

Limits of Allowable Concentration of Non-Toxic Dust in the Air of Actual Working Locations of Industrial Production Premises.

1. Limits of allowable concentrations of non-toxic dust in the air of work zones of industrial manufacturing premises must not exceed:

a) 2 mg/m^3 for dusts which contain quartz in excess of 50% (quartz dust, quartzite, etc.);

b) Up to 10 mg/m^3 of all other types of dust.

2. Limits of allowable concentrations of dust in different branches of an industry, and depending upon the nature of the dust and the characteristics of the production processes, which fall within the ramifications of paragraph 1 of Supplement 4 are to be defined and prescribed by the pertinent ministries with the approval and consent of the All-Union State Sanitary Inspectorate.

3. In special cases, where the prescribed norms for allowable air pollutant concentrations can not be attained, even as defined in above paragraphs 1 and 2, the pertinent Ministry with the approval and consent of the All-Union State Sanitary Inspectorate may permit certain deviations from the standards (norms) indicated in paragraph 1 of Supplement 4.

SANITARY-HYGIENIC LABOR PROTECTION REGULATIONS.

Item 27. Periodic Medical Examination of Workers.

A. From the order of U.S.S.R. Ministry of Health Protection No. 443, dated 17th June, 1949.

I. Establish compulsory preliminary periodic medical examinations of workers of the following industries in agreement and coordination with VTsSPS:

No.	Name of production and occupation	Time of periodic examination of workers
1	Mining, lead carbonate ores	Once semiannually
2	Mining, other lead ores	Once annually
3	Processing lead ores	Once semiannually
4	Lead ore smelting:	
	a) Lead smelting, agglomeration, refining	Once quarterly
	b) Crushing, grinding, mixing ores, work at purification installations	Once semiannually
5	Smelting, pouring, rolling, pressing of lead-containing alloys	Once semiannually
	Application of lead lining in the mechanical processing of items	Once semiannually
6	Repairing sections of coolers on locomotives which have tank condensators	Once annually
7	Manufacture of dry lead paints (all kinds)	Once quarterly
8	Production of ground lead paints	Once semiannually
9	Production of lead accumulators:	
	a) Oiling and cleaning of lead plates, grinding and paste preparation	Once quarterly
	b) Smelting, lead pouring, shaping and other processes involved in accumulator manufacture	Once annually
10	Manufacture and application of glazing material and of enamel-containing lead	Once semiannually
11	Painters occupation requiring constant use of lead paints	Once semiannually

No.	Name of production and occupation	Time of periodic examination of workers
12	Work with stereotype and in type foundries	Once annually
13	Correction and adjustment in closed pitch	Once semiannually
14	Schoope processing with lead	Once quarterly
15	Lead soldering with hydrogen flame	Once quarterly
16	Production of tetraethyl lead and ethyl fluid	Once annually
17	Mixing ethyl fluid with other fuels	Once quarterly
18	Work with ethylated benzene (all types)	Once semiannually
19	Smelting, purification, filtration, distribution, and other production processes involved in obtaining mercury from ores	Once quarterly
20	Extracting gold from ores with the aid of mercury compounds	Once quarterly
21	Production of mercury thermometers and other physical apparatus: a) Work with mercury outside of hoods b) Work with sealed or open mercury under hoods	Once quarterly Once semiannually
22	Making of pharmaceutical mercury preparations	Once semiannually
23	Production of ethyl mercuric phosphate and mercuric diethyl, preparation of glues containing such substances	Once semiannually
24	Working in electric heat and power stations in connection with mercury rectifiers	Once annually
25	Working with mercury pumps	Once semiannually
26	Working in laboratories with mercury apparatus and other equipment	Once annually
27	Grinding manganese and its compounds and applying the powdered substances	Once semiannually
28	Soldering inside closed tanks with the aid of coated electrodes, containing manganese	Once annually
29	Smelting steel containing over 10% of manganese	Once semiannually
30	Production of chromic acid and its salts	Once semiannually
31	Production and application of compounds of arsenic	Once semiannually
32	Production of yellow and red phosphorus, working with yellow phosphorus	Once quarterly
33	Crushing, grinding, and sifting tungsten and cobalt	Once annually
34	Production of hydrofluoric acid and of fluoride salts (including fluorine-beryllium)	Once semiannually

No.	Name of production and occupation	Time of periodic examination of workers
	Wood impregnation with substances containing fluorine compounds	Once semiannually
35	Electrolytic preparation of aluminum and zinc	Once semiannually
36	Electrolytic preparation of chlorine	Once annually
37	Preparation and use of chloride solutions in sulfate-cellulose plants	Once semiannually
38	Preparation and use of carbon bisulfide	Once semiannually
39	Preparation of viscose silk	Once semiannually
40	Obtaining sulfur-rich crude oil and natural gas, processing sulfur-rich crude oil (includes skilled workers, operators and their assistants, volume recorders, machinists, lubricators, mechanics, etc.)	Once annually
41	Obtaining of ozokerites, baryta and gumbrine	Once semiannually
42	Preparation of aromatic hydrocarbons from crude oil products; selective purification of lubricants, paraffin production, soot, pyrolucites	Once semiannually
43	Refining of crude oil and of gases from hydrogen sulfide, manufacture of inhibitors, hydrogen, catalyzers, production of ozokerites by extraction, benzene alkylation	Once annually
44	Preparation and filtration of sodium arsenite solutions	Once semiannually
45	Cleaning of crude oil carrying tankers, cisterns and reservoirs, cistern valve repair	Once semiannually
46	Catching of coking products from coking furnaces, distillation of coal tar and rectifying of aromatic hydrocarbons, naphthalene, anthracene in coking plants	Once semiannually
47	Production and use of coal tar, pitch, shale tars. Impregnation of railroad ties with compounds containing oil of cresole	Once annually
48	Production and use of chlorinated and brominated hydrocarbons of the fatty series	Once semiannually
49	Production and use of chlorinated naphthalenes and diphenols	Once semiannually
50	Production and processing of synthetic rubber	Once semiannually
51	Production of benzene, toluol and chlorobenzene. Use of benzene as a solvent. Use of chlorobenzene.	Once semiannually

No.	Name of production and occupation	Time of periodic examination of workers
52	Use of toluol and xylol as solvents	Once annually
53	Preparation and use of amino-, nitro- and chloro-derivatives of benzene and its homologues, phenol and its compounds	Once semiannually
54	Production of benzidine, dianizidine, toluidine, α - and β -naphthalamine	Once quarterly
55	Aniline dyes in textile plants	Once annually
56	Fur dyeing with ursol dyes	Once annually
57	Production and use of methyl spirit (methylo)	Once annually
58	Production of nicotine	Once annually
59	Ore mining:	
	a) Drillers, miners, timberers, coal and rock loaders, etc.	Once semiannually
	b) Other underground workers	Once annually
59a	Ore crushing in coal enrichment plants	Once semiannually
60	Workers in mine passages of coal and rock beds containing not less than 10% of quartz	Once semiannually
61	Polishing and coating of porcelain and glazed items	Once annually
62	Production and use of glass wool, felt and wool	Once semiannually
63	Production of refractory (fireproof) articles:	
	a) Dinas articles (refractory silica)	Once semiannually
	b) Chamotte articles (fire clay) containing 10% quartz	Once annually
64	Sandblast polishing of foundry articles	Once semiannually
65	Mining and processing asbestos	Once semiannually
66	Mining of radioactive ores. Production and use of radium and radioactive substances	Once quarterly
67	Workers in X-ray rooms and laboratories	Once semiannually
68	Workers using currents of ultra high frequency	Once semiannually

Supplemented January 18, 1952 by the following:

1	Production and use of trinitrotoluol	Once semiannually
2	Production and use of tetryl	Once annually
3	Production of fulmonate of mercury	Once semiannually
4	Production and use of tetranitromethane	Once semiannually
5	Production and use of azide of lead	Once semiannually
6	Production of nitroglycerol products	Once annually

S U P P L E M E N T 2.

Lists of Contraindications which Prevent the Employment of Workers in Industries in which Workers Undergo Periodic Medical Examinations.
(Only Specific Contradindications Are Included in the Lists).

(In addition attention must be paid to other general contraindications to the employment of workers undergoing periodic medical examinations).

List 1. Lead and its organic compounds.

1. All blood diseases and secondary anemias (Hb less than 60%).
2. Clinically detectable liver diseases.
3. Nephrites, nephroses, and nephroscleromas.
4. Hypertonic diseases.
5. Endarteritis.
6. Clinically detectable cardiosclerosis, aortosclerosis, and arteriosclerosis.
7. Coronary diseases.
8. Ulcers of the stomach and the duodenum.
9. Clinically detectable chronic colitis and enterocolitis.
10. Active forms of pulmonary tuberculosis.
11. All organic diseases of the central nervous system.
12. Chronic and relapsing diseases of the peripheral nervous system.
13. Diseases of the optic nerve and the retina.
14. Epilepsy.
15. Psychic diseases.
16. Clinically detectable endocrine and vegetative diseases.

List 2. Ethylated gasoline.

1. All organic diseases of the central nervous system.
2. Epilepsy.
3. Clinically detectable neurotic states.
4. Psychic diseases including those of recurrent stages.
5. All psychopathic diseases.
6. Clinically detectable endocrine and vegetative diseases.
7. Clinically detectable affections of the labyrinth.
8. Anosmia.
9. Clinically detectable liver diseases.
10. Nephrites, nephroses, and nephroscleromas.

11. Arterial hypotonicity.

12. Eczema of the hands.

For motorists working in motor testing add:

13. Persistent loss of hearing even in one ear (whisper at less than 3 m), otosclerosis, chronic purulent otitis.

List 3. Tetraethyl lead and ethylic fluid.

1. Organic diseases of the central nervous system.
2. Epilepsy.
3. Clinically detectable neurotic states.
4. Psychic diseases including those of recurrent stages.
5. All psychopathic diseases.
6. Narcomania, including chronic alcoholism.
7. Endocrine and vegetative diseases.
8. Clinically detectable affections of the labyrinth.
9. Clinically detectable liver diseases.
10. Nephrites, nephroses, and nephroscleromas.
11. Arterial hyper- and hypotonia.
12. All diseases of respiratory organs and of the cardiovascular system which contraindicate the use of gas masks.
13. Hyposmia.
14. All forms of eczema regardless of localization.

List 4. Mercury and its compounds.

1. Chronic or frequently recurring gingivitis, stomatitis and alveolar pyorrhea.
2. Chronic colitis.
3. Clinically detectable liver diseases.
4. Nephrites, nephroses, and nephroscleroses.
5. Organic diseases of the central nervous system.
6. Clinically detectable neurotic states.
7. Psychic diseases including those of recurring stages.
8. Psychopathic diseases.
9. Clinically detectable endocrine and vegetative diseases.

List 5. Manganese.

1. Organic diseases of the central nervous system.
2. Psychic diseases.

3. Psychopathic diseases.
4. Clinically detectable endocrine and vegetative diseases.
5. Clinically detectable liver diseases.
6. Nephrites, nephroses, and nephroscleroses.
7. Active forms of pulmonary tuberculosis.
8. Bronchitis, emphysema, pneumosclerosis, bronchial asthma, and recurrent pneumonia.

List 6. Chromic acid and its salts.

1. Atrophic rhinitis, ozena, nasal sychosis; diseases of the nasal accessory frequently becoming acute; clinically detectable nasal septum deviation.
2. Chronic laryngitis, frequently becoming acute, laryngeal stenosis.
3. Tuberculosis, scleroma and swelling in the upper respiratory tract.
4. Clinically detectable bronchitis, pulmonary emphysema and pneumosclerosis.
5. Bronchial asthma.
6. Presence of any form of eczema during examination or in anamnesis.

List 7. Inorganic arsenic compounds.

1. Atrophic rhinitis, ozena, nasal sychosis. Diseases of the nasal accessory sinuses frequently becoming acute. Clinically detectable nasal septum deviation.
2. Chronic laryngitis, frequently becoming acute.
3. Tuberculosis, scleroma and swelling in the upper respiratory tract.
4. Organic diseases of the central nervous system.
5. Clinically detectable chronic bronchitis. Bronchial asthma.
6. Chronic enterocolitis and colitis.
7. Clinically detectable liver disease.
8. Nephrites, nephroses, and nephroscleroses.
9. All blood diseases. Secondary anemia (Hb less than 60%).
10. Chronic and recurring diseases of the peripheral nervous system.
11. Eczema of the face and hands.
12. Chronic inflammatory conjunctivitis, inflammation of the cornea, of the salivary ducts and of the palpihra.

List 8. Vapors of yellow phosphorus.

1. Diseases of the jaw, dental caries, periostitis and periodontitis, not cured.
2. Chronic gingivitis. Alveolar pyorrhea.

3. Diseases of the bones, incompletely healed fractures, osteomyelitis.
4. Clinically detectable catarrhs of the upper respiratory tracts.
5. Chronic bronchitis, clinically detectable pulmonary emphysema, pneumo-sclerosis, bronchial asthma.
6. Liver diseases.
7. Nephrites, nephroses, and nephroscleroses.
8. All blood diseases, secondary anemia (Hb below 60%).
9. General emaciation.
10. Clinically detectable metabolic diseases (obesity, diabetes).

List 9. Cobalt.

1. Atrophic rhinitis, ozena, nasal sychosis. Diseases of the nasal accessory sinuses frequently becoming acute. Clinically detectable nasal septum deviation.
2. Tuberculosis, scleroma and edemas of the upper respiratory tracts.
3. Chronic bronchitis, pneumosclerosis, pulmonary emphysema, bronchial asthma.
4. Active forms of pulmonary tuberculosis.
5. Chronic inflammatory conjunctivitis, inflammation of the cornea, of the salivary ducts and of the palpibra.

List 10. Fluorine and its compounds.

1. Atrophic rhinitis, ozena, nasal sychosis. Diseases of the nasal accessory sinuses frequently becoming acute. Clinically detectable nasal septum deviation.
2. Chronic laryngitis frequently becoming acute, laryngeal stenosis of the esophagus.
3. Tuberculosis, scleroses and edemas of the upper respiratory tracts.
4. Chronic bronchitis, clinically detectable pneumosclerosis, pulmonary emphysema and bronchial asthma.
5. Active forms of pulmonary tuberculosis.
6. Bone diseases.
7. Chronic inflammatory conjunctivitis, inflammation of the cornea, of the salivary ducts and of the palpibra.

List 11. Sulfuric anhydride (sulfuric acid aerosol).

1. Atrophic rhinitis, ozena, nasal sychosis. Diseases of the nasal accessory sinuses, frequently becoming acute. Clinically detectable nasal septum deviation. Clinically detectable hyposmia.
2. Chronic laryngitis, frequently becoming acute.

3. Tuberculosis, scleromas and edemas of the upper respiratory tracts.
4. Chronic bronchitis, clinically detectable emphysema and pneumosclerosis. Bronchial asthma.
5. Active form of pulmonary tuberculosis.
6. Chronic inflammation of the conjunctiva, the cornea, the salivary ducts and the palpebra.
7. Eczema of the face and hands.

List 12. Chlorine, bromine.

1. Atrophic rhinitis, ozena, nasal sychosis. Diseases of the nasal accessory sinuses frequently becoming acute. Clinically detectable nasal septum deviation.
2. Chronic laryngitis, frequently becoming acute. Manifestations of esophageal sclerosis.
3. Tuberculosis, scleroma and edemas of the upper respiratory tracts.
4. Clinically detectable hyposmia.
5. Chronic bronchitis, pneumosclerosis, pulmonary emphysema, bronchial asthma.
6. All diseases of the respiratory organs and of the cardiovascular system which contraindicate the use of gas masks.
7. Active forms of pulmonary tuberculosis.
8. Chronic inflammation of the conjunctiva, cornea, salivary ducts and the palpebra.

List 13. Carbon bisulfide.

1. Organic diseases of the central nervous system.
2. Chronic and recurring diseases of the peripheral nervous system.
3. Diseases of the optic nerve and of the retina.
4. Epilepsy.
5. Clinically detectable neurotic states.
6. Psychic diseases including those of recurrent stages.
7. Psychopathic diseases.
8. Clinically detectable endocrine and vegetative diseases.
9. Clinically detectable liver diseases.

List 14. Hydrogen sulfide.

1. Organic diseases of the central nervous system.
2. Epilepsy.
3. Clinically detectable states of neuroses.

4. Psychic diseases.
5. Clinically detectable endocrine and vegetative diseases.
6. Atrophic rhinitis, ozena; diseases of the nasal accessory sinuses, frequently becoming acute.
7. Chronic laryngitis, frequently becoming acute. Manifestations of esophageal sclerosis.
8. Tuberculosis, scleromas and edemas of the upper respiratory tracts.
9. Chronic bronchitis, bronchial asthma.
10. All diseases of the organs of the respiratory tract and of the cardiovascular system contraindicating the use of gas masks.
11. Chronic inflammation of the conjunctiva, cornea, salivary ducts and palpihra.

List 15. Crude oil, gasoline, white spirit, kerosene, mazut (crude oil residue), lubricating materials.

1. Atrophic rhinitis, ozena, nasal sychosis. Diseases of the nasal accessory sinuses frequently becoming acute. Clinically detectable nasal septum deviation.
2. Chronic laryngitis frequently becoming acute. Manifestations of esophageal sclerosis.
3. Tuberculosis, scleroma and edemas of the upper respiratory tracts.
4. Clinically detectable hyposmia.
5. All diseases of respiratory organs and cardiovascular systems contraindicating the use of gas masks.
6. Chronic bronchitis, bronchial asthma.
7. Organic diseases of the central nervous system.
8. Epilepsy.
9. Clinically detectable neurotic states.
10. Psychic diseases.
11. Clinically detectable endocrine and vegetative diseases.
12. Chronic inflammation of the conjunctiva, cornea, salivary ducts and the palpihra.

For those who are engaged in cleaning crude oil cracking stills add:

13. Seborrhea complicated by different forms of acne.

List 16. Methylic alcohol.

1. Organic diseases of the central nervous system.
2. Clinically detectable endocrine and vegetative diseases.
3. Chronic alcoholism.

4. Diseases of the optic nerve and the retina.
5. Clinically detectable liver diseases.
6. Nephrites, nephroses, and nephroscleroses.

List 17. Chlorinated and brominated hydrocarbons.

1. Organic diseases of the central nervous system.
2. Epilepsy.
3. Clinically detectable states of neuroses.
4. Psychic diseases.
5. Clinically detectable endocrine and vegetative diseases.
6. Clinically detectable liver diseases.
7. Nephrites and nephroscleroses.
8. Organic myocardites.
9. Atrophic rhinitis, ozena, nasal sychosis. Diseases of the nasal accessory sinuses frequently becoming acute. Clinically detectable nasal septum deviation.
10. Chronic laryngitis frequently becoming acute. Manifestations of esophageal stenosis.
11. Tuberculosis, scleroma, and edemas of the upper respiratory tracts.
12. Clinically detectable hyposmia.
13. Clinically detectable bronchitis and bronchial asthma.
14. Chronic inflammation of the conjunctiva, cornea, salivary ducts and the palpihra.
15. Acute clinical seborrhea complicated with acne.

List 18. Products of coal distillation:
benzene, toluol, phenol, pyridine, etc.

1. Atrophic rhinitis, ozena, nasal sychosis. Diseases of the nasal accessory sinuses frequently becoming acute. Clinically detectable nasal septum deviation.
2. Chronic laryngitis frequently becoming acute. Manifestations of esophageal stenosis.
3. Tuberculosis, scleroma and edemas of the upper respiratory tracts.
4. Clinically detectable hyposmia.
5. Chronic bronchitis and bronchial asthma.
6. All diseases of respiratory organs and cardiovascular system contraindicating the use of gas masks.
7. All blood diseases and secondary anemia (Hb below 60%).
8. All forms of hemorrhagic diathesis.

9. Clinically detectable liver diseases.
10. Nephrites, nephroses, and nephroscleroses.
11. Organic diseases of the central nervous system.
12. Epilepsy.
13. Clinically detectable states of neuroses.
14. Psychic diseases.
15. Clinically detectable endocrine and vegetative diseases.
16. Chronic conjunctivitis, and chronic inflammation of the cornea, salivary ducts and the palpihra.

For those who work with anthracite, naphthalene and other substances which possess photodynamic activity add:

17. Diseases of the skin, accompanied by increased sensitivity to light, such, for example, as solar eczema and solar scabies, etc.

List 19. Benzene, toluol, xylol.

1. Organic diseases of the central nervous system.
2. Epilepsy.
3. Clinically detectable states of neuroses.
4. Psychic diseases.
5. All blood diseases and secondary anemia (Hb below 60%).
6. All forms of hemorrhagic diathesis.
7. Clinically detectable liver diseases.
8. Nephrites, nephroses, and nephroscleroses.

List 20. Amino- and nitro-compounds of benzene and phenol.

1. All blood diseases and secondary anemia (Hb below 60%).
 2. Clinically detectable liver diseases.
 3. Organic diseases of the central nervous system.
 4. Epilepsy.
 5. Psychic diseases.
 6. Clinically detectable endocrine and vegetative diseases.
- (a) For those who work with amino-compounds and in particular with benzene, ansidine, naphthylamine and captax which cause diseases of the urinary passages, and for those (b) who work with chlorobenzene add List No. 16.

List 21. Nicotine.

1. Clinically expressed endocrine and vegetative diseases.
2. All diseases of the cardiovascular system.

3. Gastric and duodenal ulcers.
4. Clinically expressed gastritis, and spastic colitis.
5. Temporary amaurosis causing limited field of vision.

List 22. Ursol.

1. Clinically visible catarrh of the upper respiratory tract.
2. Chronic bronchitis, bronchial asthma, pulmonary emphysema frequently becoming acute.
3. Presence of any form of eczema and allergic dermatitis, inclusive of those in anamnesis.

List 23. Pitch and schist (shale).

1. Photosensitive skin diseases (solar eczema, solar scabies, etc.).
2. Chronic conjunctivitis, and chronic inflammation of the cornea, salivary ducts and the palpihra.

List 24. Roentgen rays.

1. All blood diseases and secondary anemia (Hb below 60%).
2. Sex gland diseases and disturbances of menstrual-ovarian cycles.
3. Skin cancer at any site and precancerous diseases.
4. Clinically detectable endocrine and vegetative disturbances.

List 25. Radioactive substances.

1. All blood diseases and secondary anemia (Hb below 60%).
2. All organic diseases of the central nervous system.
3. Clinically detectable endocrine and vegetative diseases.
4. Bone diseases.
5. Skin cancer at any site and precancerous diseases.

List 26. Ultra high frequency currents.

1. All blood diseases and secondary anemia (Hb below 60%).
2. Active pulmonary tuberculosis.
3. Organic diseases of the nervous system, progressive (disseminated sclerosis, syringomyelitis, cerebro-spinal syphilis, tuberculosis of the spine, etc.).
4. Clinically detectable endocrine and vegetative diseases (Basedow's disease, Addison's disease, etc.).
5. Clinically detectable angiotrophoneurosis, etc. (Reno's disease, trophic ulcer, scleroderma, etc.).

List 27. Free silicon dioxide, asbestos.

1. Any form of pulmonary tuberculosis (presence of petrification is not to be regarded as a positive indicator).
2. Extrapulmonary tuberculosis (glands, sex glands, bones, etc.).
3. Diseases of the upper respiratory tracts and bronchitis. Clinically detectable nasal septum deviation, labored nasal breathing, atrophic rhinitis, frequently occurring chronic laryngitis, chronic inflammation of the accessory nasal sinuses, neoplasms in the upper respiratory tracts, cicatricial adhesions of the upper respiratory tracts, labored breathing (general), chronic bronchitis, bronchial asthma, bronchiectasis.
4. Non-tubercular pulmonary diseases (pneumosclerosis, pulmonary emphysema).
5. Diseases of the diaphragm.
6. Organic diseases of the cardiovascular system (heart failure, organic myocarditis, clinically detectable arteriosclerosis, hypertonic diseases).

Note: Detection of any of the above diseases in the course of periodic medical examinations of the employed should indicate the need for the worker's transfer to another occupation. In doing this each case should be decided upon by taking into consideration time record of employment, general resistance to the effects of conditions of present employment, gravity of affection, degree of compensation, sanitary-hygienic conditions of employment, and other pertinent factors.

The Effect of Industrial Poisons on the Immuno-Biological
State of the Organism.

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It has been known for a long time that some industrial poisons lowered the general resistance of the organism to certain diseases, eliciting effects in addition to their basic property of producing characteristic changes in individual organs or systems. This was noticed in particular in such diseases as the grippe, angina, pneumonia, tuberculosis, observed in some groups of workers connected with such toxic substances as lead and its inorganic compounds, tetraethyl lead, benzene, fluorides, etc.; these diseases occur comparatively frequently and follow a rather grave and at times specific course of development. It should be noted in this connection that similar affections have been encountered recently among certain sections of the country's inhabitants who were exposed to the effects of industrial discharges and atmospheric air pollutants with sulfur dioxide, nitrogen oxides, fluorides, lead and its compounds, etc. The importance of such factors to the conservation of public health should not be underestimated. There is no doubt that under certain conditions situations, such as are described above, may cause a considerable lowering in the body resistance to diseases and thereby increase population morbidity. It should also be noted that results of clinical observations and clinical statistical data coincided with the results of many experimental toxicological studies. Thus, Mattei established in 1896 that following the inhalation of carbon monoxide, carbon dioxide, hydrogen sulfide and other poisons, animals manifested a considerably lowered resistance to infection, and animals normally resistant to certain infections lost their natural immunity. Susceptibility to infections ran parallel to the duration and intensity of the effect of toxic substances. Pigeons normally possessing natural immunity to anthrax were easily infected with this agent after they have been intoxicated with alcohol or oxides of nitrogen.

E. Ronzani reported the results of his experiments in 1908. As far back as 50 years ago he was able to show, as a result of chronic experiments, that many toxic substances, such as fluorides, oxides of nitrogen, ammonia, etc.,

lowered the defense powers of the organism against such diseases as typhoid fever, anthrax, tuberculosis and other diseases. With the then limited bacteriological techniques Ronzani was able to prove that animals subjected to the effects of the indicated poisons lost resistance against many infectious diseases; he was able to show that the course of normally light infections assumed a grave character after intoxication with the substances mentioned.

The Ukrainian Institute of Labor Medicine, now known as the Ukrainian Institute of Labor Hygiene and Occupational Diseases, located in Khar'kov, published some important results of experiments conducted in 1926 - 1928. Workers of that Institute, such as Ya. D. Sakhnovskii, L. L. Kandyba and Sh. G. Perlina, E. V. Davydova, clearly demonstrated the deleterious effects of lead poisoning and of carbon monoxide, in acute experiments, on animal resistance against typhoid and paratyphoid B. bacilli and of staphylococcal infections. Animals intoxicated with carbon monoxide lost approximately $2/3$ of their resistance to tetanus toxin. Cats subjected to acute intoxication with carbon monoxide temporarily lost their normal resistance against streptococcal infection. A. T. Aldanazarov demonstrated that lead poisoning sharply reduced the defense and adaptability mechanism of the organism, as a result of which animals suffering from inflammation of the lungs and the intestinal tract perished in a considerably shorter time. Reports appearing in the literature indicate that animals subjected to the inhalation of manganese dioxide developed a greater susceptibility to experimental pneumococcal pneumonia. Numerous publications have also appeared which indicate that chronic intoxication with benzene lowered the resistance of animals against many infections, notably pneumonia and tuberculosis. The question of the mechanism which underlies such loss of resistance to infections is a subject of great theoretical and utmost practical importance.

At this point no detailed account will be presented of the complex problems with which the general immunity confronts the investigator. Attention must be called to the fact that immuno-biological reactivity of the organism is controlled by general physiological principles, and that the state of the nervous system is a factor of considerable importance in general immunogenesis and in specific immunity manifestation. In this connection attention is called to the dissertation of P. O. Ivanov "On the Effect of Poisons on the Organism in Relation to Different States of the Nervous System", which was published

in 1901. On the basis of his experiments this author concluded that in instances where the organism firmly withstood the effect of different deleterious factors, including chemical effects, the state of the nervous system played an important part. Conclusions of this nature, which in some instances have been arrived at as far back as 60 years ago, have been recently confirmed in I. P. Pavlov's laboratory by such of his students as Yu. P. Frolov, A. G. Ivanov-Smolenski and others. These authors studied the effect of the state of the central nervous system on the onset, the course and the outcome of some chemical poisonings using different physiological methods; all came to practically the same conclusions, the most important of which, in relation to the subject under present discussion, was the fact that poisons such as acetone, carbon monoxide, cyanide, alcohol, etc. produced functional cortical disturbances; such disturbances weakened the cerebral cortical activity to a point at which it lost its original capability to prevent the development of pathologic processes, including those of an infectious character, as was shown by M. K. Petrova.

It is now possible to formulate the basic principles and specific processes which are responsible for the lowered immunologic reactivity of the organism resulting from some industrial poisonings. It is well known that an anti-infection (infection-resistant) immunity can be hereditary, an individually acquired means of adaptation which resist the entrance into the organism of microbes and viruses, their proliferation and the deleterious effects of their products of elimination. Such means of adaptation, or barriers, are presented by: 1) the skin and the mucosae, 2) inflammation, phagocytosis, the reticulo-endothelial system, 3) the lymphatic tissue barrier functions, 4) humoral factors, and 5) the organism's cell reactivity (L. A. Zil'ber). There is reason to believe that to a greater or lesser degree each of the barriers can be disturbed by the effects of given poisons. However, in practice such functions were relegated to phagocytosis and to some humoral immunity factors.

I. I. Mechnikov was the first to call attention to the important part played by phagocytosis in general immunity. Many studies have been made since that time which broadened the knowledge regarding the role played by leucocytes in the complex defense mechanism of higher organisms. G. K. Khrushchov showed that in addition to the defense functions of phagocytosis and chemical breakdown of invading bodies, the blood platelets played an important part in the

processes of regeneration. In this connection the unfavorable effects of poison-producing leukopenia are of great significance. It has also been shown that toxic substances may under certain conditions reduce the number of leucocytes. Thus, I. I. Mechnikov noted a considerable reduction in the number of white blood cells in the blood of rabbits administered lethal doses of arseneous acid. Recent clinical experience with cases of industrial poisoning points to the possibility of leukopenia resulting from the chronic effect of benzene, fluorides, mercury, manganese, tetraethyl lead and many other deleterious chemical substances. The leukopenia produced in the organism by such substances leads to a reduction in the phagocytosis phase of the organism's defense against infection directly and indirectly by weakening one link in the general chain of the organism's defense mechanism.

Thus, the phagocytic property of leucocytes is lowered by certain toxic substances. A. M. Bezredka lowered the phagocytic function of leucocytes by injecting guinea pigs with carmine; the guinea pigs were then administered arseneous sulfide in doses which normally produced no deleterious effect. In this case, however, all the guinea pigs died. W. and J. Taliaferro exposed experimental animals to the effect of mustard gas and thereby reduced their phagocytic activity. Aub and his co-workers, L. L. Kandyba and Sh. G. Perlina, I. P. Petrov and others found that lead and its compounds also depressed the phagocytic activity of leukocytes. A. T. Aldanazarov found that lead acetate affected unfavorably the opsono-phagocytic activity and depressed the macrophagic absorption system and its related functions. Similar results were obtained by L. L. Kandyba and Sh. G. Perlina with manganese chloride, and by S. S. Dinkelis with tungstic mine dust. S. I. Ashbel and his co-workers noted a lowered phagocytic index in worker patients who had clearly developed pneumo-sclerosis of chemo-toxic etiology and in worker patients suffering from grave intoxication with tetraethyl lead and trinitrotoluol. Paradoxically, in light lead intoxication the phagocytic index rose to higher levels. Thus, different toxic substances can affect phagocytosis mostly in the direction of lowered potency thereby weakening one of the most important defense barriers of the organism.

In addition to the above discussed phases of the phagocytic defense of the organism the humoral immunity factors are also of considerable importance. These factors of immunity determine the bactericidal properties of blood, ex-

updates and transudates in animals and man. As far back as 50 years ago Ronzani noted a lowered bactericidal function in the lungs in relation to Bac. prodigiosus in cases of chronic poisoning with hydrogen fluoride, ammonia and oxides of nitrogen.

Results of experiments and clinical observations found in the literature present evidence of the relation existing between the effects of some industrial poisons and the fall in the bactericidal potency of blood serum. Thus, Ya. D. Sakhnovskii found that the bactericidal potency of fresh blood serum of workers connected with different phases of the lead industry was reduced considerably in its effects of typhoid and paratyphoid B bacilli which he considers as a constant and reliable symptom of lead poisoning. This was verified in experiments with rabbits. T. N. Ablina also found lowered bactericidal potency in the blood of animals experimentally exposed to fluorine-containing apatite dust. Many other investigators found that the bactericidal potency was considerably reduced in animals having inflammatory processes complicated by acute benzene intoxication. It has been established in the past that immuno-bactericidal properties of the organism are determined to a large extent by the presence of active antibodies, substances which are generated in the process of serum globulin synthesis; this is equally true of animals having natural or acquired immunity. It is now generally well accepted that many deleterious chemical substances impeded the process of antibody formation. Results of chronic animal poisoning with fluorides, sulfur dioxide, oxides of nitrogen, benzene conducted by many different investigators manifested different types of lowered production of antibodies such as agglutinin, hemolysins, bacteriolysins, precipitines, etc. This was equally true of specific antibodies generated in animals immunized to specific infections. S. I. Ashbel and co-workers used the Ioffe test and other biological indexes in studying the state of immuno-biological defense of normal and sick workers who were exposed to the effect of lead, tetraethyl lead, trinitrotoluol, etc.; they came to the conclusion that the rate of antibody generation in many of these workers was considerably depressed. Of particular interest is that phase of their work which showed that the rise in the agglutination titre was more gradual but reached higher levels after anti-typhoid vaccination in workers engaged in different chemical industries, as compared with workers otherwise employed.

I. D. Gabovich and Ya. I. Mel'nik in their experiments with rabbits and rats found that fluorine impeded the development of antibodies even when administered in comparatively low doses. K. K. Makashev concluded, on the basis of results of his experiments, that the titre of such immune bodies as agglutinins, hemolysins and precipitins were sharply lowered in the blood of immunized rabbits in lead poisoning. It should be pointed out that following stimulation by antigens the titre of immune bodies in the above animals at first rose, never reaching the original level, and then rapidly fell again.

Finally mention should be made of the important observations made during the post-war years at the Department of Labor Hygiene of the Khar'kov Institute of Post-Graduate Medicine, by V. K. Navrotskii and others; these investigators paid particular attention to changes in immuno-biological reactivity in the incipient stages of chronic intoxication; they worked with benzene, aniline, nitrobenzene, dichlorethane, carbon tetrachloride, lead and tetraethyl lead; as indexes of depressed or enhanced immuno-biological reactions they used the agglutination titre after typhoid vaccine immunization. Their results showed that all the above-mentioned poisons depressed the agglutination titre. On the other hand, poisoning with nitrobenzene, dichlorethane, carbon tetrachloride and tetraethyl lead produced no such effects (elicited no such reactions). V. K. Navrotskii concluded that immuno-biological reactivity is depressed most by vagotropic poisons.

The above-cited experiments once more confirm the opinions variously expressed regarding the deleterious effects exerted by chemical poisons on the humoral phase of immunity. There is, however, another group of body defense barriers consisting of the skin, the mucosae, lymphatic tissues, etc. Each of these barriers, and in particular the tissues, can be variously disturbed or weakened by some industrial poisons. Mention can be made in this connection of the defense functions of the skin and mucosae as mechanical barriers to the penetration of most microorganisms. In addition, these barriers also possess bactericidal potency. In this connection consideration should be given to the possibility of many deleterious chemical substances to damage the skin or the mucosae and thereby break down their function as bacterial penetration barriers; such changes can be of a functional nature or they can be of the nature of permanent anatomical damage. Previous investigations pointed to the considerable importance played by the above-

mentioned factors and it is suggested that in practical evaluation of chemical effects these factors should not be ignored. No specific recommendation can be made at this point in connection with the breakdown of the above-mentioned defense barriers, since this phase of the organism's defense mechanism has been studied comparatively little.

It should be emphasized at this point that in the sum total of the barriers' action as a phase of antibacterial immunity they manifest a variety of mechanisms of which one may be of a synergistic character. Of particular importance in this respect are antibodies which change the microbes in the direction of involution, lowered virulence, and susceptibility to phagocytosis. The presence in immune serums of such antibodies as the opsonins and tropins renders the microorganisms more susceptible to phagocytosis by leucocytes and by cells of the reticulo-endothelial system. Vice versa, deleterious effect of many toxic substances on the development of antibodies must be evaluated not only from the viewpoint of their direct effect as agents lowering organic immunity, but also from the viewpoint of their disturbing the organism's defense function, which results in a lowered effectiveness of phagocytosis.

The importance of different chemical substances in lowering the resistance of organisms varies with different infections. It has been noted that in the case of infection with organisms to which the particular animal body is highly susceptible, that is, where the infecting agent proved to be highly virulent the part played by all the previously mentioned, secondary factors lose their significance. The situation is reversed in cases where the microorganism is less virulent and the host is more resistant. In such instances the state of the organism, as determined by different external and secondary factors, becomes of great importance. Many investigators, notably L. A. Zil'ber, showed that natural immunity to saprophytes can be weakened or broken down by inoculation with large doses of microorganisms.

In connection with the above attention is called to the results of L. L. Kandyba who elicited clearly-defined differences in the reactions in carbon monoxide-intoxicated cats to higher and lower dose inoculations with streptococci and staphylococci. In the case of massive inoculations with streptococci this author noted no difference in the course of the resultant infection in the control and in the carbon monoxide-intoxicated cats. Control cats, inoculated with low doses of the streptococci, resisted the development

of the infection; carbon monoxide-intoxicated cats, inoculated with similar doses, developed a typical streptococcal infection. Similar results were obtained with Staphylococcus aureus.

The state of the organism prior to the chemical infection determines the course and outcome of the intoxication and consequently of all the immunobiological sequelae as well as the effect of any particular concentration of the poison. Thus, I. E. Levin of the Leningrad Institute of Labor Hygiene and Occupational Diseases demonstrated the following: rabbits previously inoculated with tubercule bacilli were exposed to sulfur dioxide; control rabbits were inoculated with similar doses of tubercule bacilli but were not exposed to the sulfur dioxide gas. Clinical observation indicated that tuberculosis developed in the sulfur dioxide-poisoned rabbits inoculated with considerably lower doses of tubercule microorganisms; at the same time the effects produced by sulfur dioxide, such as broncho-epithelial proliferation and alveolar-epithelial metoplasia were more highly developed in the sulfur dioxide-poisoned rabbits.

The above-cited experimental results are in complete agreement with analogous clinical observation, all of which point to the certain highly deleterious effects of even low concentrations of toxic substances on the immunobiological reaction of persons having active pathologic infections. In such instances the mutually enhancing effect of the primary infection and the chemical poisoning appear even at such concentrations of the poison which appear to have no effect on normally healthy persons.

Thus, where the pathogenic factor is clearly defined and where the industrial working conditions are unsatisfactory as regards possible intoxication the manifold individual reactions to the unfavorable factors tend to disappear. Vice versa, differences in the individual reactions become more pronounced where the virulence of the infecting agent is low or where the effect of the chemical poison is limited to low doses or concentrations. Under the present-day production conditions intoxication with low doses or low concentrations of the toxic agent are encountered most frequently. Therefore, the problem of chronic effects of toxic substances under industrial conditions in general and on the immuno-biological reaction of the organism in particular become of particular importance.

Bibliography.

Алданазаров А. Т. Труды ин-та краевой патологии АН Казахской ССР, 1956, т. 4, стр. 42—49. — Ашбель С. И., Глезерова Н. Н., Столпечкая Н. Г., Хиль Р. Г., Лашенко Н. С., Постникова Т. Б. Тезисы докладов на научной сессии Горьковского ин-та гигиены труда 21—25 июня 1948 г. Изд. ин-та, 1948. — Вредные вещества в промышленности. Л., 1954, ч. 2, стр. 488—489. — Габович Р. Д., Мельник Я. И. Врач. дело, 1951, № 12, стр. 1119—1122. — Давыдова Э. В. В кн.: Промышленные яды. Харьков, 1928, стр. 130—137. — Динкелс С. С. В кн.: Борьба с силикозом. М., 1955, т. 2, стр. 348—357. — Здродовский П. Ф. Проблема реактивности в учении об инфекции и иммунитете. М., 1950. — Зильбер Л. А. Основы иммунологии. М., 1958. — Иванов П. А. О действии ядов на организм в зависимости от различного состояния нервной системы. Дисс. докт. СПб, 1901. — Иванов-Смоленский А. Г. Очерки патофизиологии высшей нервной деятельности. М., 1952, стр. 144—160. — Кандыба Л. Л. В кн.: Промышленные яды. Харьков, 1928, стр. 138—146. — Кандыба Л. Л., Перлина Ш. Г. Труды и материалы Украинск. гос. ин-та рабочей медицины. Харьков, 1926, в. 3, стр. 104—122. — Кельш Ф. Общая промышленная гигиена и профессиональная патология. М.—Л., 1926, стр. 123. — Левин И. Е. Труды Ленингр. ин-та по изучению профессион. заболеваний. Л., 1934, т. 8, стр. 85—88. — Макашев К. К. Труды ин-та краевой патологии АН Казахской ССР. Алма-Ата, 1956, т. 4, стр. 34—41. — Мечников И. И. Невосприимчивость в инфекционных болезнях. М., 1947, стр. 489—494. — Навроцкий В. К. Тезисы докл. 13-го Всесоюзного съезда гигиенистов, эпидемиологов, микробиологов и инфекционистов. М., 1956, кн. 1, стр. 145—147. — Петров И. Р. В кн.: Промышленная пыль и борьба с ней. Л., 1933, ч. 1, стр. 96—104. — Петрова М. К. О роли функционально ослабленной коры головного мозга в возникновении различных патологических процессов в организме. Л., 1946, стр. 41—42. — Сахновский Я. Д. Труды и материалы Украинского гос. ин-та рабочей медицины. Харьков, 1926, в. 3, стр. 92—103. — Фридлянд И. Г. О так называемом неспецифическом действии промышленных ядов. М., 1957. — Фролов Ю. П. Высшая нервная деятельность при токсикозах. М., 1944. — Хрушов Г. К. Роль лейкоцитов крови в восстановительных процессах в тканях. М.—Л., 1945. — Aub J. C. Lead Poisoning. Baltimore, 1926. — Ronzani E. Arch. f. Hyg., 1908, Bd. 67, S. 287—366. — Idem. Ibid, 1909, Bd. 70, S. 217—269. — Taliaferro W. H., Taliaferro L. G. J. Infect. Dis., 1948, v. 82, p. 5—30.

Effect of Chronic Low Concentration Sulfur Dioxide Poisoning on the Immuno-Biological Reactivity of Rabbits.

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Results of recent investigations conclusively indicated that sulfur dioxide was a local and also a general toxic substance. This brings into the foreground many important sanitary-hygienic problems, such as the determination of threshold and limit of allowable SO_2 concentrations under chronic SO_2 intoxication conditions. Of equal importance is the problem of the effect of SO_2 on the organism's immunological reactivity and its value as a physiological indicator of the general functional state of the organism in chronic

SO₂ poisoning; the problem is also related directly to the frequently observed increased rate of morbidity among workers exposed to the effects of SO₂.

In the present studies rabbits were used as the experimental animals. They were exposed to 0.018 - 0.022 mg/li of SO₂ for 2 hours daily over 5.5 to 8.5 months. Thirty rabbits were divided into 3 groups of 10 rabbits each. Rabbits of group 1 were immunized with typhoid vaccine only; rabbits of group 2 were preliminarily exposed to SO₂ for 1 month and were then immunized; rabbits of group 3 were immunized during the course of exposure to SO₂. In all cases animals were injected intravenously 3 times with typhoid vaccine containing 1.5 milliards of microorganisms as follows: first injection 0,5 ml of the vaccine; 2nd and 3rd injections were of 0.8 ml. Agglutination titre developed after the injection and the blood complement titre were used as indexes of the immuno-biological reaction. Records were kept of the following: blood morphology; blood protein fractions, determined electrophoretically; acetylcholine and cholinesterase activity. Analytical determinations were made every 10 days. The results of determinations are listed in Table 1. The data in Table 1 show that chronic poisoning with sulfur dioxide in allowable concentrations elicited acute depression of agglutinin formation. The fall in agglutination titre in rabbits of the 2nd group which were exposed to SO₂ for 1 month prior to the vaccine injection was 4 - 8 times as great as in

T A B L E 1.

Average values of maximal agglutination titres after immunization in control and exposed animals.

Factors observed	First (control) group		Second group		Third group	
	Observations	Agglutination titre	Observations	Agglutination titre	Observations	Agglutination titre
Original control data	20	1:70	18	1:80	18	1:70
After exposure	-	-	18	1:80	-	-
1st immunization	10	1:8,700	10	1:1,770	10	1:7,960
2nd immunization	10	1:24,500	10	1:3,270	10	1:4,380
3rd immunization	10	1:17,400	10	1:3,680	10	1:2,980

the control group; it was 5 - 6 times as great in the rabbits of group 3, which were immunized during the course of exposure to SO₂. It should be noted in this connection that the fall in the agglutination titre in the latter case began to appear after the second vaccine injection. Exposure to sulfur dioxide considerably shortened the period of high agglutination titre persistence, as can be seen from the data listed in Table 2. Persistence of high agglutination titre in the rabbits of the second group was cut to 1/3 to 1/4 of the control; in the rabbits of the third group it was cut to 1/2 to 1/3 of the controls.

Results of changes in the blood complement titre, as an indicator of the

T A B L E 2.

After duration of high agglutination titre persistence in days.

Immunization:	First (control) group	Second group	Third group
First	44	14	39
Second	66	18	34
Third	108	28	34

state of immuno-biological activity is shown in Table 3. The data indicate that blood complement titre was only slightly, if at all, affected by the experimental procedures used, probably due to the fact that from the viewpoint of evolution it is the oldest index of body immunity or resistance.

T A B L E 3.

Average values of blood complement titration.

Factors observed	First (control) group		Second group		Third group	
	Observations	Blood complement titre	Observations	Blood complement titre	Observations	Blood complement titre
Original control data	20	0.082	18	0.106	18	0.075
After exposure	-	-	31	0.095	-	-
1st immunization	59	0.107	30	0.078	46	0.088
2nd immunization	69	0.093	35	0.104	33	0.105
3rd immunization	87	0.089	37	0.106	32	0.102

Changes in the morphological blood picture of animals of all groups ranged within the limits of normal fluctuations. Control animals which were subjected to vaccine injections only showed practically no changes in the erythrocyte picture, the leucocytes rose from 8,300 to 10,000. Rabbits of the second series which were exposed to SO₂ prior to immunization showed a hemoglobin fall from 57 to 53%, erythrocyte number fell from 4,400,000 to 4,200,000 and the leucocytes dropped from 11,280 to 8,700. Rabbits of the third group showed the following blood changes: hemoglobin fell from 60 to 58%, erythrocytes from 4,750,000 to 4,360,000, while the number of leucocytes remained unchanged. The results indicate that blood morphology constitutes an insufficiently sensitive index of SO₂ effect in the concentrations under study.

Changes in blood protein fractions are shown in Table 4. In the rabbits of group 1, or the control group, total protein, albumin and globulin fell to a slight degree after the first and second vaccine injections. This lowered the value of the albumin/globulin coefficient. Following the third vaccine injection total proteins and both fractions returned to the original levels. In the rabbits of group 2 blood changes were limited to the serum globulin section which was lowered somewhat after the first and second vaccine injections. Blood picture changes in the rabbits of group 3 were insignificant: only a

T A B L E 4.

Average values in mg% of blood protein fractions.

	First (control) group					Second group					Third group				
	Number	Total	Alb	Glob	coef	Number	Total	Alb	Glob	coef	Number	Total	Alb	Glob	coef
Factors	of ob-	of ob-spre-	Albu-	Glob-	coef-	of ob-	of ob-spre-	Albu-	Glob-	coef-	of ob-	of ob-spre-	Albu-	Glob-	coef-
erved	serva-	stein	mins	ulins	fi-	serva-	stein	mins	ulins	fi-	serva-	stein	mins	ulins	fi-
tions	tions				cient	tions				cient	tions				cient
Original control data	20	7.36	4.20	3.16	1.33	18	6.31	3.41	2.90	1.20	18	6.10	2.93	3.17	0.90
After exposure						38	6.00	3.27	2.73	1.20	-	-	-	-	-
1st immunization	58	6.47	3.48	2.99	1.17	30	6.32	3.25	3.07	1.06	45	6.15	3.22	3.03	1.08
2nd immunization	70	6.24	3.28	2.96	1.07	35	6.36	3.34	3.02	1.10	33	6.08	3.24	2.84	1.10
3rd immunization	93	7.17	4.26	2.91	1.43	37	6.10	3.31	2.79	1.20	32	6.33	3.19	3.14	1.01

very slight increase in the albumin was seen at the end of the immunization. Generally speaking, changes in the blood protein fractions were insignificant and followed no specific or regular course. As was recorded in connection with previous investigations, blood protein fractions changed almost imperceptibly in cases of more clearly expressed poisoning with a regular tendency to shift in the direction of increased globulin. Interesting shifts in the globulin fraction occurred in the course of immunization which are shown in Table 5. No correlation was discerned between the globulin concentration and agglutination titre after immunization in the healthy or control rabbits; regardless of the slight rise in agglutination after the second and third vaccine injections, the γ -globulins remained unchanged. A slight increase in the γ -globulin concentration was observed following the immunization of rabbits in group 2 and after the third vaccine injection in rabbits of group 3.

T A B L E 5.

Average values in mg% of protein globulin fractions.

Factors observed	First (control) group			Second group			Third group		
	α -	β -	γ -	α -	β -	γ -	α -	β -	γ -
	globu- lin	globu- lin	globu- lin	globu- lin	globu- lin	globu- lin	globu- lin	globu- lin	globu- lin
Original control data	0.87	0.81	1.48	0.90	0.83	1.17	1.08	1.41	1.48
After exposure	-	-	-	0.92	0.63	1.18	-	-	-
First immunization	0.68	0.77	1.53	1.03	0.59	1.35	0.90	0.65	1.48
Second immunization	0.89	0.64	1.43	0.95	0.65	1.37	0.79	0.62	1.43
Third immunization	0.82	0.64	1.45	0.84	0.58	1.37	0.86	0.64	1.67

Data related to the accumulation of acetylcholine in the blood and blood cholinesterase average activity are listed in Table 6. The data show that acetylcholine accumulated in the blood and that cholinesterase activity rose in a parallel manner; this must be regarded as an index of the state of humoral compensation, which to a degree reflects the state of functional balance of the two divisions of the vegetative nervous system. The significance of blood acetylcholine in industrial poisoning and its role in immuno-genesis were discussed by this author in a paper entitled "Effect of Chronic Benzene Intoxication, etc.", which appeared in *Gigiena Truda i Professional'nye Zabolevaniya*, No. 2, 1957.

T A B L E 6.

Percent of cases with positive acetylcholine and average
cholinesterase activity values.

Factors observed	First (control group)		Second group		Third group	
	Acetyl- choline	Cholin- esterase activity	Acetyl- choline	Cholin- esterase activity	Acetyl- choline	Cholin- esterase activity
Original control data	0	30.56	0	22.71	0.0	27.65
After exposure	-	-	0	29.72	-	-
1st immu- nization	0	30.56	0	27.48	0.0	32.76
2nd immu- nization	45	46.35	0	27.96	14.2	41.62
3rd immu- nization	83	57.65	73	66.61	100.0	80.20

T A B L E 7.

Agglutination titres.

Days after revaccina- tion	Rabbits			
	First	Second	Third	Fourth
10	1:80	1:160	1:80	1:160
20	1:160	1:320	1:160	1:160

The results obtained in this investigation further prove that sulfur dioxide is a general toxin. Its effects are stable and of long duration. Two months after exposure 4 of the rabbits were given a supplemental intravenous injection of 0.8 ml of the typhoid

vaccine. The results of agglutination titre are shown in Table 7. Substantially, the rabbits failed to react to the antigen injections, that is, they were non-reactive. Of considerable interest is the fact that SO_2 inhibited immuno-biological reactivity to a greater extent than such toxic substances as carbon tetrachloride and dichlorethane, the first of which produced similar results at 4 mg/li and the second at 2 mg/li concentrations. The mechanism of sulfur dioxide action is of considerable importance. According to I. V. Sidorenkov and V. A. Litkens, SO_2 depressed enzymic processes, and, as a consequence, disturbed general metabolism. The facts presented by these authors are incontrovertible. It can be reasonably assumed that SO_2 circulated in the blood and dissolved in the blood plasma became converted to H_2SO_4 which in turn depressed general metabolism. However, this does not explain certain specific

SO₂ properties. The previously mentioned carbon tetrachloride and especially dichlorethane impeded the effects of enzymes and the course of general metabolism to a greater extent than sulfur dioxide; however, these toxic substances fail to inhibit immuno-biological reactivity. The highly irritating properties of sulfur dioxide undoubtedly play a significant role in regard to effects on immuno-biological reactivity. It can be reasonably assumed that this gas, becoming dissolved in the blood and circulated through the organism, came in contact with the interoceptors, strongly irritated them and thereby elicited most intensive reflex response of the type which disturbed the basic enzyme processes and general metabolism, which resulted in acute depression of immuno-biological reactivity. (Notation by the editor of *Gigiena i Sanitariya*: "The last assumption does not necessarily follow from the previously stated positions of the author and, therefore, is a type of apriori supposition of the author".).

Regardless of the true nature or mechanism of sulfuric acid action, the fact remains that this gas manifests general toxic activity and cannot be regarded as indifferent to the organism in concentrations as low as 0.02 mg/li; therefore, the limit of allowable SO₂ concentration in the air of working premises must be brought down to a lower level. N. F. Issev, Z. B. Smelyanskii and others proposed that the limit of allowable concentration for sulfur dioxide be set at 0.005 mg/li; this author is of the opinion that such a proposition is ill-founded. Results of the above-reported investigations of sulfur dioxide effect on immuno-biological activity prompt this author to direct the attention of practicing physicians to the need of investigating the role played by low concentrations of this gas in the total morbidity among workers.

Bibliography.

Елешковский К. Ф., Пейсахович И. М. Труды и материалы Украинского института патологов. 1928, в. 6, стр. 380—385. — Исаев Н. С., Смелянский З. Б., Хоняев Л. К. и др. Гиг. труда и проф. заболевания, 1967, № 4, стр. 3—11. — Литкенс В. А. Гиг. и сан., 1965, № 8, стр. 15—19. — Литкенс В. А., Сакнынь А. В. В кн.: Вопросы гигиены труда, профессион., патол. и токсикол. в промышл. Свердловск, 1965, стр. 160—172. — Свдоренков И. В. Тезисы 2-го Всесоюзного совещания по вопросам промышленной токсикологии. М., 1952, стр. 14—15. — Стерехова Н. П. В кн.: Вопросы гигиены труда, профессион. патол. и токсикол. в промышленности Свердловской обл. Свердловск, 1955, стр. 173—178.

Effect of Low and High Surrounding Air Temperature on the Immuno-Biological Reactivity of the Animal Organism.

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External environmental factors, and among them high and low temperatures, play an important part in the organism's changes in its reactivity. Under certain conditions cooling of the organism lowered its immuno-biological properties and made it susceptible to infection. S. P. Fel'dman demonstrated that many microorganisms of the nasal mucosa which under normal conditions acted as simple saprophytes (such for instance as toxic staphylococcus, Friedlander's diplobacillus and mucoid streptococcus) became highly virulent and elicited purulent processes following cooling of the body. The intratracheal injection of staphylococcal cultures into rabbits followed by body cooling developed febrile conditions. Similar inoculation of rabbits by F. M. Khaletskaya under normal conditions produced no febrile conditions. V. A. Kozlov also demonstrated that cooling of mice lowered their resistance to tetanus infection. On the other hand evidence existed in the literature which showed that organisms subjected to hypothermy manifested an increased resistance to certain diseases processes. Thus, rats subjected to hypothermy followed by burns did not develop any inflammatory processes, as was shown by E. V. Maistrakh.

A. G. Bukhtiyarov showed that cats subjected to hypothermy developed no hetero-transfusion shock. E. V. Maistrakh showed that rabbits subjected to hypothermy developed no allergic reaction of the Schwartzman type.

Generally, all biological processes proceeded at a reduced rate at lower body temperatures; this is especially true of metabolic processes, blood circulation, respiration, conductivity and nerve stimulability. Something akin to the above has been noted in hibernating animals. The method of hypothermy has also been used in surgical practice. Changes in the reactivity of the organism under the effect of surrounding air temperature, other than those leading to hypothermy, have not received the deserved attention, and much remains to be explained. In certain phases of the coal, building, peat, ship-building, lumber manufacturing, etc. workers are exposed to low surrounding air temperatures. In this connection it becomes important to determine the

effect of low temperatures on the immuno-biological reactivity in instances which exclude the possibility of hypothermy development.

It has been known that low external air temperature, as well as high temperature, affected the organism's resistance. A survey of the literature indicated that conclusions arrived at by those who investigated the effect of high temperature on the course of infectious processes and on the rate of antibody formation were contradictory. K. A. Fride, Schwartzman and Galanova pointed out that a rise in the surrounding air temperature affected unfavorably the course of experimental recurrent typhus in rats. The authors expressed the opinion that the unfavorable effect of animals overheating depended not upon the depressed defense mechanism of the organism (since increased temperature frequently produced a rise in the titre of spirochetal antibodies), but was the result of a disturbance in the hemato-encephalitic barrier. V. D. Akhnazarova, and others showed that high temperature lowered the resistance of rabbits to dysenteric toxin. Equally contradictory results were obtained by those who studied the effect of elevated temperatures on the formation and content of antibodies. Most of the investigators believe that higher surrounding air temperature stimulated antibody formation; among such investigators are M. K. Ebert, P. N. Kosyakov and N. N. Zhukov. Other investigators, notably L. M. Karmanova, found that higher temperatures had no effect on antibody formation. Contradictory results were also obtained by those who investigated the effect of high temperature on the complement titre. Thus, Lyudke observed that high temperatures tended to increase the complement titre; K. A. Fride, Schwartzman and Galanova found that higher temperatures raised the complement titre in 35% of their experiments, had no effect in 43%, and lowered the complement titre in 22%. The reason for the contradictory conclusions may be found in the fact that the authors above referred to failed to take into account the degree of animals adaptability to higher temperatures under different periods of adaptation processes.

The purpose of the investigation herein reported on was the determination of effects of low and high air temperatures, which had not disturbed the thermoregulation mechanism, on the immuno-biological reactivity of animals. The effect of low temperatures on the immuno-biological reactivity was conducted with animals kept at surrounding air temperature of -5° to $+5^{\circ}$ throughout the period of experimentation. Experiments were performed with 4 groups of 10 rabbits each. Group I - animals of this group were immunized and cooled

simultaneously; group II - animals of this group were cooled first then immunized while still under hypothermic conditions; group III - animals of this group were simultaneously cooled and triple immunized at 7 day intervals; this triple immunization differed from the triple immunization of animals in groups I and II in that second and third immunizations were made at the time when the agglutination titre fell to the original level; group IV, control group - animals of this group were immunized and kept in a room at 18 - 20°.

In the experiments designed for the determination of high surrounding air temperatures on the immuno-biological reactivity of rabbits the latter were placed in a chamber at a temperature ranging between 36 - 38°. Daily exposure lasted 5 hours; remaining hours of the day animals were kept under conditions similar to those of the controls. Tests were made with 30 rabbits which were divided into 3 equal groups. Rabbits of group I were simultaneously superheated and immunized; rabbits of group II were subjected to superheating for 3 months; they were then immunized and the process of superheating continued. Animals of group III constituted the controls; they were immunized and kept under normal conditions of surrounding air temperature. Immunization was performed with typhoid fever vaccine containing 1.5 millyard of micro-organisms using the London strain No. 62 of abdominal typhoid bacilli; rabbits were injected first with 0.5, second with 0.8 and third with 0.8 ml of the vaccine. Changes in the immuno-biological reactivity of the organism were evaluated on the basis of agglutination and complement titres. Physiological interpretation of the results obtained was made with the aid of blood acetylcholine, cholinesterase activity, blood protein fractions, blood morphology, body temperature, and electrical skin resistance. Tests were made every 7th day up to the time of agglutination titre return to the original level.

In the experiments conducted for the determination of low temperature effect, as shown in Table 1, the maximal agglutination titre occurred on the 7th day after the first immunization and the titre was the same as in the control animals. Maximal agglutination titre after the second injection was also observed on the 7th day, the same as in the control animals; however, the agglutination titre was at a considerably lower level. The change appearing in the agglutination titre after the third immunization was a slight one.

A slight rise in the agglutination titre was observed in rabbits of group II, which were subjected to hypothermy for 1 month prior to immunization. In

T A B L E 1.

Average maximal agglutination titre values in animals subjected to cooling.

Factors observed	Control			Simultaneous cooling and immunization			
	No. of animals	No. of days	Agglutination titre	No. of animals	No. of days	Agglutination titre	Difference reliability
Original	9	20	1:1020±44 m±10	15	36	1:1410±74 m±12	
1st immunization	9	9	1:18,2040±5573 m±1857	15	15	1:11,0930±6177 m±162	1.21
2nd immunization	9	9	1:27,3060±12,770 m±4257	11	11	1:15900±949 m±287	6.03
3rd immunization	9	9	1:19,3420±8958 m±2986	10	10	1:6720±223 m±71	6.25

Factors observed	Preliminary cooling and immunization				Simultaneous cooling and triple immunization at 7 day intervals			
	No. of animals	No. of days	Agglutination titre	Difference reliability	No. of animals	No. of days	Agglutination titre	Difference reliability
Original	22	44	1:2180±150 m±22		9	18	1:1910±96 m±22	
1st immunization	22	22	1:6690±271 m±51	9.1	8	8	1:28,1600±12,000 m±4284	2.13
2nd immunization	12	12	1:6400±345 m±101	6.26	8	8	1:16,7940±5942 m±2285	2.18
3rd immunization	9	9	1:6400±213 m±71	6.2	8	8	1:85330±2413 m±1005	3.5

rabbits of group III a slight agglutination titre was noted after the first and second immunizations; the rise was about the same in the control animals; following the third immunization the agglutination titre amounted to 1:8500 as compared with 1:19,300 in the controls. Conditions of hypothermy had only a slight effect on the complement titre of the 3 groups of experimental rabbits.

Cooling reduced the animals' body temperature to some extent; the average body temperature of the experimental animals amounted to 38.5° and of the con-

trols to 39°. Electrical skin resistance increased in all rabbits of the 3 experimental groups, notably so in rabbits of group II.

Blood studies indicated a considerable lowering in the number of instances manifesting blood acetylcholine and a lowered blood cholinesterase activity in all the experimental animals. On the other hand, blood acetylcholine was found and a 100% rise in cholinesterase activity was observed in all rabbits of the control group. Results are shown in Table 2.

T A B L E 2.

Percent of positive acetylcholine in relation to the total number of studies and average values of cholinesterase activity in the animals following their cooling.

Factors observed	Controls		Simultaneous cooling and immunization		Preliminary cooling and immunization		Simultaneous cooling and triple immunization at 7-day intervals	
	Acetyl- choline	Cholin- esterase	Acetyl- choline	Cholin- esterase	Acetyl- choline	Cholin- esterase	Acetyl- choline	Cholin- esterase
Original	0	27.3	0	33	0	33	0	
1st immu- nization	0	35.0	18	38	30	23	-	
2nd immu- nization	66	40.0	16	24	20	22	50	42
3rd immu- nization	100	54.0	11	20	16	20	25	37

Experiments with the effect of high-temperatures indicated that the agglutination titre dropped to lower levels in rabbits simultaneously immunized and subjected to the effects of higher surrounding air temperatures. Rabbits kept at higher temperature conditions for 30 days prior to immunization had the same agglutination titre as did the control rabbits. With the increase in the time of higher temperature effects, that is, between the first and third immunization, the agglutination titre rose as shown by the data listed in Table 3.

The activity of the process can be conveniently described as follows: duration of high agglutination titre between the first and third immunization fell to lower levels in rabbits of group I; the agglutination titre retained its high level between the first and third immunization for a longer time in rabbits of group II, although the level was not quite as high as in the control group, as is shown by the data presented in Table 4.

TABLE 3.

Average maximal agglutination titre values in animals exposed to elevated temperatures.

Factors observed	Controls			Simultaneous heating and immunization				Preliminary heating and immunization			
	No. of animals	No. of days	Agglutination titre	No. of animals	No. of days	Agglutination titre	Difference reliability	No. of animals	No. of days	Agglutination titre	Difference reliability
Original	9	20	1:102 \pm 44 m \pm 10	10	20	1:104 \pm 36 m \pm 8		10	20	1:76 \pm 45 m \pm 10	
1st immunization	9	9	1:18,204 \pm 5573 m \pm 1857	10	10	1:10,240 \pm 5608 m \pm 1869	3.02	10	10	1:11,947 \pm 4827 m \pm 1609	2.55
2nd immunization	9	9	1:27,306 \pm 12,770 m \pm 4257	10	10	1:5120 \pm 1982 m \pm 660	5.15	10	10	1:16,640 \pm 4957 m \pm 1770	2.32
3rd immunization	9	9	1:19,342 \pm 8958 m \pm 2986	10	10	1:6144 \pm 2048 m \pm 682	4.31	9	9	1:18,432 \pm 4095 m \pm 1365	0.28

Elevated surrounding air temperature had no effect on the complement titre of rabbits of groups I and II. Changes in the cholinesterase activity and acetylcholine accumulation paralleled the changes in agglutination titre. Cholinesterase activity and acetylcholine accumulation rose after the first immunization, and then fell to lower levels in rabbits of group I; acetylcholine accumulation and cholinesterase activity were enhanced in rabbits of group II; upon third immunization they attained normal values; as is shown by the data listed in Table 5.

Body temperature of experimental rabbits subjected to higher surrounding air temperatures fluctuated within the limits of 39.1 and 39.5°, which is equivalent to the upper limits of normal rabbit temperature (38.5 - 39.5°). Electric rabbit skin resistance was lowered as the result of exposure to higher surrounding air temperatures. No regular or otherwise noteworthy changes were observed in the blood protein fractions or in the blood morphology of rabbits kept at low or high surrounding air temperatures; therefore, the experimental data are not herein tabulated.

TABLE 4.

Average persistence in days of high agglutination titres in animals exposed to elevated temperatures.

Factors observed	Controls			Simultaneous heating and immunization				Preliminary heating and immunization			
	No. of animals	No. of days	Duration of titre level	No. of animals	No. of days	Duration of titre level	Difference reliability	No. of animals	No. of days	Duration of titre level	Difference reliability
Original	9	20	-	10	20	-		10	20	-	
1st immunization	9	53	38 ± 7 $m \pm 2.5$	10	60	23.7 ± 3 $m \pm 1$	5.16	10	60	16.3 ± 4 $m \pm 1$	7.47
2nd immunization	9	53	37 ± 8 $m \pm 27$	10	60	17.7 ± 2 $m \pm 0.7$	7.71	10	35	25.5 ± 6 $m \pm 2$	3.36
3rd immunization	9	66	45 ± 5 $m \pm 2$	10	61	32 ± 3 $m \pm 1$	5.70	9	36	34 ± 2 $m \pm 0.8$	5.20

It is the opinion of the present author that the above described changes may have been due to the depressing effect exerted by cold (hypothermy) on the central nervous system, that is, due to the increased inhibition processes. The results obtained in the study of acetylcholine and cholinesterase activity strongly point to a depressed or inhibited function of the parasympathetic division of the vegetative nervous system. It was shown by Gordienko, P. F. Zhdovskii, V. K. Navrotski, and others, that the parasympathetic nervous system played an important part in the formation of immune bodies. Increase in the electrical skin resistance reflected a loss in tissue stimulability, that is, a fall in the stimulability of the conductors (leads) and the senders. Maslov demonstrated that such fall in stimulability was connected with a reduction in ionic permeability caused by thickening of cellular membranes under the influence of lowered temperatures. However, in this case one apparently dealt with stimulability of the sympathetic section of the vegetative nervous system (constriction of skin blood vessels) paralleled by the depression or inhibition in the

T A B L E 5.

Percent of positive acetylcholine in relation to the total number of studies and average values of cholinesterase activity in the animals following their exposure to elevated temperatures.

Factors observed	Controls				Simultaneous heating and immunization				Preliminary heating and immunization			
	No. of animals	No. of studies	Acetylcholine in %	Cholinesterase	No. of animals	No. of studies	Acetylcholine in %	Cholinesterase	No. of animals	No. of studies	Acetylcholine in %	Cholinesterase
Original	6	6	0	27	10	10	0	32	6	12	0	24
1st immunization	6	6	0	35	10	20	50	46	6	10	19	27
2nd immunization	6	9	66	40	10	20	15	31	6	18	48	34
3rd immunization	6	11	100	54	10	20	21	34	6	12	53	37

parasympathetic nervous system. Reference should also be made to the studies of B. L. Palant, N. I. Germanov, N. P. Efimova and L. V. Kalugina, V. A. Strigina and others, who demonstrated that, in cerebral cortical inhibition, formation of antibodies was sharply depressed; under conditions of stimulated cerebral cortex rate of antibody formation was considerably enhanced.

The results of the experiments herein reported showed that transfer of the animals from lower surrounding air temperatures to 18 - 20°, or normal temperature, gradually raised the animals immuno-biological reactivity over 15 to 30 days, after which it returned to the normal level; in the case of animals intoxicated by industrial poisons the drop in immuno-biological reactivity failed to return to the normal level even after 30 days recovery as was shown by V. K. Navrotskii. This illustrated the essence in the differences of adaptation to cold and to high surrounding air temperatures. Analysis of the data obtained in this investigation, particularly as related to higher surrounding air temperatures, pointed to the fact that simultaneous temperature increase and immunization resulted in a fall in rabbits' immuno-biological reactivity. Maintaining rabbits under conditions of surrounding higher air temperatures, which did not cause hyperthermy, seems to have no connection with disturbance in the thermoregulatory mechanism and in hyperthermy; nevertheless, it manifested characteristics of high intensity thermoregulation activity, the purpose of which was to maintain normal body temperature. Fol-

lowing the first immunization the thermoregulation activity was of a lower intensity. This period of immunization was accompanied by a high (normal) agglutination titre. Later, the thermoregulation mechanism had undergone a rise and the agglutination titre fell to considerably lower levels. In instances of prolonged body superheating the immuno-biological reactivity of the organism may rise as a reflection of adaptation; this was clearly indicated by the results of experiments conducted with rabbits of group II.

Heat seemed to act as an inhibitory agent on the activity of the nervous system and of the cerebral cortex. A reduction in the acetylcholine accumulation in experimental rabbits of group I even during immunization confirmed the inhibiting effect of high temperature on the nervous system. It seemed that inhibition in the nervous activity was the cause of reduced immuno-biological activity in rabbits of group I kept at higher surrounding air temperature. The results obtained with rabbits preliminarily subjected to high temperature followed by immunization and again by prolonged maintaining of such animals at high air temperature, showed considerable adaptation on the part of the rabbits to external environmental conditions. The adaptation on the part of the rabbits to high surrounding air temperature was manifested by the fact that the agglutination titre in rabbits of series II after their immunization attained levels equivalent to those of the control animals. Data obtained on changes in acetylcholine accumulation and cholinesterase activity also pointed to the ability of the rabbits to physiologically adapt themselves to the effects of external air temperatures ranging between 36 and 38°. As animals were allowed to remain for longer periods of time under conditions of higher surrounding air temperature the acetylcholine accumulation and cholinesterase activity increased under the effects of the third immunization, rising to levels approximating those of the control animals.

Conclusions.

1. Low surrounding air temperatures ranging between -5° and +5° inhibited or depressed immuno-biological activity.
2. Heat, or high air temperature arrested or inhibited the immuno-biological activity of the organism; the ability of the organism to adapt itself to higher surrounding air temperature plays an important part in the normalization of the organism's immuno-biological activity.

Bibliography.

Ахназарова В. Д. Журн. микробиол., эпидемиол. и иммунобиол., 1956, № 2, стр. 76—78. — Бухтияров А. Г. В кн.: Механизмы патологических реакций. Л., 1952, в. 21—25, стр. 282—295. — Германов Н. И. Журн. микробиол., эпидемиол. и иммунобиол., 1953, № 12, стр. 33. — Ефимова Н. П., Калугина Л. В. Журн. микробиол., эпидемиол. и иммунобиол., 1953, № 12, стр. 21—27. — Здродовский П. Ф. Проблемы реактивности в учении об инфекции и иммунитете. М., 1950. — Карманова Л. М. Журн. микробиол., эпидемиол. и иммунобиол., 1935, т. 14, № 5, стр. 753—759. — Козлов В. А. В кн.: Механизмы патолог. реакций. Л., 1950, в. 16—20, стр. 81—85. — Косяков П. Н., Жуков-Вережников Н. Н. Журн. микробиол. и иммунобиол., 1933, т. 11, № 2, стр. 225—229. — Майстрах Е. В. В кн.: Проблемы реактивности и шока. М., 1952, стр. 171—173. — Навроцкий В. К. В кн.: Тез. докл. 13 Всесоюз. съезда гиг., эпидемиол., микробиол., Л., 1956, т. 1, стр. 145—147. — Палант Б. Л. Журн. микробиол., эпидемиол. и иммунобиол., 1954, № 3, стр. 89. — Сахновский Я. Д., Карцева Н. В. В кн.: Изменение в организме при действии лучистой энергии и при охлаждении. Харьков, 1940, стр. 7—29, 30—44. — Стригун В. А. Журн. микробиол., эпидемиол. и иммунобиол., 1953, № 12, стр. 19—21. — Фельдман С. П. Вестн. оториноларингол., 1948, № 6, стр. 42—46. — Фриде К. А., Эберт М. К. Журн. микробиол., эпидемиол. и иммунобиол., 1937, т. 18, № 3, стр. 440—444. — Халецкая Ф. М. Арх. биол. наук, 1940, т. 60, в. 3, № 12, стр. 3—13. — Эберт М. К. Журн. микробиол., эпидемиол. и иммунобиол., 1941, № 12, стр. 96—100.

The Effect of External Industrial Production Environment on the Immuno-Biological Reaction of the Organism. Communication 1. Effect of Chronic Intoxication with Benzene and Its Nitro- and Amino-Derivatives on the Immuno-Biological Reaction of Rabbits.

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It is a well established fact now that the reactivity of the organism plays a substantial part in the onset and course of pathologic processes. Many varied factors of the external industrial production medium, physical and chemical, may have a great effect on the change in the organism's reactions and, hence, in the origin and course of diseases. Unfortunately, this problem, so important to morbidity reduction, which would also reduce loss of time and productivity among industrial workers, has not been studied extensively enough. The present studies were designed for the clarification of the nature and cause of reactivity changes in the human organism resulting from (elicited by) chemical factors prevailing in external industrial production environment. In ac-

cordance with present-day prevailing views these authors regard immuno-biologic reactivity as a general physiological organism reactivity subject to physico-chemical laws and which can serve as a potent index of the specific organism resistance and of the general state of the organism's function.

A review of foreign and especially of U.S.S.R. literature disclosed a number of publications related to the study of external environment effects on immuno-biological indexes and on the course of infectious diseases. O. F. Sharovarov and E. I. Andreeva studied the effect of high temperature and E. B. Kurlyandskaya studied the effect of infrared rays on the state of allergy in animals. Karmanova studied the formation of antibodies under the effect of high air temperature and Fride, Shvartsman and Gal'nova studied the course of recurrent fever under similar conditions. Many authors, such as A. E. Tsvetkova and P. B. Prigorovskii, G. M. Ermilova, E. I. Ponomareva and A. V. Kirilova, and others studied the effect of ultraviolet radiation on antibody formation. G. M. Ermilova, I. B. Mints, E. I. Ponomareva, and others also studied the effect of Roentgen and ultraviolet rays on antibody formation. Ya. F. Sakhnovskii, E. B. Davydova, Sh. G. Perlina, L. A. Kandyba, G. A. Ionkin and M. N. Khanin, Ya. I. Mel'nik and R. D. Gabovich, Meloni, and others, studied the effect of lead, carbon monoxide, chlorine, fluorine and other chemical substances which occur as industrial poisons on the organism's immuno-biological reactivity. The above investigators studied the effect of external factors on the organism's immuno-biological reactivity under different conditions using different methods of approach, different procedures of investigation, and frequently, obtained contradictory results. Investigations were mostly conducted under chronic conditions of grave lead intoxication and of grave acute carbon monoxide intoxication, which were of no practical value. The studies herein reported on were conducted under conditions of incipient stages of chronic intoxication, since a general survey indicated that frank chronic poisoning, especially of extreme gravity, recently has been seen under industrial conditions on rare occasions only.

Rabbits were injected subcutaneously daily with 0.35 g/kg of benzene, 0.15 g/kg of aniline and 0.15 g/kg of nitrobenzene. Animals received triple typhoid fever vaccinations: they were injected the first time intravenously with 0.5 ml of the vaccine which contained 1 million up to 1 1/2 billion microorganisms; and the second and third times they received 0.8 ml of the vaccine. The second and third injections were made at intervals indicated by stability in the ag-

glutination rise. Three groups of 12 rabbits each were used for each of the poisonous substances tested. The first, or control, group received no injections of any of the poisonous substances; rabbits of the second group were injected with the vaccine after receiving the subcutaneous administration of the poisonous substances; rabbits of the third group were vaccinated and injected with the poisonous substances simultaneously. The following studies were made with the blood of each rabbit: blood morphology, agglutination titre, complement titre; blood protein fractions, acetylcholine and cholinesterase activity. These studies were made on a so-called dynamic basis, that is, every 10th day throughout the course of the investigation.

Blood morphological studies served as indicators of intoxication degree. Only results of final blood enzyme changes have been presented here. No changes were observed in the red or white blood elements of the control animals, that is, immunized but receiving no poison injections. Rabbits injected with benzene followed by immunization showed no red blood changes 10 months later, but the leucocytes dropped from 7,730 to 5,400, pointing to an incipient stage of poisoning. Rabbits immunized and poisoned with benzene simultaneously showed considerably graver blood picture signs 9 months later: hemoglobin dropped from 55 to 42%, erythrocytes from 4,515,000 to 3,800,000 and the leucocytes from 9,520 to 2,750. Rabbits of groups 2 and 3 poisoned with aniline presented the following blood picture 8 to 9 months after intoxication: hemoglobin dropped from 60 to 50%, number of erythrocytes from 4,845,000 to 4,250,000 and number of leucocytes from 10,270 to 8,100. It should be noted at this point that in the above-mentioned animals blood changes were as follows 6 months after intoxication: number of red blood cells negligible changes, number of leucocytes in one case increased from 8,270 to 11,300 and in another case from 9,100 to 15,100. Thus, it can be stated that the chronic stage of poisoning was of a light form with the exception of one series of animals receiving benzene injections. The effect of poison injections on the blood protein fractions will be discussed later. The effect of chronic benzene poisoning and of its amino- and nitro-derivatives on the agglutination titre are shown in Table 1. The data in the Table show that average values of maximal agglutination titre following immunization of the poisoned animals were at considerably lower levels in animals of both groups. The results also indicate that the poisonous effects of benzene were less pronounced than the effects of its derivatives. The agglutina-

T A B L E 1.

Average maximal agglutination titres after normal immunization
and after successive poisoning.

Nature of analytical results	Normal		Benzene poisoned		Aniline poisoned		Nitrobenzene poisoned	
	Average maximal titres	Average in days of maximal titre persistence	Average maximal titres	Average in days of maximal titre persistence	Average maximal titres	Average in days of maximal titre persistence	Average maximal titres	Average in days of maximal titre persistence

I. Preliminary poisoning followed by successive immunization.

Original values	1:135	-	1:120	-	1:60	-	1:230	-
After poisoning	-	-	1:200	-	1:250	-	1:240	-
After 1st immunization	1:15,360	55	1:2,900	-	1:15,300	16	1:20,800	28
After 2nd immunization	1:42,660	76	1:11,910	88	1:16,000	24	1:850	-
After 3rd immunization	1:30,780	54	1:21,540	89	1:10,240	15	1:640	-

II. Simultaneous poisoning and immunization.

Original values	-	-	1:250	-	1:100	-	1:160	-
After 1st immunization	-	-	1:270	-	1:12,600	18	1:17,680	29
After 2nd immunization	-	-	1:9,500	56	1:9,800	60	1:8,700	12
After 3rd immunization	-	-	1:17,600	57	1:14,590	40	1:750	-

Note: Number of animals in each test ranged between 10 and 12. Hence, average maximal agglutination titre was computed accordingly.

tion titre of group 1 rabbits injected with benzene was 1.5 to 5 times lower than in the control group, and in the rabbits of the second group it was 2 to 50 times lower than in the control group; however, the duration of the rise in titre was practically the same in the second group and by 12 to 35 days longer in the rabbits of the first group. The lower titre values in the second group of rabbits may have been due to higher degrees of intoxication as indicated by the blood changes.

The agglutination titres after the second immunization of animals intoxicated with aniline were of lower value in rabbits of both series by 2 to 4 times as compared with the controls; in this case the duration of agglutination rise in rabbits of the first group was also considerably shortened. A sharp drop in the titre even to the point of complete nonreactivity was observed after the second immunization in animals which were poisoned with nitrobenzene; in this case the duration of the titre rise was also sharply reduced. The results, thus, show that the 3 poisons depressed the organism's immuno-biological reactivity and that the 2 benzene derivatives were more toxic than benzene itself.

Complement titres, as a rule, are stable blood indexes; however, in chronic poisoning with benzene and its 2 derivatives a considerable titre lowering was observed. It was not as pronounced in the case of benzene and aniline, as can be seen from the data in Table 2.

Average albumin-globulin coefficients are shown in Table 3. The data in that Table show that the albumin-globulin coefficient remained practically normal after immunization, indicating that the protein-fraction values were not affected. In rabbits of groups 2 and 3 the albumin-globulin coefficient dropped considerably; this was accompanied by a lowering in the total protein content and in the albumin fraction; in the rabbits of group 2 the globulin fraction remained unchanged; in rabbits of group 3 the albumins were reduced and the globulins slightly increased.

In rabbits poisoned with aniline the albumin-globulin coefficient changed only slightly in groups 2 and 3; this was accompanied by slight changes in the blood protein fractions; the total protein content remained unchanged. Rabbits intoxicated with nitrobenzene manifested practically the same type of blood pictures. In rabbits immunized and nitrobenzene poisoned simultaneously the albumin-globulin coefficient was slightly increased accompanied by a partial drop in the total protein and in the globulin-fraction.

T A B L E 2.

Average blood complement titres in normal and poisoned experimental animals.

Nature of analytical results	Normal	Benzene poisoned		Aniline poisoned		Nitrobenzene poisoned	
	Average complement titres	Average complement titres	Poisoning time in months	Average complement titres	Poisoning time in months	Average complement titres	Poisoning time in months

Preliminary poisoning followed by immunization.

Original results	0.12	0.11	-	0.15	-	0.083	-
After poisoning	-	-	-	0.20	6	0.030	3
After 1st immunization	0.12	0.12	1	-	-	0.100	4
After 2nd immunization	0.11	0.13	2	-	-	0.150	5
After 3rd immunization	0.12	0.15	3	-	-	0.200	6

Note: Average complement titration values were computed on the basis of 102 control tests and on the basis of 36 - 42 tests of poisoned animals.

T A B L E 3.

Average albumin-globulin coefficient values for non-poisoned immunized and poisoned and immunized experimental animals.

Nature of analyses	Normal	Benzene poisoned	Aniline poisoned	Nitrobenzene poisoned
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I. Preliminary poisoning followed by immunization.

Original results	1.6	2.1	1.70	1.4
After poisoning	-	1.4	1.75	1.3
After first immunization	1.5	-	1.60	1.4
After second immunization	1.8	1.6	1.65	1.6
After third immunization	1.5	1.6	1.58	1.4

II. Simultaneous poisoning and immunization.

Original results	-	2.6	1.70	1.3
After first immunization	-	-	1.77	1.4
After second immunization	-	1.8	1.50	1.6
After third immunization	-	2.0	1.60	1.6

It has been known for some time that ratios between blood protein fractions were of no specific significance, and appeared in a variety of diseases and occupational or industrial poisonings. As a rule, in such cases a considerable shift has been observed in the direction of the globulin fraction with a simultaneous drop in the albumins. However, such changes were only seen in cases of clearly defined poisoning. Such phenomena have not been observed in the rabbits under the present study. Consequently, there was no reason to expect considerable changes in the albumin-globulin coefficient accompanied by increase in the globulin content. It should be noted at this point that the correlation between values of agglutination titres and total globulin fractions have not been observed in the cases under study. It is possible that such a correlation might have been detected in connection with the α -globulins or the so-called immuno-globulins. This phase is at present under study.

In all cases under present study, including the controls or normal immunization an accumulation of acetylcholine in the blood was observed accompanied by changes in cholinesterase activity, as indicated by the data presented in Table 4. A slight accumulation of acetylcholine was observed during normal rabbit immunization in some instances; acetylcholine was more frequently found in larger quantities in rabbits subjected to poisoning and immunization. Increase in cholinesterase activity ran parallel to acetylcholine accumulation.

Acetylcholine accumulation in blood in many diseases and in practically all industrial cases of poisoning led to the assumption of the existence of a particular type, possibly acetylcholine, defense function. In this connection it appeared interesting, if not important, to determine the part played by acetylcholine in agglutinin formation under the conditions of the presently described experiment, especially in view of the fact that evidence in the literature pointed to the positive role played by acetylcholine in immunogenesis, as was shown by P. F. Zdrovskii, M. D. Poltseva and others. After the third immunization, when the agglutination titre dropped, the rabbits received daily subcutaneous injections of 0.05 mg of acetylcholine in 1 ml of solution on 6 successive days; their agglutination titres were determined over a long period of time; the data are presented in Table 5. The results show that in the doses administered acetylcholine enhanced the agglutination titre considerably in the previously inoculated control as well as in the previously poisoned and inoculated rabbits; it also prolonged the duration period of the enhanced titre. As was to have been expected, the rise in titre and prolonged

T A B L E 4.

Acetylcholine and average blood cholinesterase activity intensity in percent of acetylcholine hydrolysis during the period of the experiment after immunization alone and after poisoning and immunization.

Type of analytical results	Normal				Benzene poisoned				Aniline poisoned				Nitrobenzene poisoned			
	% of blood acetylcho- line posi- tive cases	Cholin- esterase activity	% of blood acetylcho- line posi- tive cases	Cholin- esterase activity	% of blood acetylcho- line posi- tive cases	Cholin- esterase activity	% of blood acetylcho- line posi- tive cases	Cholin- esterase activity	% of blood acetylcho- line posi- tive cases	Cholin- esterase activity	% of blood acetylcho- line posi- tive cases	Cholin- esterase activity	% of blood acetylcho- line posi- tive cases	Cholin- esterase activity	% of blood acetylcho- line posi- tive cases	Cholin- esterase activity

I. Preliminary poisoning followed by immunization.

Original results	0	20.0	0	20.00	0	20.8	0.0	26.2
After poisoning	-	-	0	25.30	50	39.2	75.0	45.7
After 1st immunization	14	42.4	-	-	50	40.7	0.0	19.0
After 2nd immunization	40	37.0	84	45.00	50	60.3	100.0	40.7
After 3rd immunization	45	41.1	100	69.60	-	-	100.0	61.5

II. Simultaneous poisoning and immunization.

Original results	-	-	0	23.60	0	23.9	0.0	32.6
After 1st immunization	-	-	-	-	40	42.4	50.0	35.9
After 2nd immunization	-	-	50	47.64	77	46.5	66.0	42.7
After 3rd immunization	-	-	35	46.20	100	54.9	6.6	37.5

period of titre increase were not as pronounced in the intoxicated and immunized rabbits as in the controls. In normal non-immunized rabbits acetylcholine elicited only a slight rise in the agglutination titre as shown by the data presented in Table 5. A study was made of adrenalin effect on agglutinin formation: fol-

T A B L E 5.

Effect of acetylcholine on the titre of agglutinin.

Time of analysis	No. of animals	Highest agglutinin level after 3rd immunization	Original agglutinin level before acetylcholine administration	Maximal agglutinin level after acetylcholine administration	Persistence in months of highest agglutinin level after acetylcholine administration
Immunization only	7	1:82,000	1:320	1:20,480	3.0
Ditto	50	1:10,240	1:2560	1:10,240	8.5
Ditto	54	1:40,960	1:5120	1:40,960	8.5
Ditto	56	1:20,480	1:1280	1:20,480	6.0
Aniline poisoning and simultaneous immunization	5	1:40,960	1:160	1:5120	2.5
Preliminary aniline poisoning followed by immunization	91	1:82,000	1:160	1:5120	1.0
Benzene poisoning and simultaneous immunization	47	1:20,480	1:160	1:10,240	8.5
Ditto	45	1:40,960	1:320	1:10,240	20 days (rabbit died at agglutination titre 1:320)
Rabbits not immunized nor poisoned	79	-	1:160	1:640	
Ditto	80	-	1:320	1:640	

Following the drop in the agglutinin titre after the third immunization, rabbits were subcutaneously injected on 5 successive days with 1 ml of 0.1% of adrenalin. No rise in agglutinin titre was observed. The results justify the conclusion regarding the role played by acetylcholine in immunogenesis and of the part played by the parasympathetic nervous section of the vegetative nervous system. It appears that the role played by acetylcholine was related to changes in the functional state of the cerebral cortex, as was shown by many authors, notably Volkova, Mikhel'son, and others, who showed that acetylcholine in small doses enhanced the processes of stimulation, and in large doses arrested them. It has been known for some time that a state of stimulation of cerebral cortex

was beneficial to the formation of immune bodies; it is, therefore, readily understandable why in the presence of acetylcholine, which acts as a defense agent, generation and accumulation of antibodies should be of a moderate degree. The results of the investigations here described can be summarized as follows: benzene and its amino- and nitro-derivatives depressed immuno-biological reactions in animals in chronic and incipient stages of intoxication; the amino- and nitro-benzenes proved more active in this respect than was the primary benzene.

Bibliography.

- Давыдова Э. Б. В кн.: Промышленные яды, окисл. углерода, свинец, сернистые газы. Харьков, 1928, стр. 130-137. — Ермакова Е. М., Пинаморова Е. П., Кириллова А. В. Курортол. и физиотерап. 1936, № 5, стр. 77-83. — Ермакова Е. М., Мрин И. Я. В кн.: Проблемы физиотерапии и курортологии. Свердловск, 1940, стр. 202-210. — Здродовский П. Ф. Проблемы реактивности в учении об инфекции и иммунитете. М., 1950. — Ионкин Г. А., Ханян М. Н. Респираторол., эпидемиол., паразитол., 1939, т. 12, в. 3-4, стр. 254-266. — Кандыба Л. А., Перлина Ш. Г. В кн.: Исследования по свинцовому отравлению. Харьков, 1926, стр. 194-121. — Карманова Л. М. Журн. микробиол., эпидемиол. и иммунобиол. 1935, т. 15, в. 5, стр. 753-759. — Мельник Я. И., Габович Р. Д. Врач. дело, 1951, № 12, стр. 1119-1122. — Михальсон М. Я. в кн.: Тезисы докладов совещания по вопросам химической передачи нервного импульса. — Мелопи Г. А. Исследования, т. 47, № 1-2, р. 80-81. — Мокшанова Гиг. труда и техн. безопасности, 1937, № 3, стр. 70-71. — Перлина Ш. Г. Врач. дело, 1941, № 5-6, стр. 257-258. — Попцова М. Д. Тезисы докладов Молотовского научно-исследовательского института вакцин и сывороток итоговой научной конференции. Молотов, 1953, стр. 45-45. — Сахновский Я. Д. В кн.: Исследования по свинцовому отравлению. Харьков, 1926, стр. 92-103. — Фриде К. А., Шаарцман Л. А., Гачанова Н. В. Журн. микробиол., эпидемиол. и иммунобиол. 1935, т. 15, в. 3, стр. 345-356. — Курляндская Э. Б. Бюлл. эксперим. биол. и мед. 1938, т. 6, в. 5, стр. 544-546. — Фридлянд И. Г. Сов. врач. журн. 1939, № 10, стр. 557-566. — Он же. Сборник научных работ за годы Отечественной войны Ленинградского института гигиены труда и профзаболеваний, Л., 1945, стр. 145-154. — Хилл-Винклер П. И. Туберкулез легких у свинцовых рабочих. Труды Ленинградского института по изучению профессиональных заболеваний, 1937. — Цветкова А. Э., Пригорьский В. П. Б. Журн. микробиол., эпидемиол. и иммунобиол. 1938, т. 20, в. 3-4, стр. 74-80. — Шароватова О. Ф., Андреева Е. И. Физиол. журн. СССР, 1951, т. 26, в. 1, стр. 61-68.

Effect of Chronic Benzene Intoxication on the Phagocytic Activity of Rabbits.

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Lower morbidity among workers in industrial enterprises is one of the urgent tasks of Soviet public health. It is quite well known that rate of morbidity was closely related to unfavorable working conditions. Therefore, pertinent data were collected on workers who were exposed to the effect of benzene in artificial leather producing plants in Leningrad. Much production time was lost due to the occurrence of the grippe, angina, and tuberculosis among workers exposed to chronic benzene intoxication (O. N. Olimpiyev). The effect of a number of chemical substances, such as lead, chlorine, fluorine, carbon monoxide, and benzene on the immuno-biological reactivity was studied by many Russian and foreign authors (Ya. D. Sakhnovskii, Sh. G. Perlina, L. L. Kandyba, G. A. Ionkin, and M. N. Khanin, Ya. I. Mel'nik, and P. D. Gabovich, V. K. Navrotskii, and others). The experimental studies of J. Hektoen indicated that in benzene intoxication the resistance to infection in the experimental animals was lowered, and arrested infections became active. Thus, there is reason to suppose that benzene intoxication lowered the resistance of the body to infection. However, this problem has not been studied sufficiently.

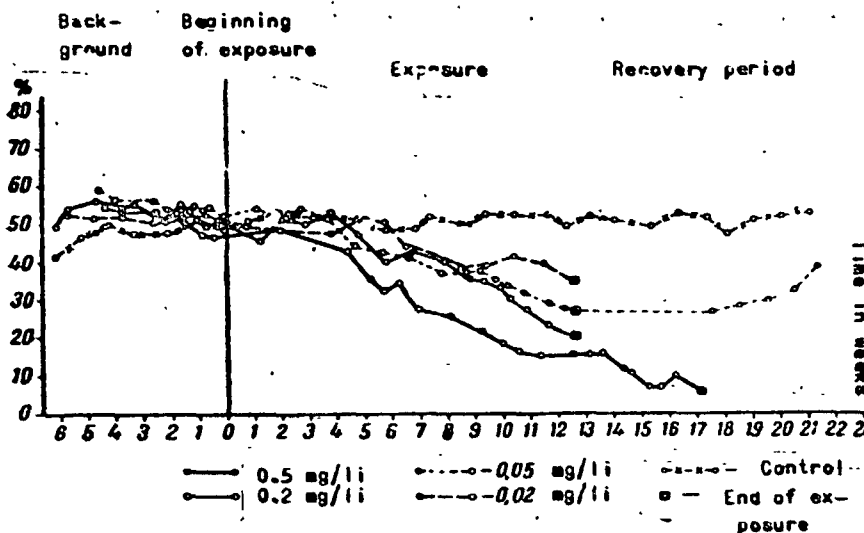
This work is devoted to the study of the effect of chronic benzene intoxication on the phagocytic activity in rabbits, inasmuch as the latter is an important factor in the body's defense against infection. The second stage of the work constituted an investigation of phagocytic activity in the blood of workers poisoned by benzene vapors.

Experiments consisted of 4 series of rabbits which were used because their blood easily underwent typical changes under the effect of benzene. A total of 28 animals were used, of which 8 served as controls. Concentrations of benzene most frequently encountered under actual working conditions (0.5, 0.2, 0.05, 0.02 mg/li) were used in the experimental exposures by the dynamic method, that is 3 hours daily for 3 months. Throughout the duration of the experiment the benzene concentration in the air in the exposure room was controlled. Benzene was determined by the method of T. N. Kozlyaba and I. G. Vorokhobin.

Phagocytic activity in the rabbits was determined by the generally accepted method of G. E. Platonov. A 1.5 billion suspension of a 3-day-old culture of

Friedman's bacillus was taken as the object for phagocytosis. The phagocytic index was determined in the smear on the basis of 100 neutrophile count. The number of microorganisms phagocytosed by one neutrophile (phagocytic number), was also taken into account. Besides the phagocytic activity blood of the animals was analyzed for the hemoglobin content, number of erythrocytes, leucocytes, thrombocytes, reticulocytes, as well as the differential leucocyte count. Weight and behavior of the animals were recorded. The initial, or control, levels of all the indices were determined before each series of experiments.

Typical benzene intoxication resulted following a 3-month daily exposure to benzene vapor. Deepest change was observed in animals which inhaled benzene in concentration of 0.5 mg/li. A lowered phagocytic activity appeared first on the third week of exposure. Before the beginning of the experiment the average phagocytic index of the animals was 53%; at the end of the 13th week of exposure it dropped to 15% (see Fig.). In many rabbits only 7 of 100 neutrophiles showed



Phagocytic activity of leucocytes
(averages of 28 rabbits).

signs of phagocytosis at the end of the experiments. The number of phagocytosed microorganisms also dropped; by the end of the exposure the average number of phagocytosed microorganisms per neutrophile dropped from 10 to 2 - 3. At the same time, no changes whatsoever in phagocytic activity were observed in the control animals.

Benzene intoxication with 0.5 mg/li concentration produced leucopenia, anemia, thrombopenia, and reticulocytosis. Thus, the hemoglobin dropped from 54 to 45%, the number of erythrocytes from 4,500,000 to 54,000 and the number of reticulocytes increased from 6.1 to 18%. Neutrophilosis followed by lymphocytosis and monopenia were determined from a study of the leucocytic formula. A pre-existing anisocytosis had undergone qualitative changes.

The experimental animals lagged behind the controls in weight, and manifested changes in their behavior by the end of the experiment; they became sluggish

and slow-moving. There were cases in which the course of the benzene intoxication was complicated by the presence of pus in the organism due to infected swelling of the paws. Despite high concentrations of benzene which usually depressed hemogenesis in noninfected animals, leucocytosis counts of 15,000 - 17,000 were observed in the infected animals. At the same time, comparatively high hemoglobin concentrations and erythrocytosis were also noted. Leucopenia, characteristic to benzene intoxication, appeared only at the beginning of the 9th week of exposure. At the same time the fall in phagocytic activity observed in the infected animals was more pronounced than in the non-infected ones: in the non-infected animals 15 of 100 neutrophils showed phagocytosis; only 12 of 100 neutrophils of the infected animals showed signs of phagocytosis. Therefore, it can be assumed that the presence of purulent processes in the body changed the reaction to the effects of benzene by eliciting a leucocytosis instead of a leucopenia. Thus, benzene vapor inhalation in 0.5 mg/li concentration caused a typical benzene intoxication accompanied by a sharp depression of phagocytic activity of the animals; these changes appeared earlier than other blood changes.

Analogous changes in phagocytosis activity in the blood were observed in the second series of experiments in the benzene vapor concentration of 0.2 mg/li. However, they appeared later and were of lesser severity.

In 0.05 mg/li benzene concentration (the third series of experiments), phagocytic activity had markedly changed in a manner similar to the first 2 series. The phagocytic index fell from 55% at the beginning of the experiment to 27% at the 13th week of exposure (see Fig.). The number of microorganisms phagocytosed by one neutrophil had also decreased from 8 - 10 at the beginning of the experiment to 2 - 3 at the end of it. Leucocyte phagocytic activity began the 5th week of exposure and preceded other changes in the blood, shown as moderate leucopenia, anemia, thrombopenia and reticulocytosis. No changes were observed in the leucocytic formula. The weight of the experimental animals did not differ from the weight of the control animals.

In this series of experiments records were kept of the rate at which the phagocytic activity was restored and the blood picture returned to normal after exposure was discontinued.

Disturbed indices were restored in reverse order: the phagocytic function of the leucocytes became normalized only 3 months after exposure had been discontinued; the indices of white blood, the thrombocytes and reticulocytes re-

turned to normal approximately after 2 months. Percentages of hemoglobin content and the number of erythrocytes were restored the fastest. Consequently, at benzene concentration equal to 0.05 mg/li poisoning is of a light form accompanied by a decrease in phagocytic activity. Blood changes as in the first 2 series, became manifested later than changes in phagocytic activity.

In view of the fact that in concentration corresponding to the allowable limit, benzene vapor lowered phagocyte activity, a fourth series of experiments was conducted at benzene vapor concentration of 0.02 mg/li. In this series of experiments, phagocyte activity began to drop on the 8th week of exposure and the phagocytic index fell to 35% at the end of the 12th week as against 52% at the beginning of the experiment. No special changes were noted in the blood, except for a slight leucocytosis (10,000 - 11,000), which became manifest the 6th week of exposure and lasted throughout the entire experiment. Apparently, the irritation phase of the hemopoietic organs appeared at this benzene concentration.

When the experiments were concluded, animals of all series were killed and their organs were pathologically and anatomically examined. Animals of the first and second series showed the following lung changes: multiple punctate hemorrhages, measuring in spots 3 x 4.5 mm; a bloody frothy liquid exuded from the lung tissues; the liver was flabby and broke through easily upon pressure; liver outlines were raggedy; stomach mucosa showed many punctate hemorrhages, mostly in the area of the large curvature; there were multiple punctate hemorrhages in the medullary and cortex layers of the kidneys; the bone marrow of the tibia was paler than in the control animals. No special changes were noted in the organs of the rabbits of the third and fourth series.

Conclusions.

1. Inhalation of benzene vapor in concentrations of 0.5, 0.2, 0.05 and 0.02 mg/li for 3 months changed the immuno-biological reactivity of the organism; it decreased the phagocytic index and the phagocytic number.
2. Exposure to benzene vapor of 0.5, 0.2 and 0.05 mg/li for 3 months produced a typical picture of benzene poisoning in the experimental animals, characterized by leucopenia, thrombopenia, anemia, and reticulocytosis. Slight leucocytosis was observed in rabbits exposed to benzene fumes of 0.02 mg/li.
3. Changes in phagocytic activity began earlier than changes in the blood. Because of the great sensitivity of this reaction its use as a diagnostic test is suggested.

4. The restoration of phagocytic activity progressed slowly. In animals exposed to concentration of 0.05 mg/li the phagocytic activity became normalized only after 3 months.

5. The data received concerning the decrease of phagocytosis activity in exposure to benzene vapor concentration of 0.05 mg/li (which, at the present time, is within the allowed limit) and even to a concentration of 0.02 mg/li indicated that such concentrations were not harmful to the organism.

Above results can serve as a basis for a review of the existing limit of allowable benzene vapor air concentration. The conclusions were verified by subsequent studies of the immuno-biological reactivity of men who worked with benzene.

Bibliography.

- Ионкин Г. А., Хаян М. Н. Вестн. микробиол., эпидемиол., паразитол., 1939, т. 18, № 3—4, стр. 254—266. — Кандыба Л. Л. Перлина Ш. Г. В кн.: Исследования по свинцовому отравлению. Харьков, 1926, стр. 104—121. — Козляева Т. Н. Ворохобин И. Г. В кн.: Труды Всесоюзн. научн.-исслед. ин-та охраны труда ВЦСПС. Л., 1953, стр. 369—371. — Латышева Н. И. Журн. микробиол., эпидемиол. и иммунобиол., 1955, № 1, стр. 76—81. — Мельник Я. И. Габович Р. Д. Врач. дело, 1951, № 12, стр. 1119—1122. — Мытник П. Я. Фармакол. и токсикол., 1939, т. 2, № 3, стр. 9—16. — Навроцкий В. К. Гиг. труда и проф. забл., 1957, № 2, стр. 12—19. — Перлина Ш. Г. Врач. дело, 1931, № 5—8, стр. 255—258. — Сахновский Я. Д. В кн.: Исследования по свинцовому отравлению. Харьков, 1926, стр. 92—103. — Несторен J. J. Infect. Diseases, 1916, v. 19, p. 69.

**Air Temperature Effect on the Processes of Conversion and Detoxification
of Aniline in the Animal Organism.**

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Gigiena Truda i Professional'nye Zabolevaniya, Vol. 2, No. 4, 30-36, 1958.

Under practical industrial conditions workers (and others) are frequently subjected to the simultaneous effects of several unfavorable factors, such, for instance, as deleterious effects of chemical substances accompanied by surrounding high temperature. The effect of surrounding air temperature on the organism has been studied extensively in the past; however, the simultaneous effect of temperature and of different chemical substances on the human organism has not received the deserved attention.

Reports in literature indicate that high external temperature in most cases hastened and enhanced the appearance of intoxication symptoms and generally lowered the lethal dose of poison, although in isolated instances the reverse effects have been observed. The mechanism of external temperature effect on the course of toxic properties has not been studied sufficiently. There is some reason to believe that changes in the action of chemical substances on the organism accompanied by temperature effects may be closely connected with elicited functional shifts. Thus, a rise in air temperature elicited a dyspnea, as a result of which more of the gaseous or vaporized substances can penetrate into the organism, which, in turn, may intensify the toxic effect, as was shown by R. G. Leipes and by V. A. Solov'eva.

In explaining the toxicity of poisons in relation to external temperature some authors emphasized (laid more stress) upon the importance of absorption (inhalation) and distribution of the substances in the organism; the importance of elimination was also given consideration, as was mentioned by Gast, by Stokinger and by others. Others explained the enhanced toxic effect on the basis of changes in the reactivity of the organism caused by external air temperature conditions. Such studies were conducted by L. I. Levkovich, V. A. Pokrovskii, V. K. Navrotskii and S. N. Dubashinskaya, A. I. Pakhomycheva, T. A. Kozlova, E. I. Korenevskaya, and others.

In 1889 Borovskii studied the elimination of mercury via the urine in persons treated medically with mercury preparations; as a result of his observations he expressed the opinion that temperature may affect the part played in the metabolic processes by chemical substances which found their way into the organism. The processes of poisons and especially industrial poisons conversion and detoxification in the organism vary with the chemical and physico-chemical reactions which constitute total metabolism. Therefore, it can be assumed that metabolic changes resulting from different causes and in particular from temperature effects will affect the processes of certain poison detoxification and thereby change the course of their action. Such an assumption was previously advanced by Jacobi, and Günther and Odoriz, who studied the effect of surrounding temperature on the course of intoxication. It should be added at this point that studies of this nature were few and were not accompanied by chemical analysis and that no similar studies were made in direct application to effects of occupational poisons. The present author investigated the possible effect of air temperature on the rate of poison conversion and detoxification in the organism, with particular reference to aniline which is widely used in industry. In the production of aniline, dimethylaniline, diphenylaniline, and black aniline dye, workers may be subjected to the simultaneous effects of the related chemicals and increased temperature. Preliminary tests were conducted for the determination of possible temperature effects on the course of aniline intoxication.

White mice 18 - 21 g were used in these experiments. Reference is made at this point to the work of Z. A. Khatskevich, Z. A. Voltova. Aniline was administered subcutaneously, in preference to the method of inhalation or absorption through the skin for the following reasons: at different temperatures different quantities of the aniline inhaled or applied to the skin might find their way into the organism as a result of changes in the respiration rate and of the peripheral blood circulation, as was indicated by V. A. Solov'eva. Aniline dissolved in oil was injected subcutaneously at the rate of 15 mg per mouse (0.05 ml of the oil solution); the mice were then placed for 2 hours into chambers at following temperatures: 4°, 7 - 8°, 12°, 18°, 21 - 23°, 26°, 32 - 35°, 38 - 40° and 42°. Mice were then closely observed for 2 hours and records kept of their general condition and behavior and of the time of appearance of poisoning symptoms. The mice were then placed into

the vivarium kept at 18 - 19° temperature. Record was kept of the number of mice surviving at the end of the day. Results of the study clearly indicated that there existed a correlation between the course of the aniline intoxication in white mice and the surrounding temperature. At 26° the general state of health of the intoxicated mice was of a light gravity and the survival rate was greater. At higher or lower air temperature symptoms of intoxication appeared sooner and survival rate was lower, and death occurred at a shorter period of time. All mice injected with the aniline and kept at 4 and 42° perished, whereas 55% of the mice kept at 26° survived. Results of the experiment are presented graphically in Fig. 1. Control mice, that

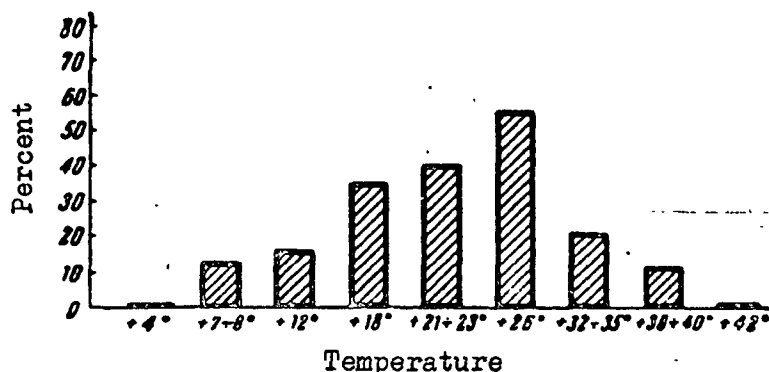


Fig. 1. Survival in percent of white mice poisoned with aniline at different surrounding air temperatures.

is, animals not injected with aniline and kept at any of the indicated temperatures survived indefinitely. Thus, the effect of temperature changes on the course of aniline intoxication has been clearly established in principle. In the next phase studies were made of the nature of aniline conversion processes in the animal organism under different surrounding conditions.

Effect of air temperature on the processes of aniline conversion in the organism. It has been generally known that aniline became oxidized in the organism to less toxic substances, such, for instance, as phenol, and predominantly paraminophenol. The latter combined with glucuronic and sulfuric acids forming conjugated compounds, in which form they were eliminated from the organism via the urine. Numerous experiments performed in the pathophysiological laboratory of the Institute of Labor Hygiene and Occupational Diseases, Academy of Medical Sciences, S.S.S.R. showed that following the introduction of aniline into rabbits organism the greater part of the conjugated paraminophenol was eliminated via the urine within 24 hours after the injection of the aniline. Paraminophenol was found only in trace amounts in the urine collected after 24 hours. According to reports in the literature the urinary tract constituted the basic route of aniline elimination. All

other routes were of no substantial importance; accordingly, rate of aniline conversion and detoxification was judged on the basis of paraminophenol elimination via the urine during the first 24 hours. It is the opinion of this author that a study of the blood for the content of aniline and paraminophenol might serve as an important supplemental source of information regarding the rate of conversion and detoxification of aniline in the organism. The method of blood study was as follows: rabbits received subcutaneous injections of aniline and were placed immediately into chambers of different temperatures for 2 hours. Each temperature set had control rabbits of both sexes and of similar weight and fur color. The control rabbits were kept at 18 - 22°. Aniline injections in most cases were intravenous at the rate of 100 mg/kg; this procedure eliminated the previously mentioned possibility of external temperature effects on the amount of poison which entered the organism. During the 2 hours of exposure to different temperatures 30-minute records were kept of the rectal rabbit temperatures. Two hours after the aniline injection and in a number of cases 21 and 22 hours later blood samples were taken from the marginal ear vein for the determination of aniline and paraminophenol. Urine was tested for the total amount of paraminophenol eliminated in 24 hours. Aniline determinations were made by the color reaction with phenol and sodium hypochlorite; paraminophenol was determined by the color reaction with phenol in the presence of chromic acid and ammonia, according to A. A. Rubanovskaya. Generally, 20 to 30 seconds after the beginning of the aniline injection, which means practically during the aniline injection, fine convulsions in the form of fine tremor appeared over the entire body, occasionally accompanied by clonic twitching of the extremities. Following the aniline injection animals upright posture became unsteady and shaky, some of them fell on their sides due to the appearance of the above-mentioned clonic twitching of the front or hind legs. Usually this condition lasted only 2 to 3 minutes. As soon as such symptoms disappeared the animals were placed into the different temperature chambers for 2 hours.

Two series of experiments were conducted for the determination of air temperature effect on the rate of aniline conversion. In the first series of tests the rabbits were injected with the aniline and then placed in the experimental chamber at 34 - 37°, which is approximately the temperature prevailing in industries using aniline. Rabbits similarly injected with aniline and

placed in a room having an air temperature of 18 - 22° were used as controls. The condition of the poisoned rabbits kept at higher temperatures appeared to be of a grave nature. It was noted that at the end of 2 hours, rabbits injected with aniline and kept at 18 - 22° showed signs of recovery and began to move about more freely; similarly injected rabbits kept at 34 - 37° appeared to become progressively inert, their respiration became more frequent and some of them salivated. Four of the 26 rabbits kept at the higher temperature died at different periods after the injection of the aniline during the first 10 days; whereas 2 of the 20 control rabbits died at considerably later periods.

Blood analysis showed the following results: 2 hours after the poison injection most of the rabbits kept at the warmer temperature showed a higher blood aniline concentration than did the control rabbits; the paraminophenol concentration was lower in the blood of the animals kept at higher temperature than in the controls. The ratio of blood aniline to blood paraminophenol varied with the number of individual factors; therefore, it can be used only as a provisional preliminary index in cases of aniline poisoning. On the other hand the amount of paraminophenol eliminated with the urine in the course of 24 hours can be used as a more reliable index of the rate of aniline conversion. It was noted that paraminophenol was eliminated with the urine at a lower rate in most rabbits kept at the higher air temperature. This was indicated by the fact that the average 24-hour paraminophenol elimination with the urine amounted to 57.9 mg/kg, whereas it amounted to 46.7 mg/kg in the rabbits kept at the higher temperature. In other words, the paraminophenol elimination was less by 19%. Results of these experiments are plotted in block form in Fig. 2. In this connection it should be noted that rabbits were injected with the aniline on the basis of kilograms of body weight and that weight of animals and 24-hour urine elimination volume differed, therefore, final calculations of paraminophenol elimination were made on the basis of kilograms of rabbit body weight. The data presented above indicate that the rate of the injected poison eliminated by rabbits was lower at higher air temperature. This may be due to unfavorable changes in such functions which are brought about in the living organism by increased surrounding temperature; to facilitate its elimination conversion of aniline appears to be one of such functions. According to reports found in the literature, higher air tempera-

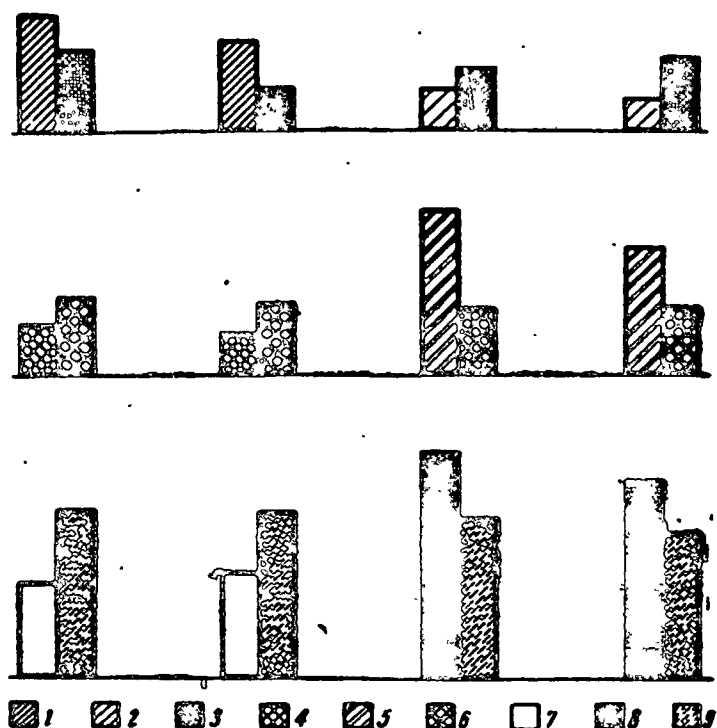


Fig. 2. Effect of air temperature on the rate of aniline conversion in the organism. Blocks 1, 2, 3 - Blood aniline concentrations in mg% correspondingly of heated, cooled and control rabbits; 4, 5, 6 - Blood paraminophenol concentrations in mg% correspondingly of heated, cooled and control rabbits; 7, 8, 9 - Urine paraminophenol concentrations in mg/kg in heated, cooled and control rabbits.

tures impeded blood circulation in internal organs, disturbed the liver function, in particular the glycogenic and detoxification functions which are closely connected with liver function. The oxidizing processes fell to lower levels, a condition which persisted for a time after surrounding temperature had been brought down to normal. Cellular dehydrase and cytochromoxidase activities, according to E. A. Rozan, fell to lower levels in the brain and liver, the latter being the basic organs in which aniline breakdown occurred (A. A. Rubanovskaya, M. L. Beloborodova).

Surrounding air temperature has been regarded as the most important exogenic factor affecting the rate of the organism's general metabolism; therefore, an

attempt was made to produce changes in the rate of aniline oxidation by changing the surrounding air temperature. A second series of experiments was designed to establish this possibility. The general course of experimental procedure was the same as above with the following exception: after having been injected with aniline the rabbits were placed for 2 hours into a chamber at -5 to $+5^{\circ}$. Aniline was administered subcutaneously at the rate of 300 mg/kg, or it was injected into the marginal ear vein at the rate of 100 mg/kg in slightly warm physiological solution. Rabbits similarly injected with the aniline and kept at normal room temperature served as controls. Results of the lower temperature experiments showed no noteworthy differences from the results obtained with the elevated temperature experiments. Rabbits kept at a lower temperature showed occasional signs of convulsions. One of the 22 poisoned rabbits kept

at the lower temperature died at the end of 15 days. None of the control rabbits died.

Blood analyses were made 2 hours after the administration of aniline. The results showed that the amount of aniline in the blood was lower in the animals kept at below normal air temperature than in the corresponding controls. Results of paraminophenol blood analysis were of the reverse order. The paraminophenol in 24-hour urine of poisoned rabbits kept at temperatures below normal was at a higher level than in corresponding controls. Thus, the average in the case of rabbits kept at the lower temperature was 70.9 mg/kg, whereas in the controls it amounted to 54.4 mg/kg, a difference of 30%. The results are plotted in block form in Fig. 2.

Following subcutaneous aniline injection 80.8 mg/kg was eliminated with the urine of poisoned rabbits kept at normal temperature, whereas 107.7 mg/kg, or 33% more, was eliminated by poisoned rabbits kept at below normal air temperature. The results indicate that a temperature of $\pm 5^{\circ}$ enhanced the process of aniline breakdown (conversion) in the organism. This author is of the opinion that the above was due to the combination of physiological shifts arising in animal organisms at moderately low temperatures, affecting basic metabolism in general and carbohydrate metabolism in particular. A comparison of the above cited results in the case of rabbits with the previously described results obtained with white mice off hand appeared contradictory: in the case of rabbits lower temperature seemed to enhance the physiological processes of aniline detoxification, while the reverse appeared to be true in experiments with white mice. This can be explained by differences in physiological defense functions of the 2 types of animals, particularly as regards their thermoregulatory and thermoresistant mechanisms; the difference in aniline dosage administration likewise may have played a part in the difference of results obtained. It must be understood, however, that the intensity of physiological detoxification of the poison used was far from being the only factor which determined the course of intoxication. Apparently, in acute large dose intoxication with the poisonous substance the defense mechanism of an organism is hard hit and weakened; in such cases the poison detoxification factor has no substantial significance and can not impede the rapid development of damage. Vice versa in small dose intoxication the detoxification rate plays an important part.

A survey of foreign literature indicated that attempts have been made to determine the part played by body temperature in the effect of chemical substances on the organism and to equate the results with the law of Van't Hoff. However, it would be too much to expect that in the interplay of many complex processes, such as exist in an organism, any simple law could play as important a part as it did in the case of non-living matter. In the experiments herein reported body temperature of the animals was recorded every 30 minutes. The results obtained indicated that the administration of aniline at 18 to 22° and at $\pm 5^\circ$ air temperature were accompanied by hypothermy. The degree of fall in body temperature varied with the individual animal, and bore no relation to changes in temperature between - 5 and + 22°. Quite the contrary, in the case of higher temperatures, administration of aniline elicited hyperthermy. Data illustrating this are shown in Fig. 3. Analysis of the results leads to the conclusion that aniline changed the organism's reactivity with regard to temperature effects. In the results herein reported it was possible to note a relationship between the rate of aniline conversion in rabbits' organism and changes in the body temperature within the limits of 36 to 44°. Hence, the results herein reported confirm the opinion expressed by investigators who believed that the law of Van't Hoff did not apply to higher animals.

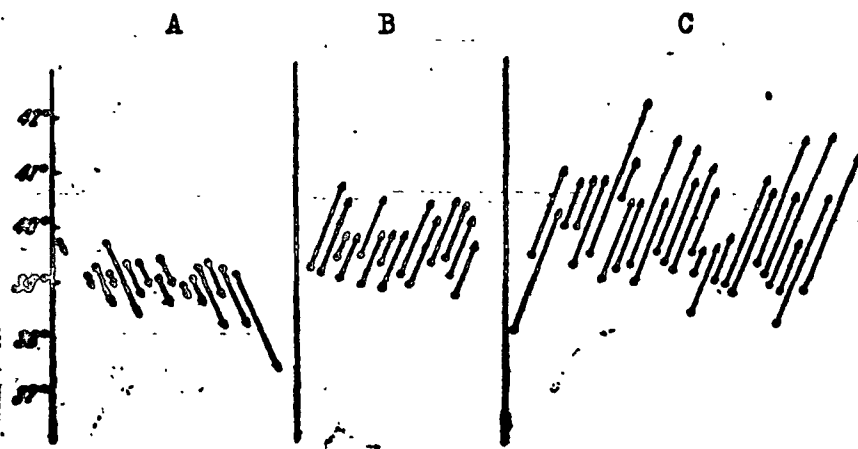


Fig. 3. Changes in rabbits' body temperature.
 A - In rabbits poisoned with aniline at 10 - 20° air temperature; B - At 34 - 37° (high) air temperature;
 C - In rabbits poisoned with aniline and simultaneously exposed to 34 - 37° (elevated) air temperature.

Conclusions.

1. Rise in temperature affected the rate of aniline detoxification in rabbits: a) the effect of temperature rise within the limits of 34 - 37° impeded the processes of aniline conversion to paraminophenol and the elimination of the latter with the urine; b) moderate general cooling of rabbits at temperatures between + 5 and - 5° enhanced such processes, that is, it aided the organism in freeing itself of the poison.
2. Aniline intoxication, similar to aniline detoxification process in the organism, followed different courses, depending upon the temperature conditions of the surrounding air.
3. Aniline disturbed the thermoregulation of the animals used eliciting hypothermy under normal air temperature conditions and hyperthermy under conditions of elevated air temperature.
4. The data herein presented fail to discern any connection between the rate of aniline conversion in the organism and body temperature within the limits of 36 - 44°.

Bibliography.

- Белобородова Н. Л. Экспериментальные данные о влиянии нервной системы на процесс обезвреживания анилина в организме. Десс. М., 1933. — Боровский В. О влиянии тепла на выделение ртути мочой. Десс. СПб., 1899. — Левкович Л. М. Бюлл. эксперим. биол. и мед., 1938, т. 5, № 3, стр. 270—272. — Лейтес Р. Г. Arch. Hyg., 1929, Bd. 102, S. 91—110. — Навроцкий В. К., Дубашинская С. М. Гиг. и сан., 1931, № 8, стр. 22—28. — Пахомов А. И., Козлова Т. А., Кореньевская Е. И. В кн.: XIII Всесоюз. съезд гигиенистов, эпидемиолог., микробиол. и паразитол. Тез. докл. М., 1936, в. 1, стр. 168—170. — Покровский В. А. В кн.: Сб. реф. науч. работ Воронежского мед. ин-та, 1943, т. 16, в. 1, стр. 94—98. — Розин Е. А. В кн.: Военно-морская мед. академ. Науч. конф. слушателей, 10-я. Труды, Л., 1953, стр. 123—129. — Рубановская А. А. Охрана и гигиена, 1945, т. 8, № 4, стр. 24—31. — Хацкевич З. А. Влияние температуры внешней среды на процессы превращения и обезвреживания анилина в организме животных. Десс., М., 1930. — Gast W. Arch. exper. Path. u. Pharmacol., 1943, Bd. 201, S. 297—304. — Günther B., Odoriz J. B. J. Pharmacol. u. Exper. Therap., 1944, v. 82, p. 303—309. — Stokinger H. E. Am. J. Syph., 1944, v. 21, p. 466—470. — Jacobi C. Arch. exper. Path. u. Pharmacol., 1930, Bd. 27, S. 149—157.

Sanitary-Hygienic Labor Conditions in the Production of Polymethylmetacrylate.

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Polymethylmetacrylate is one of the most extensively used present-day plastics, obtained by polymerization; it is an organic glass, or plexiglass, now widely used in many branches of industry. Organic acrylate glass has a low specific gravity and is mechanically durable; its light transparency is absolute and ultraviolet rays pass through it with ease; light and water do not affect it unfavorably. Such properties make it fit for use in aviation, in the radio industry, in machine-building, in the production of artificial fibers, unbreakable eye-glasses, watch glasses and lenses, in dielectrics, in architecture, in the building industry, and in the preparation of glues, lacquers, and paints. The property of the basic material, methylmetacrylate, to co-polymerize with other monomers is responsible for its wide range of use.

Polymethylmetacrylate is produced by polymerizing methyl ester with α -metacrylic acid (methylmetacrylate) with the aid of heat and in the presence of peroxides in the shape of sheaves, in solution, and in emulsion. The sheaf method yields finished products, sheets or lamina of polymethylmetacrylate; ester polymerization in organic solvents yields a variety of lacquers; the emulsion method yields a powder-like polymer. In each case the finished product contains a residue which failed to undergo completion of the polymerization. It has been universally demonstrated that polymethylmetacrylate produced in the laboratory under careful supervision was free from traces of unreacted monomers and possessed no toxic properties. Results of experimental implanting of polymethylmetacrylate platelets in the soft tissues and in the brain of animals indicated that acrylate was the most indifferent plastic to the organism. Therefore, it was possible to utilize acrylic plastics in different phases of plastic surgery and in orthopedics: in cranio- and rhinoplasty, in eye prosthesis, in joint replacing, in bone defects, and in stomatology for filling teeth because of the aseptic properties of the monomer. However, unlike plastics obtained in the laboratory, many plastics produced under present-day manufacturing conditions contain monomer admixtures which constitute an occult factor of potential danger. Hence, extreme caution should be used where

workers come in contact with the unfinished products and, in particular, with press powders which invariably liberate monomer fumes. The toxic properties of the polymethylmetacrylate base, methylacrylate, were studied in 1940 by L. Z. Ponomareva-Astrakhanseva, and later by Deichmann who determined the toxic concentrations of this substance and observed degenerative changes and multiple hemorrhages in the parenchyma of experimental animals. Results of other experiments demonstrated that methylmetacrylate vapor irritated the skin and mucous membranes, and also caused sarcoma development when scales containing methylmetacrylate were implanted into soft tissues.

In 1952, B. D. Karpov of the Leningrad Sanitary-Hygienic Medical Institute showed that metacrylate vapor disturbed the stimulation and inhibition processes of the upper portion of the central nervous system in experimental animals and depressed unconditioned reflexes, vascular receptors, the respiratory center, and the thermoregulation mechanism. Karpov also examined workers engaged in the synthesis and polymerization of methylmetacrylate surrounded by air which contained 0.1 to 0.8 mg/li of methylmetacrylate. The workers complained of general weakness, irritability, exhaustion, somnolence, headaches, and loss of appetite. The symptoms increased toward the end of the shift. Hypotonia with blood pressure fluctuations from 80/50 to 105/75 was detected in 43% of the workers. Pronounced symptoms of vegetative asthenia were observed in accidental acute poisoning. As a result of the above mentioned tests, B. D. Karpov suggested that 0.5 mg/li of methylmetacrylate vapor be considered as the maximum permissible concentration of methylmetacrylate in the air of working premises.

Results of toxicologic studies of primary methylmetacrylate substances and of the possible development of pathology through contact with them indicated the need to examine the Moscow Balakirev button factory workers engaged in processing polymethylmetacrylate accompanied by liberation into the air of the working premises of high quantities of monomer vapors.

The raw material for making buttons and other products came in the form of polymethylmetacrylate platelets, sheets, and press powder. The acrylate sheets and plates were produced by the block method, and press powder by the emulsion method. As a consequence the sheets and press powder contained admixtures of non-reacted monomers. Liberation of monomer dust into the surrounding air was also one of the chief occupational hazards arising from processing polymethylmetacrylate.

Different sizes of sheets and plates of the organic glass 0.5 - 5 cm thick were sawed, stamped, machined, painted, and glued. During the sawing process, in the absence of ventilation, 0.8 - 0.95 mg/li of methylmetacrylate dust was liberated into the air; thereby exceeding the suggested maximum permissible concentration 16 - 20 times. Recirculating ventilation in the stamping, machining, and lathe shops almost completely removed the dust from the air, and obviated methylmetacrylate fume liberation into the shop air. Dust concentrations reached 1011 mg/m³, that is, 100 times over the maximum permissible concentration in the drum shop, where buttons were polished in small drums containing abrasives; this was particularly true during loading and unloading of the drums and of the open revolving screen sections. Despite the presence of recirculation ventilation, dust concentrations reached 40 mg/m³ in the polishing shop. The greater part of the work was performed with the aid of manually operated machines. No monomer dust was liberated at any of the other stages of organic glass processing.

Another method of manufacturing plastics consisted in compressing a mixture of L-1 polymethylmetacrylate powder containing benzoyl peroxide as the catalyzer, with dibutyl phthalate and pigmentary and aliphatic dyes and metacrylic acid as the plasticizer. The addition to the latex powder of the solvent methylmetacrylate in 1:3 ratio produced upon mixing a thick cheese-like mass which emitted a strong ester-like odor. The thick mass is cut manually into suitable-size pieces and delivered to the press room. The mixing is done in a room below the press room; it is equipped with a stationary exhaust fan. The monomer concentration in the air of the mixing department exceeded the prescribed limit of permissible concentration on the average of 38 times; the highest concentration exceeded the required standard 84 times. The area in this department is comparatively small, so that some of the mass had to be mixed in the general room of the workshop, thus polluting the air of the working area with methylmetacrylate fumes. The mass was pressed at 130 - 150° which resulted in partial decomposition of the polymer and in the liberation of methylmetacrylate fumes to a concentration of 0.5 - 0.7 mg/li, which exceeded the maximum permissible concentration by 10 - 14 times.

Thus, it can be seen that workers in the press workshop were exposed to the effect of the monomer more than any other workers. Therefore, this was selected as the starting point in the study of morbidities among the employed. A comparative morbidity study was made during 1956 - 1958 of all factory em-

ployees with the morbidity among workers in the lower press room. It was found that the morbidity rate among the press room workers was higher by 20% and work days lost by 10.5% than among all factory workers; occurrence of bronchitis was 3 times as frequent and hypotonic diseases only half as frequent, possibly due to the hypotensive effect of esters. Such preliminary data pointed to the need of a thorough inspection of shop workers; such an inspection was made at the suggestion of the Sanitary-Hygienic Epidemiological Station of the Baumansk rayon plant, during 1957 - 1958. The inspection was made cooperatively by medical occupational specialists, pathologists-therapists, neuropathologists, otorhinolaryngologists, and laboratory personnel.

Analysis of the data showed that the labor turnover in the lower press workshop was considerable. Of 118 workers assigned to different sections, 38 remained on the job no more than 6 months; therefore, morbidity data of this group of workers were excluded from the statistical study. The remaining shop workers were divided according to occupations as follows: 61 pressers, 8 mixers, 5 rolling press workers, and 6 inspectors. Of the total number of workers, 5 (6.5%) were 19 years old or younger; ages of the other workers (64%) ranged between 20 and 39 years. Thirty-five (43.5%) worked from 6 months to 2 years, 28 (35%) from 2 - 5 years, 9 (11.5%) from 5 - 10 years, and 8 (10%) more than 10 years. Most of the shopworkers were women.

Analysis of the inspection results showed the following: of the total number of 80 inspected workers, 42 (52%) manifested a low blood pressure ranging from 80/50 to 110/65; 20 (25%) had diseases of the upper respiratory passages in the form of subatrophic and atrophic rhinitis, nasopharyngitis, and laryngitis. A significant portion of the workers complained of headaches and quick exhaustion; however, pronounced functional changes in the nervous system in the form of vegeto-asthenic reactions were seen in only 9 (11.5%). Inflammation of the conjunctiva of varying degrees was detected in 47 (59%).

Analyses of the blood and urine revealed no essential deviations from normal. The data obtained are evidence of the fact that, on the whole, changes due to the effect of methylmetacrylate fumes on the organism, affected the nervous system, mucous membranes of the upper respiratory passages, the eyes, and the vascular receptors, which agreed with results recorded in the literature.

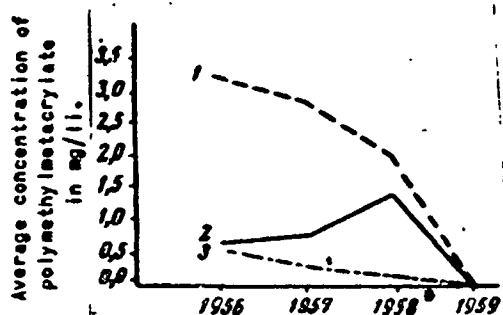
More than 100 air samples were collected in different factory shops and analyzed for the content of dust, formaldehyde, methylmetacrylate, and other

toxic substances; this was done in 1956 - 1958 by the Industrial Section of the laboratory of the Sanitary-Hygienic Epidemiological Station. The following Table shows data on the contamination of the air in working premises by methylmetacrylate. The method, described in the manual, Determination of Harmful Substances in the Air of Industrial Premises, by M. V. Alekseyeva, B. Ye. Andronov, S. S. Gurvits, and A. S. Zhitkova, was employed in determining the presence of methylmetacrylate fumes in the air.

Content of methylmetacrylate fumes in the air at separate points of the lower press workshop in 1956 - 1958

Place of sampling	Air temp.	Number of samples	Concentration in mg/li		Times of increase above maximum permissible concentration	Ventilation installations
			Maximum	Average		
Large presses	23°	8	2.5	1.25	25 - 50	Parallel supply and exhaust ventilation
Pouring presses	21°	2	0.2	0.1	2 - 4	
Mixing division	19°	7	4.2	1.8	38 - 84	2 exhaust hoods; intake from shop
Rollers	23°	1	0.4	0.4	8	Exhaust pipe
Neutral zone (Receivers' point)	18°	4	0.5	0.25	5 - 10	General intake pipe
Entire production department		22	1.56	0.76	15 - 30	General supply and exhaust ventilation

On the basis of results obtained it was suggested to the factory management that appropriate health measures be instituted in the most health-affecting sections. At the present time, ventilation has been installed in shops according to the plan approved by the Industrial Section of the Sanitary-Epidemiological Station; the exhaust ventilation has been remodeled and intake air supply increased in the mixing rooms; rolling machines were moved to separate rooms; an apparatus for mechanically mixing the polymethylmetacrylate powder is being tried and tested. As a result of such measures no methylmetacrylate fumes could be detected in March 1959 by analyses of air samples taken in the shop in general, at the large hot and small pour presses, and in the mixing section (as can be seen from the Fig.).



Dynamics of content of methylmethacrylate fumes in the air of the main sections of the lower press shop from 1956 to 1959.

1 - Mixing section; 2 - Large presses;
3 - Receivers' working areas.

*Ventilation equipment was dismantled in 1958.

At the recommendation of the authorities of the Sanitary-Epidemiological Station, the usual vacation of a number of workers in the lower press shop (machinists who handle the hot presses, rollers, and inspectors) was extended by 6 days. In addition, it was suggested to the factory management and to the manager of the Sanitary-Epidemiological Station that a stationary inhalator be installed for the prophylaxis and treatment of diseases of the upper respiratory passages prevalent among the factory workers.

Bibliography.

- Лазарев Н. В. (ред.). В кн.: Вредные вещества в промышленности. Л., 1954. т. I, стр. 493, 499, 502, 717, 722, 727. — Петров Г. С., Петрова Л. Г. Пластмассы. М., Л., 1953. — Ревзин П. И. Тезисы докл. конференции по применению пластических масс в медицине. М., 1954, стр. 4. — Henrichsen E., Jansen K., Krogh-Poulsen W., Acta Orthop. Scandinav., 1952, v. 22, p. 141. — Laskin D. M., Robinson I. B., Weinmann J. P., Proc. Soc. Exper. Biol. a. Med., 1954, v. 87, p. 329.

Labor Hygiene Problems in the Use of Dichlorethane by the Aviation Industry.

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This author studied the sanitary-hygienic labor conditions in an industrial plant where dichlorethane was used extensively as an organic cement solvent. Investigations showed that the concentration of dichlorethane vapor in the air persisted at 0.05 mg/li during 70 to 75% of a single shift; it fell to lower levels only intermittently; about 25 - 30% of the time the dichlorethane concentration ranged between 0.08 and 0.15 mg/li.

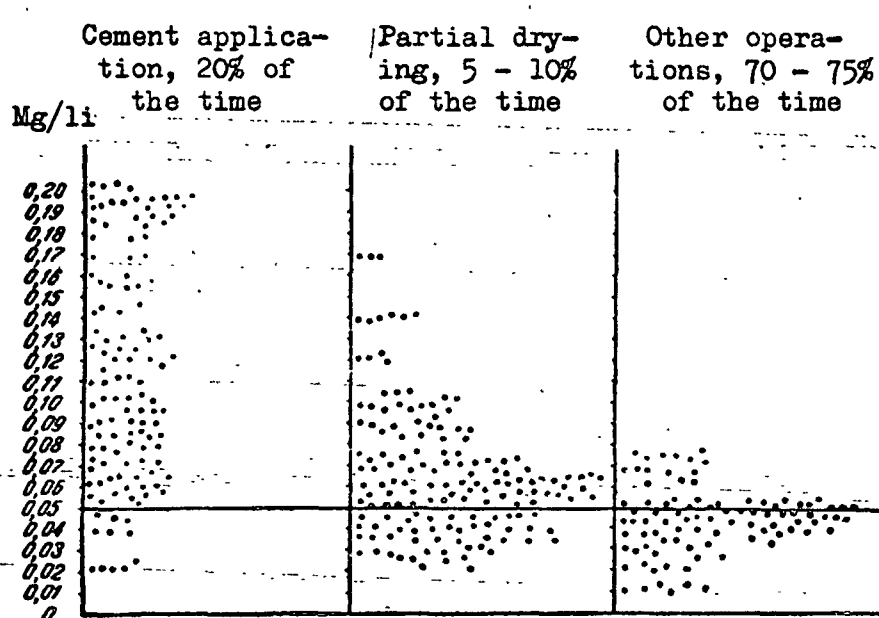
Medical examinations of women workers showed shifts in the functional state of the central nervous system, basically in the form of disturbed motor and weakened internal inhibition, also as disturbed states of the upper extremities motor apparatus manifested as lowered force and resistance. Disturbances were also observed in the general state of health, usually observed in dichlorethane poisoning, and of the neuro-muscular apparatus of the upper extremities manifested as characteristic forms of work performance motions.

White mice were exposed to the effect of 0.05 - 0.01 mg/li of dichlorethane followed by experimental investigation of changes in the higher nervous activity and in the intraneuro connections of the cerebral cortex; the latter present earliest symptoms and indexes of the organism's reaction to external factors. Results of such observations led to the conclusion that 0.005 mg/li of dichlorethane should be regarded as the limit of allowable concentration of this air pollutant. Practical means for the sanitization of working conditions in the plant under study (and in similar plants) have been developed and formulated. Because of peculiar specific technological processes employed in some departments of airplane building plants many of the vats are made of pliable material. The greater part of the workers producing the pliable tanks were women cementers, tank makers and producers of rubber parts. From the sanitary-hygienic point of view most important of the production phases were the large surfaces which were coated with dichlorethane-dissolved organic cement; in this stage of pliable tank making the vaporization of the dichlorethane into the air of the production premises was intense. From the viewpoint

of working technique the women workers performed a function limited to a monotype body movement, accompanied by considerable muscular tension.

Results of 500 air analyses showed that intensity of dichlorethane vaporization into the air differed at different times, causing short duration fluctuations in the dichlorethane concentration in the air. Highest dichlorethane concentration, ranging between 0.08 - 0.158 mg/li, were observed at the time the dichlorethane-dissolved cement was applied to the rubber sheets. Such concentrations persisted for only 5 - 6 minutes, and at the moment of the cement setting or drying, approximately 15 minutes, the concentration dropped to 0.03 - 0.04 mg/li. The application of the dichlorethane-dissolved cement was usually made during the first half of the shift; during the second half the rubber sheets were attached and reinforcements were applied. The concentration of dichlorethane in the air of the working premises persisted at the 0.05 mg/li level or lower during the greater part of the working shift. Washings from the surface of the workers' hands showed a concentration of 0.001 - 0.002 mg/cm².

The technological processes involved in the type of work under consideration require a temperature of 23°; however, the temperature prevailing in the working premises was 26 - 28°; this augmented the dichlorethane vaporization and increased its concentration in the air as shown by the results of 400



analyses of samples taken at 12 different working points at different temperatures.

Thus, at air temperature of 31°, at the point where rubber sheets were coated with the cement, the dichlorethane concentration amounted to 0.145 mg/li; at 27° it amounted to 0.094 mg/li; and at 25° it amounted to 0.080 mg/li.

Fig. 1. Dichlorethane concentrations at different operations and their persistence in the course of a work shift.

In the particular workroom where these observations were conducted the rubber sheets were placed over flat tables in 4 rows, and the dichlorethane-dissolved cement was spread over their surfaces; the metallic tanks were placed near the tables. Ventilation in such working rooms operated as follows: air was coming in from above and was exhausted through grated openings in the floor along the alleys between the working tables. In the opinion of this author such a ventilation system was rational for conditions prevailing in the workrooms. The dichlorethane fumes which spread over the cement application tables showed a tendency to cling to the table surfaces and did not rise upward; this facilitated their being directed downward to the floor gratings by the air coming from above and their being sucked into the floor openings by the negative exhaust. Application of the dichlorethane-dissolved cement to the metal tank surfaces farthest away from the exhaust channels created a different sanitary-hygienic condition; here the vapors rose upward and were distributed in all directions. During the cement application under such conditions the dichlorethane concentration rose to the order of 10ths of a milligram per li. As a general rule the dichlorethane vapor did not spread far beyond the point of the cement application, as can be seen from the following:

At the table of application - - - - -	0.110 mg/li
At 50 cm from the table - - - - -	0.094 mg/li
At 1 m from the table - - - - -	0.054 mg/li
At 2.5 m from the table - - - - -	0.037 mg/li
One m above the floor - - - - -	0.160 mg/li
Two m above the floor - - - - -	0.024 mg/li
Three m above the floor - - - - -	0.006 mg/li

The capacity of the ventilation system was not sufficient to remove the entire dichlorethane vaporized during a single shift. The ventilation efficiency occasionally fell short of the required due to the fact that the inflowing air constituted only 56% of the exhaust air volume.

As was indicated above, in addition to the air pollution with dichlorethane vapor, other purely physical factors added to the discomfort of the women workers. Thus, rolling on the cement-applied rubber sheet was accomplished by monotype motions during which the roller handle was firmly grasped. In working with the roller the cement worker performs 80 to 200 motions per minute throughout the day, amounting to a total of 8,000 move-

ments a day. In the process of applying the cement the women worker made 7 to 120 movements and in the course of the day 1,200 to 1,300. A dynamometer built into the roller handle recorded an exerted pressure amounting to 8 - 12 kg. Labor conditions in other workrooms of the plant were much the same. In the department where the metallic forms were disassembled and the rubber coats were removed the dichlorethane concentration in the air reached 0.175 - 0.210 mg/li; this was due to the intense vapor elimination of the dichlorethane originally adsorbed to or absorbed by the rubber.

The sanitary-hygienic evaluation of the effect of dichlorethane vapor on the workers' organism was studied with the aid of the visual-motor reaction. The apparatus used made possible determinations of simple reaction time, of reaction time complicated by light differentiation, and by complex reaction conversion determinations to 100ths of a second. Visual-motor reaction rate studies were made at the beginning and at the end of a work day over 14 days; studies included 2 groups of women workers - 17 cementers and 10 women of the mechanical machinist department who were used as controls. Records were made of each of the 3 above indicated reactions; the total of records thus made amounted to 3,700. A comparative study of the average values of the 3 reaction rates disclosed no noteworthy differences between the groups prior to and after work. In the case of the so-called complex reactions and their conversion certain peculiarities were noted: the number of persons with determination errors, the number of total errors and, consequently, the average of errors per test person differed in these 2 groups. The controls or mechanical workers manifested no determination errors, whereas, the reverse was the case in most of the rubber cement workers. In the case of the complex conversion reaction 4 of 10 workers manifested determination errors only towards the end of the day; on the other hand, 15 of the 17 rubber cement workers notably manifested errors of determination. The average of errors manifested per rubber cement worker amounted to 30% as compared with 10% in the case of the control women mechanics. Errors which occurred in connection with the complex conversion reactions indicated that the balance and mobility of the nerve processes were disturbed. Such disturbances may have been the result of the development of defense inhibition. After some rest such conditions disappeared and the 3 type reactions ran their normal course, free from errors, at the beginning of a new work day. The above mentioned disturbances

in the nerve reaction balance and mobility were more sharply expressed and were manifested not only in the complex conversion reactions but in the light differentiation complex reactions. In most workers of this type the disturbances persisted even after a rest period. It would seem, therefore, that more or less permanent disturbances occurred in the cortical processes of the rubber cement workers manifested basically in the form of disturbed mobility, weakened internal arrest or inhibition elicited by the prolonged dichlorethane vapor effect.

As was indicated above, the women rubber cement workers had to perform a considerable number of monotone, oft-repeated motions which called for considerable muscular exertion. A study of the muscular force and endurance among the rubber cement workers showed that the average muscle power was somewhat below that of the women mechanics, and that their endurance was approximately 50% of the endurance of the women mechanics. It was noted that the muscular force and work endurance among the women rubber cementers decreased with the increase in the duration of employment. The work endurance increased towards the end of the day in the women mechanics whose work was not accompanied by any considerable hand muscle exertion. The reverse was the case in the women rubber cement workers regardless of the time of employment. Thus, the study brought into evidence clear-cut shifts in the functional state of the motor apparatus of the upper extremities, which must have been closely connected with the labor conditions.

The next phase of the study included a survey of the general health of the workers, and analysis of morbidity and loss of working time (according to Form 3-1), for the period of 1951 - 1955 inclusive. The results of this study show that the morbidity index among workers employed in the soft tank department was higher than in any other department; the same was true of the days lost due to incapacity to work. In the section of the soft tank making morbidity due to gastro-intestinal diseases, neuritis, radiculitis, etc. was greater than among workers of the factory as a whole through all the years studied, as is shown by the data presented in Table 1.

A closer analysis of the morbidity rate and days lost due to incapacity for 1954 - 1955 disclosed a frequent occurrence of gastro-intestinal, liver, biliary apparatus, muscle, tendon and ganglionic diseases, as can be seen in Table 2.

T A B L E 1.

Year		Total morbidity		Acute gastro-enteritis		Neuritis and radiculitis		Other diseases	
		Per 100 workers							
		Through-out the plant	In the section	Through-out the plant	In the section	Through-out the plant	In the section	Through-out the plant	In the section
1951	Cases	120.2	159.8	5.1	11.6	5.2	13.0	34.4	43.2
	Days	995.8	1445.5	19.3	43.5	59.9	127.0	354.2	541.8
1952	Cases	124.0	137.6	4.2	5.7	5.0	9.7	34.0	40.8
	Days	960.9	996.0	15.1	23.1	44.8	94.5	335.2	378.7
1953	Cases	135.6	163.9	14.4	6.2	7.5	16.5	35.3	53.5
	Days	1040.8	1236.5	15.6	19.1	67.3	146.0	338.3	524.0
1954	Cases	150.7	191.8	5.3	9.6	7.9	16.7	40.8	63.8
	Days	1175.9	1563.2	19.3	31.8	73.8	182.8	386.4	596.2
1955	Cases	127.6	176.6	3.6	5.0	5.9	10.3	37.9	63.3
	Days	978.4	1462.4	12.1	15.3	51.1	90.2	345.7	640.5

T A B L E 2.

Year	Liver and biliary duct diseases		Acute gastritis		Chronic gastritis		Muscular, tendon and gangliar affections	
	Per 100 workers							
	Cases	Days	Cases	Days	Cases	Days	Cases	Days
1954	21	251.5	13	64.5	6	45	48	170
1955	24	290.0	8	27.0	3	14	8	50

The occurrence of liver and biliary tract diseases can be regarded as the result of specific dichlorethane toxic effect. Dyspeptic manifestations noted in dichlorethane poisoning had been diagnosed frequently as gastritis. Such diseases as myalgia, myocitis, myofasciculitis, tendovaginitis of the upper extremities, etc. may be the result of the particular monotype motions used in spreading and rolling on of the rubber cement.

Results obtained from statistical morbidity analysis confirm the results of special medical examinations of the general health conducted by physicians of the Department of Occupational Diseases of the Central Institute of Post-Graduate Medicine. Eighty-three women rubber-cement workers were thus examined, with the following results: liver and bile tract diseases, 19 workers;

state of neuroses in 13 workers; vegetative dystonia in 11 workers; -state of asthenia in 5 workers; goiter (struma) and hyperthyriosis in 10 workers. Diseases of the upper extremities motor apparatus such as neuromyalgia, myofasciculitis, tendovaginitis, angioneurosis, etc. were seen in 67.8% of the examined workers. The results of the above described medical examinations lead to the conclusion that prolonged effect of dichlorethane vapor in concentrations approaching the allowable limit or in concentrations slightly exceeding the allowable limit elicited clear-cut changes in the function and general condition of the liver, and the nervous system so characteristic of dichlorethane poisoning. According to data found in the literature the presently adopted limit of allowable dichlorethane concentration can not be regarded as rationally founded; it was also noted that workers exposed to dichlorethane concentrations approaching the allowable limits manifested clearly expressed disturbances of general health. Results of supplemental investigations of the higher nervous activity in rats exposed to dichlorethane concentrations of 0.05 - 0.01 mg/li 4 hours daily over 6 months confirmed the above observation. Thus, it was established that dichlorethane in 0.05 mg/li concentration elicited clear-cut changes in the conditioned reflex activity several days after exposure without showing any clinical symptoms of intoxication. Changes in the conditioned reflex activity of all animals appeared in the form of extended latent period, weakening of the response reaction to bell ringing and to light, reflex falling out, differentiation disruption, and in the appearance of compensating and paradoxical phases. Animals exposed to 0.01 mg/li dichlorethane concentration also showed signs of disturbed conditioned reflex activity which appeared 3 months after exposure in a weaker form than in animals exposed to 0.05 mg/li dichlorethane vapor.

The disturbances in the conditioned reflex activity of the rats above described reflect a lowered functional capacity of the nervous cells as a result of animal exposure to the effect of dichlorethane vapor which caused a weakening in the process of active internal inhibition. Normalization of the conditioned reflex activity of rats exposed to 0.05 mg/li of dichlorethane vapor appeared 3 months after exposure to the vapor was discontinued; in rats exposed to 0.01 mg/li of dichlorethane vapor normalization of conditioned reflex activity appeared 7 - 10 days after exposure discontinuation.

An attempt was made to establish possible connection between the functional disturbances in the higher nervous activity of rats and the morphologic changes

in the brain cortex. In this connection a study was made of the interneural association (bonds) which represent (constitute) the structural basis of the most delicate processes of cortical activity. According to records found in the literature disturbances in the interneural bonds are the earliest and most sensitive indexes of the organism's reaction to external influences. (S. A. Sukhanov, A. D. Zuradashvili, M. S. Tolgskaya, and others). In summary it can be stated that exposure of rats to the inhalation of air containing 0.05 and 0.01 mg/li of dichlorethane caused disturbances in the interneural connections in the brain cortex which appeared in the form of changes in the protoplasmic processes of nerve cells. Such changes were of a reversible character and disappeared after the conditioned reflex activity returned to normal, as can be seen in Figs. 2 and 3.



Fig. 2.



Fig. 3.

In 0.01 mg/li concentration dichlorethane elicited ill-defined changes in the conditioned reflex activity which appeared at the end of 3 months exposure and which disappeared within 7 to 10 days after exposure, a relatively short period of time. The disturbances in the interneural connections also disappeared in this short time; therefore, it is concluded that 0.01 mg/li constituted a near threshold concentration. A comparison of the experimental re-

sults with the results obtained from the study of morbidity and loss of time due to incapacity among workers employed in the production of the pliable tanks clearly indicated that the presently adopted limit of dichlorethane concentration in the air of working premises should be substantially lowered.

Conclusions.

1. It is recommended that the limit of allowable concentration of dichlorethane in the air of working premises should be lowered to 0.005 mg/li. In view of the fact that it might be practically impossible to lower the dichlorethane concentration in the air of this type of working premises, it is recommended that dichlorethane as a solvent be replaced by another less toxic solvent.

2. In the interim, and on a temporary basis, rubber cement coating of the rubber sheets should be done under a hood.

3. The volume of ventilation air supplied to the tank coating room should be increased in accordance with the total dichlorethane vaporization. It is recommended in particular that the rate of inflowing ventilation air be increased and that the floor grates over the exhaust conduits be moved away from the tanks.

4. The exhaust ventilation system should be reorganized so that dichlorethane vapor would be removed more efficiently from the tank-making rooms and especially from the points normally representing the workers' position. In rearranging the exhaust ventilation system consideration should be given to numerous factors, most important of which is the variable use of dichlorethane in the course of the shift.

5. Those working inside the tanks should mandatorily wear respirators and in addition fresh air should be constantly supplied.

6. The process of coating tank walls with rubber sheets should be mechanized and the manual application be discontinued.

7. Measures should be taken to prevent disturbances of the neuro-muscular apparatus of workers upper extremities; to this end it is recommended that washrooms be installed next to the workrooms, and workers be taught to massage their hands and arms.

8. It should be recommended to the VTsSPS that, in view of the dangers which accompany the manufacture of pliable tanks, as above indicated, the work day in this industry be reduced to 6 hours.

Bibliography.

Барабин В. И., К клинике отравлений дихлорэтаном, Военно-санитарное дело, 1941, № 9, стр. 52—54. — Брыжин Ф. Ф., Патоморфологические изменения внутренних органов при отравлении дихлорэтаном через пищеварительные пути, Фармакол. и токсикол., 1945, т. VIII, № 5. — Давыдова Г. Н., Клинические наблюдения над острым отравлением дихлорэтаном, Сб. научных работ за годы Отечественной войны Ленинградского института гигиены труда и профзаболеваний, Л., 1945, стр. 165—167. — Дорофеев М. П., Лобанов А. А., Павлов Н. Н., К вопросу ингаляционного действия дихлорэтана, Военно-медицинский журнал, 1952, № 9, стр. 47—49. — Лазарев Н. В., О силе наркотического действия паров хлорзамещенных производных метана, этана и этилена, Журнал экспериментальной биологии и медицины, 1929, 33, 319. — Ларионов Л. Ф., К вопросу о минимальных токсических концентрациях хлорзамещенных углеводородов при хронических отравлениях, Сб. Экспериментальные исследования по промышленным ядам, Ленинградский Институт гигиены труда и профзаболеваний, Л., 1936, в. XXV. — Розенбаум Н. Д., Дихлорэтан как промышленный яд, Гигиена и санитария, 1947, № 2, стр. 17. — Трибук С. Л., Шахновская С. Б., Уланова И. П., Малиновская Н. М., Кранцфельд В. Д., Вопросы гигиены труда при применении хлорированных углеводородов, Научная сессия, посвященная 30-летию Института гигиены труда и профзаболеваний АМН СССР 23—28 ноября 1953, Тезисы докладов, стр. 81—84. — Штейнберг Г. Б., Вопросы гигиены труда в производстве синтимицина, Гигиена и санитария, 1956, № 1, стр. 50—53.

The Toxicity of Aromatic Hydrocarbons.

1. Comparative Toxicity of Some Aromatic Hydrocarbons.
2. Some Problems of the Toxic-Hygienic Properties of Aromatic Hydrocarbons. (Abstract)

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Trudy Voronezh. Med. Inst., 35, 247-255, 257-262, 1958.

Tests were made by the method of acute experimental intoxication of laboratory animals. The results showed that lethal doses of benzene in mg/li were for mice 45 and for rats 60; toluol, for mice 35 and for rats 50; ethylated benzene, correspondingly 50 and 70; for a mixture of xylol isomers, 55 and 75; and for styrole, 45 and 55. Threshold doses in mg/li affecting the central nervous system were: for benzene - 1.5; for toluol - 1.0; for ethylated benzene - 0.75; for xylol isomers - 0.75; and for styrole - 0.62; for diisopropylbenzene the dose was 0.62. Concentrations which caused the experimental animals to fall on their sides were for mice: benzene - 15; toluol - 10; ethylated benzene - 15; xylol isomers - 20; styrole - 10. DL_{50} for mice were: benzene - 30; toluol - 25; ethylated benzene - 35.5; xylol isomers - 39; styrole - 34.5. Toluol possessed the highest toxic properties and styrole and diisopropylbenzene the lowest. It was believed that the active toxicity of benzene in the order of the homologues decreased from the higher to the lower homologues and

that average toxicity at low concentration levels accorded more with the principle of Richardson than at the levels of lethal and narcotic concentrations. Results of intragastric administration showed that absolute lethal doses were in g/kg: for benzene - 10; for toluol - 8; for ethylated benzene - 6; for xylol isomers - 9; for styrole - 8 and for diisopropylbenzene - 10. Results of tests with fresh water fish of different species exposed for 24 hours showed the following absolutely lethal concentrations in mg/li: benzene - 45; toluol - 55; ethylated benzene - 60; xylol isomers - 55, and styrole - 45. In the latter case it appeared as if the hydrocarbon toxicity decreased with the increase in the molecular weight and with lesser degree of solubility in water. Results of organoleptic studies of water polluted with hydrocarbons indicated that the odor and taste intensity ran parallel to the molecular weight and that the practical threshold of water taste perception was below the odor perception threshold. The practical threshold of taste and odor perception of hydrocarbons in water were not very far apart; in mg/li concentrations they were as follows: for benzene - 2.1 and 7.1; for toluol - 1.1 and 2.9; for ethylated benzene - 0.1 and 0.2; for xylol isomers - 0.6 and 0.8; for styrole - 0.08 and 0.19; and for diisopropylbenzene - 0.25 and 0.25. It is suggested that the present limits of allowable hydrocarbon concentrations in the air of working premises were set at too high levels and that they should be revised and brought down to lower levels.

The Effect of Colloids on the Accuracy of Photocolorimetric Determinations.

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(Leningrad Institute of the Refrigeration and Dairy Industry).

Zhurnal Prikladnoi Khimii, Vol. 25, No. 6, 634-639, 1952.

In this paper are presented results of a study made for the purpose of determining the effect of small quantities of colloids on the accuracy of photocolorimetric determinations. The authors were primarily concerned with solutions which visually appeared as true solutions, that is, they appeared as optically blank media but actually contained small quantities of colloids which imparted to the medium a degree of optical activity. Our investigations showed that the presence of small quantities of colloids produced considerable optical distortion which was responsible for erroneous photocolorimetric determinations. Investigators in the field of visual colorimetry proposed many correction formulas for use in colorimetric determinations of colored colloid-dispersed systems. Among such are formulas proposed by Nikitin, Slesarev, Uspenskii and Shemyakin [1], Inkler, Kobr [2], and others. However, none of these authors studied the effect of colloids on the accuracy of colorimetric determination.

Experimental part. The following non-ferrous salts were used which cover the entire color spectrum, from the red to the violet: $\text{CoSO}_4 \cdot 7\text{H}_2\text{O}$ - red; $\text{K}_2\text{Cr}_2\text{O}_7$ - orange; K_2CrO_4 - yellow; $\text{NiSO}_4 \cdot 7\text{H}_2\text{O}$ - green; $\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$ - blue; and $\text{KCr}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$ - violet. The observing investigator was first examined for sensitivity to different colors; the photocolorimeter used in the investigation was similarly checked. The test for eye sensitivity to colors was conducted as follows: two identical test tubes were used; water was poured into one of them and the different salts under investigation in 0.02 mol. was placed in the other. The colored salt solution was gradually diluted to the point where the difference between the color of the water-containing tube and the one containing the salt was no more perceptible. The comparison between the 2 tubes was made visually with the aid of an Ozimov optical compensator [3]. The same procedure was used in checking the colorimeter. The Ozimov testing photocolorimeter [4] was used throughout the entire study. Curves in Fig. 1 are plots of eye and photocolorimeter sensitivity to the different spectral colors. The points plotted were averages of several de-

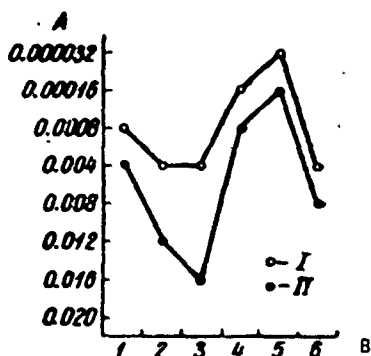


Fig. 1. Limit of eye and photocolormeter sensitivity in relation to solution concentration.

A - Molar concentration of solution; B - Solution color.
 1 - Violet - $\text{KCr}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$;
 2 - Blue - $\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$;
 3 - Green - $\text{NiSO}_4 \cdot 7\text{H}_2\text{O}$; 4 - Yellow - K_2CrO_4 ; 5 - Orange - $\text{K}_2\text{Cr}_2\text{O}_7$; 6 - Red - $\text{CoSO}_4 \cdot 7\text{H}_2\text{O}$.
 I - Limit of photometer sensitivity; II - Limit of eye sensitivity.

terminations. The results show a close agreement at all points between the eye sensitivity and the sensitivity of the selenium photoelement. Some discrepancies can be explained by the fact that the colors of mineral salts did not possess the characteristics of pure spectral colors. Highest sensitivity was found in the interval of the yellow and orange colors, both for the eye and for the selenium photoelement.

The above control study was followed by a study of pure mineral salt solutions and of the same solutions to which colloids were added. The colloid-dispersion phase was attained with the aid of BaCl_2 . This was accomplished as follows: to 10 ml of the solution 1 or 2 drops of a solution of BaCl_2 was added. Solutions of $\text{KCr}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$, $\text{NiSO}_4 \cdot 7\text{H}_2\text{O}$ and $\text{CoSO}_4 \cdot 7\text{H}_2\text{O}$ were made in a 1% sulfuric acid solution; solutions of $\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$, K_2CrO_4 and $\text{K}_2\text{Cr}_2\text{O}_7$ were made in a 1% K_2SO_4 solution. The BaCl_2 solution was prepared so that 1 drop in the presence of the SO_4^{--} ion contained 6.77 γ BaSO_4 and 2 drops contained 13.54 γ of BaSO_4 . Assuming that the solubility of BaSO_4 in 100 ml of water is equal to $2.4 \times 10^{-4} \text{ g}$ then the solubility of BaSO_4 in 10 ml of the solution was equal to 2.4 γ . Accordingly, in 10 ml of the solution BaSO_4 in colloidal dispersion resulting from the addition of 1 drop of the BaCl_2 solution should contain $6.77 \gamma - 2.4 \gamma = 4.37 \gamma$, and from 2 drops it should have $13.54 \gamma - 2.4 \gamma = 11.14 \gamma$. Denser dispersion concentrations of BaSO_4 were not considered suitable, since upon the addition of a third drop of the BaCl_2 solution opalescence appeared visible even to the naked eye, which made it unsuitable for photocolormetric study. The purpose of this study was to establish the effect of colloidal systems not visible to the naked eye. To attain this light absorption determinations were made for true solutions of the colored mineral salts with and without the addition of BaSO_4 . Solution concentrations ranging between 0.004 and 0.04 mol. were used in this investigation.

1) In the red light region and with a solution of $\text{CoSO}_4 \cdot 7\text{H}_2\text{O}$ (Fig. 2). A pure $\text{CoSO}_4 \cdot 7\text{H}_2\text{O}$ concentration within the range of 0.004 to 0.04 mol. yielded

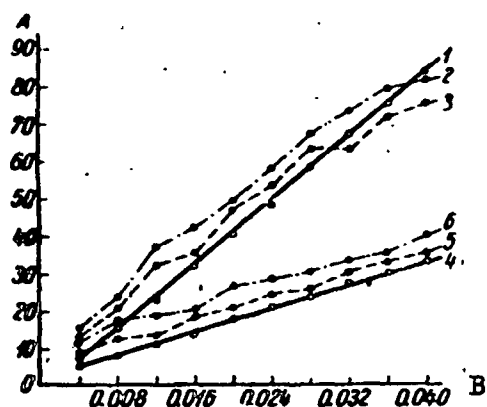


Fig. 2. Light absorption in the region of red ($\text{CoSO}_4 \cdot 7\text{H}_2\text{O}$) and green ($\text{NiSO}_4 \cdot 7\text{H}_2\text{O}$) lights. A - Galvanometer readings; B - Molar per liter concentrations. 1 - Pure solution of $\text{CoSO}_4 \cdot 7\text{H}_2\text{O}$; same with added BaSO_4 ; 2 - 11.14 γ ; 3 - 4.37 γ ; 4 - Pure $\text{NiSO}_4 \cdot 7\text{H}_2\text{O}$ solution and with added BaSO_4 ; 5 - 4.37 γ ; 6 - 11.14 γ .

therefore, the curve plotted had a considerably lower inclination slope. Errors caused by the addition of BaSO_4 were of greater magnitude in the green light region than in the red light region. Highest error occurred upon the addition of 4.37 γ of BaSO_4 and was equal to +110%.

TABLE 1.

Precision of determination in relation to concentration of $\text{CoSO}_4 \cdot 7\text{H}_2\text{O}$ solution.

Test No.	Molar concentration		Percent of error	Molar concentration	
	$\text{CoSO}_4 \cdot 7\text{H}_2\text{O}$	$\text{CoSO}_4 \cdot 7\text{H}_2\text{O} + 4.37 \gamma \text{BaSO}_4$		$\text{CoSO}_4 \cdot 7\text{H}_2\text{O} + 11.14 \gamma \text{BaSO}_4$	Percent of error
	Computed	Found		Found	
1	0.004	0.007	+75.0	0.008	+100.0
2	0.008	0.010	+25.0	0.013	+62.5
3	0.012	0.0165	+37.5	0.019	+58.1
4	0.016	0.017	+5.5	0.022	+37.5
5	0.020	0.023	+15.0	0.025	+25.0
6	0.024	0.025	+4.1	0.027	+12.5
7	0.028	0.030	+7.1	0.032	+14.2
8	0.032	0.030	-6.3	0.035	+9.3
9	0.036	0.033	-8.4	0.038	+5.5
10	0.040	0.036	-10.0	0.039	-2.5

T A B L E 2.

Precision of determination in relation to concentration
of $\text{NiSO}_4 \cdot 7\text{H}_2\text{O}$ solution.

Test No.	Molar concentration		Percent of error	Molar concentration	
	$\text{NiSO}_4 \cdot 7\text{H}_2\text{O}$	$\text{NiSO}_4 \cdot 7\text{H}_2\text{O} + 4.37 \gamma \text{BaSO}_4$		$\text{NiSO}_4 \cdot 7\text{H}_2\text{O} + 11.14 \gamma \text{BaSO}_4$	Percent of error
	Computed	Found		Found	
1	0.004	0.0084	+110.0	0.014	+250.0
2	0.008	0.0128	+60.0	0.020	+150.0
3	0.012	0.0138	+15.0	0.022	+83.3
4	0.016	0.0204	+27.5	0.024	+50.0
5	0.020	0.0432	+16.1	0.032	+60.0
6	0.024	0.028	+16.5	0.034	+41.6
7	0.028	0.0284	+1.42	0.036	+28.0
8	0.032	0.036	+12.5	0.040	+25.0
9	0.036	0.039	+8.3	0.042	+16.6
10	0.040	0.042	+5.0	0.042	+16.6

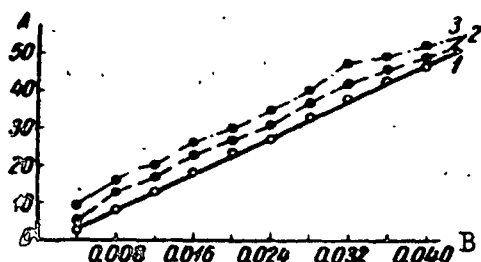


Fig. 3. Light absorption in the region of the blue light $[\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}]$.

A - Galvanometer readings;
B - Molar per liter concentration.

1 - Pure $\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$ solution and with added BaSO_4 ;
2 - 4.37 γ ; 3 - 11.14 γ .

3) In the region of the blue light, with a solution of $\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$ (Fig. 3). The curve of light absorption in the case of $\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$ occupied an intermediate position between the 2 previous curves. Highest error was recorded upon the addition of 4.37 γBaSO_4 which was equal to 50%, and upon the addition of 11.14 γ of BaSO_4 it was equal to +125%. Correspondingly, the lowest errors were +5% and +16.6% (Table 3).

4) In the region of the yellow light with solution K_2CrO_4 (Fig. 4). The outstanding characteristic of the K_2CrO_4 curve of light absorption was its low slope which may have been due to the fact that yellow light possesses a high degree of permeability. Eye and selenium photoelement color sensitivity were highest in this spectral region, which affected the nature of the errors; unlike in the instances of the red and green lights, errors in the yellow spectral region increased with concentration increases, within the limits of 0.02 and 0.028 mol. Highest error upon the addition of 4.37 γ of BaSO_4 was +100% at 0.02 mol. and at concentration 0.004 mol. the

TABLE 3.

Precision of determination in relation to concentration
of $\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$ solution.

Test No.	Molar concentration		Percent of error	Molar concentration		Percent of error
	$\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$	$\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O} +$ 4.37 γ BaSO ₄		$\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O} +$ 11.14 γ BaSO ₄		
	Computed	Found		Found		
1	0.004	0.006	+50.0	0.009	+125.0	
2	0.008	0.012	+50.0	0.014	+75.0	
3	0.012	0.015	+25.0	0.018	+50.0	
4	0.016	0.019	+18.7	0.024	+50.0	
5	0.020	0.024	+20.0	0.026	+30.0	
6	0.024	0.026	+8.3	0.030	+25.0	
7	0.028	0.031	+10.7	0.034	+21.4	
8	0.032	0.035	+9.3	0.041	+28.1	
9	0.036	0.038	+5.5	0.042	+16.6	
10	0.040	0.042	+5.0			

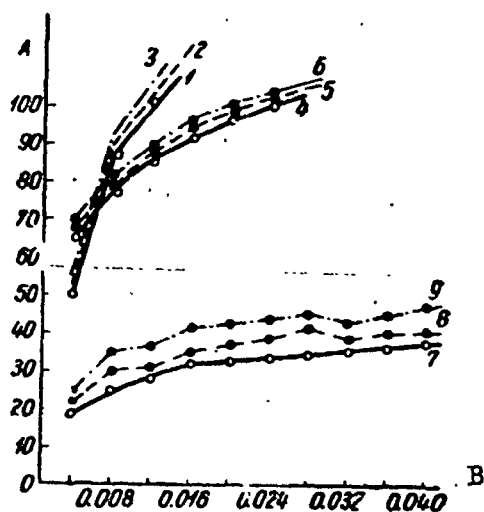


Fig. 4. Light absorption in the region of the yellow (K_2CrO_4) and orange ($\text{K}_2\text{Cr}_2\text{O}_7$) colors.

A - Galvanometer readings; B - Molar per liter concentration.
1 - Pure $\text{KCr}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$ solution and with BaSO_4 added; 2 - 4.37 γ ; 3 - 11.14 γ ; 4 - Pure $\text{K}_2\text{Cr}_2\text{O}_7$ solution and with added BaSO_4 ; 5 - 4.38 γ ; 6 - 11.14 γ ; 7 - Pure K_2CrO_4 solution and with added BaSO_4 ; 8 - 4.37 γ ; 9 - 11.14 γ .

error was +50%. The picture was much the same when 11.14 γ of BaSO_4 was added, in which case the corresponding errors were +75% and +200% (Table 4).

5) In the region of the orange color with solution $\text{K}_2\text{Cr}_2\text{O}_7$ (Fig. 4). This solution is characterized by a considerably higher degree of light absorption, as is evidenced by the greater slope of its curve. The errors produced by the addition of colloids are of considerably lower magnitude. Highest error upon the addition of 4.37 γ of BaSO_4 was equal to +24% and with the addition of 11.14 γ of BaSO_4 it was equal to +37.5%. Lowest errors correspondingly were +8.3% and +16.6% (Table 5).

6) In the region of the violet color with solution of $\text{KCr}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$ (Fig. 4). The solution of this color-producing metal-

T A B L E 4.

Precision of determination in relation to concentration
of K_2CrO_4 solution.

Test No.	Molar concentration		Percent of error	Molar concentration		Percent of error
	K_2CrO_4	$K_2CrO_4 +$ 4.37 γ $BaSO_4$		$K_2CrO_4 +$ 11.14 γ $BaSO_4$		
		Computed		Found	Found	
1	0.004	0.006	+50.0	0.007	+75.0	
2	0.008	0.014	+75.0	0.028	+250.0	
3	0.012	0.014	+16.6	0.036	+200.0	
4	0.016	0.032	+100.0	More than 0.040		
5	0.020	0.040	+100.0	"	"	"
6	0.024	More than 0.040		"	"	"
7	0.028	"	"	"	"	"
8	0.032	"	"	"	"	"
9	0.036	"	"	"	"	"
10	0.040	"	"	"	"	"

lic salt has a considerable degree of light absorption. The concentrations used in this experiment produced only 3 points as the basis for the light absorption curve. In this case the magnitude of errors was even lower than in the case of the orange light as was shown by the fact that upon the addition of 4.37 γ $BaSO_4$ it amounted to +20% and +6.6% (Table 5).

Photocolorimetric determinations of optically active color solutions should be made in the spectral regions in which highest light absorption occurs (red, orange, green, violet). The above assertion is made in the

T A B L E 5.

Precision of determination in relation to concentration
of $K_2Cr_2O_7$ and $KCr(SO_4)_2 \cdot 12H_2O$ solutions.

Tests No.	Molar concentration		Per- cent error	Molar con- centration		Per- cent error	Molar concentration		Per- cent error	Molar con- centration		Per- cent error
	$K_2Cr_2O_7$ and 4.37 gamma of $BaSO_4$			$K_2Cr_2O_7$ and 11.43 gamma of $BaSO_4$			$KCr(SO_4)_2 \cdot 12H_2O$ and 4.37 gamma of $BaSO_4$			$KCr(SO_4)_2 \cdot 12H_2O$ and 11.43 gamma of $BaSO_4$		
	Computed	Found		Computed	Found		Computed	Found		Computed	Found	
1	0.004	0.005	+25.0	0.055	+37.5	0.004	0.0048	+20.0	0.0056	+40.0		
2	0.008	0.009	+12.5	0.010	+25.0	0.008	0.0088	+10.0	0.0096	+20.0		
3	0.012	0.0125	+4.1	0.014	+16.6	0.012	0.0128	+6.6	0.0140	+16.6		
4	0.016	0.018	+12.5	0.020	+25.0							
5	0.020	0.022	+10.0	0.024	+20.0							
6	0.024	0.026	+8.3	0.028	+16.6							

form of a recommendation even though visual determinations could not be made to support it. To make determinations in accordance with the above recommendation it is necessary that the work be conducted with reagents which possess the above-mentioned colors. Under no circumstances shall recommendations be made to make colorimetric determinations in the region of the yellow color, due to the fact that errors of the highest degree occur in this region. It was pointed out above that with increase in the color intensity of the solution, that is, with the increase in the color reagent concentration, the error decreased, consequently, in the case of optically active systems it becomes necessary to work under a set of optimum conditions favorable to photocolometric determinations. This is equally true when light filters are used. The quality of colloid dispersion systems is affected by many factors such as aggregation, temperature, hydrolysis, etc.; therefore, deviations from the absorption curve of pure colored mineral salt solutions follow the course of a broken curve, indicating a degree of inconstancy.

Conclusions.

1. A study was made of the effect of colloid dispersion systems on the photocolometric determination of colored mineral salt solutions covering the entire light spectrum. The results showed that lowest errors occurred when the solutions employed possessed a higher degree of light absorption, that is, they were in the regions of the red, blue, and violet colors; conversely, greatest errors occurred in the region of low light absorption such as the region of yellow light.
2. In the presence of low concentrations of interfering colloids the determination error is correspondingly lower as the concentration of the colloid metallic salt increased.
3. In making colorimetric determinations of solutions herein dealt with it is necessary first to establish optimal conditions in every individual case; in other words, it is necessary to carefully choose the concentration in a way that the error might tend to approach zero.

Bibliography.

- [1] А. Успенский, Уч. зап. МГУ им. Ломоносова, LXXI, М. (1941). — [2] V. Kober, J. H. Colorimetry, 1 (1928). — [3] Б. В. Озимов, ЖПХ, XXIII, 4 (1950). — [4] Б. В. Озимов, ЖПХ, XXIII, 2 (1950).

Chromatographic Partitioning and Analysis of Methane Chloro Derivatives.

D. A. Vyakhirev and L. D. Reshetnikova.

Zhurnal Prikladnoi Khimii, Vol. 31, No. 5, 802-805, 1958.

The method of fractional redistillation (rectification) was most widely used in the analysis of derivative mixtures containing CH_3Cl , CH_2Cl_2 , CHCl_3 , and CCl_4 . The methods are time-consuming and lack precision. Recently infrared methods and mass-spectroscopy [1, 3] have been proposed for the analysis of mixtures of the above mentioned derivatives. However, the methods are highly complex and have not gained extensive practical recognition. Results of studies herein reported indicated that the chromatographic method proposed by Zhukhovitskii and his collaborators [4] in 1951 possessed the properties of simplicity, rapidity and adequate sensitivity. This method has been presently used in the determination of the content of simple hydrocarbons, such as CH_4 , C_2H_4 , C_2H_6 , C_3H_6 , C_3H_8 , C_4H_{10} , etc., in the air, in natural gases, in cracking gases and in pyrolysis of crude oil products [4 - 9]. The method is superior to the well known low temperature rectification method [10] because it is more accurate and less time-consuming.

Experimental part. The purpose of the experiment was to determine optimal partition parameters and to develop an analytical method applicable to industrial control. Experiments were performed with a chromatographic set-up

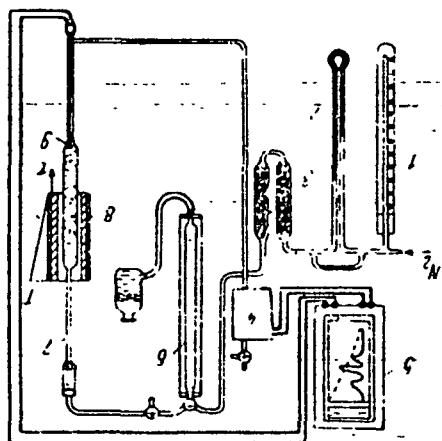


Fig. 1. Plan of the semi-automatic chromatographic gas analyzer.
1 - Manostat (manometer); 2 - Flow meter; 3 - Glass tube containing CCl_2 ; 4 - Gas analyzer GEUK-21; 5 - Automatically recording millivoltmeter; 6 - Gas burette; 7 - Chromatographic column; 8 - Movable heating unit; 9 - Thermocouple.

shown in Fig. 1. The system differed from previously described chromatographic systems [6 - 9] in that concentration and temperature curves were recorded automatically by an attached millivoltmeter SG-6 connected to the gas analyzer by means of heat conductor GEUK-21 and CU-NI constantum thermocouple. Use was made of a double thermocouple which made possible temperature measurements with an accuracy of $\pm 1^\circ$. The thermocouple was disconnected after optimum partition parameters were determined. Analysis was conducted as follows: the solution of the liquid component was taken up by a micropipette and deposited on the column through the upper wide open end; it was dis-

tributed through the absorbent by way of heat application and by passing a current of nitrogen. The gaseous methyl chloride or the sample of the derivative gas was measured in a burette and placed into the column accordingly. When the mixture under analysis reached the absorbent, the lower part of the feeding unit was connected with the thermocouple. This was followed by switching in the previously adjusted nitrogen flow, the movable mechanism of the heating unit and of the automatic recorder. This point was regarded as the beginning of the experiment. The ratio of the rate of the movable unit (v) to the rate of flow of the nitrogen gas (z) was kept constant during the experiment. However, it differed with each experiment. Upon leaving the column the gas was directed into 2 chambers of the gas analyzer via the heat conductor, while 2 other chambers were filled with nitrogen. The concentration of the analyzed mixture components were desorbed from the column by the action of 2 factors, the nitrogen flow acting as the developer, and the movable temperature field of the heating unit; the concentration was recorded on a movable tape by a millivoltmeter automatic recorder connected with the gas analyzer. Simultaneously the temperature curve was recorded on the same tape which made possible the measurement of the components' desorption temperature by means of which the order of the separation from the column and the optimum partition parameters could be established. The quantitative analysis was made on the basis of the curve peaks as shown below. Silicagels ASK, ASM, MSM and activated charcoals AP-3, AG-2 and KAD were tested as the sorbents; they were ground to particle diameters ranging between $d = 0.25 - 0.5$ mm and dried at 240° to constant weight. In addition silicagels ASK and MSM were used upon the recommendation of Professor A. A. Zhukrovitskii after preliminary treatment with concentrated hydrochloric acid and washing with a solution of KOH and distilled water, to obviate any possible catalytic influences. Several sorbents were prepared the active principle of which is based on the so-called steam phase partition chromatography [11]. Use was also made of kieselgur saturated with high molecular substances such as dibutylphthalate, nitrobenzene, tetralene, sunflowerseed oil and medicated vaseline. Substances studied were synthetic mixtures of chloromethane and gases produced during chlorination of methane. The primary substances used in the preparation of the synthetic mixtures were carefully purified by fractional distillation.

The selection of optimal conditions in the partitioning of each of the sorbents used was made by varying the following experimental parameters:

ratio $\eta = v/a$, the quantity of mixture placed into the column, the maximal heating unit temperature, the ratios between the mixture components, etc.

Results of investigations showed that partitioning of a mixture of chloromethanes containing 4 components attained different degrees with the different sorbents tested. In the case of activated charcoal the CHCl_3 and CCl_4 decomposed with the elimination of HCl and Cl_2 , indicating that this sorbent could not be used in the contemplated tests. Partial decomposition also occurred on the untreated silicagels MSM, ASM and ASK. This excluded the use of these 3 sorbents. Silicagels ASK and MSM, treated as previously described, satisfactorily partitioned the substances tested to a degree (incompletely). Tests were first made with CH_3Cl then with a mixture of CH_2Cl_2 and CCl_4 and finally with CHCl_3 . Fig. 2 depicts a typical chromatogram of a mixture of 4 synthetic components which was obtained with the use of purified silicagel MSM. Practically complete partitioning was obtained by the chromatographic method using kiselgur, which is diatomaceous earth, saturated with vaseline, as shown by the chromatogram depicted in Fig. 3. Analogous partitioning results were obtained with the same sorbent by the elution method, which agrees with the data of Parnell and Spencer [12]. It should be noted at this point that the latter authors added stearic acid to the vaseline. In the case of kiselgur saturated with vaseline the order of desorption was different, namely: 1) CH_3Cl , 2) CH_2Cl_2 ,

3) CHCl_3 and 4) CCl_4 , counting from the start of the experiment.

The content of each component in the mixed sample tested was proportional to the height of the corresponding peaks in the chromatograms [4, 6]. The calibrated curves obtained for each of the 4 chloromethanes are not presented for lack of space; sufficient to say that they were all of the nature of straight lines, which verifies the statement that the component content was proportional to the height of the peak. The suitability of the proposed analytical

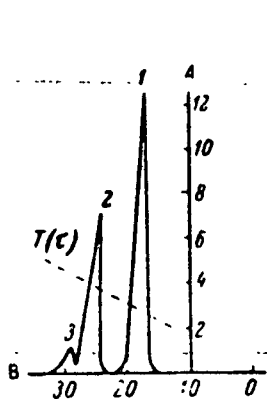


Fig. 2. Chromatogram of vapors of an artificial 4-component mixture partitioned on silicagel MSM. A - Tension in mV; B - Time in minutes. 1 - CH_3Cl ; 2 - CH_2Cl_2 plus CCl_4 ; 3 - CHCl_3 ; T (small tau) - Temperature curve.

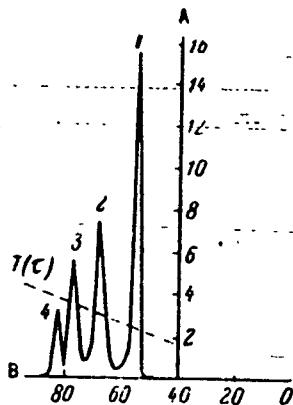


Fig. 3. Chromatogram of vapors of an artificial 4-component mixture partitioned on vaseline treated kiselgur. A - Tension in mV; B - Time in minutes. 1 - CH_3Cl ; 2 - CH_2Cl_2 ; 3 - CHCl_3 ; 4 - CCl_4 ; T (small tau) - Temperature curve.

method was checked with the aid of the aforementioned straight-line graphs constructed on the basis of chromatograms obtained with different samples of standard artificial mixtures. Data obtained with such check analyses using HCl and KOH treated MSM and kiselgur saturated with vaseline are shown in Tables 1 and 2; in the Tables q_1 and q_2 represent correspondingly the quantity of a given component used in the analysis and the quantity determined by the calibrated graph expressed in ml of vapor under normal conditions; δ is the relative error of the component determination in percent; α' is the volume rate of the nitrogen flow in ml/min; α is the linear rate of the nitrogen flow in cm/min; v is the rate of the heating unit movement in cm/min. The data in the Tables show that the average arithmetical error of chloromethane determination in the first case was in percent: CH_3Cl - 1.64, $\text{CH}_2\text{Cl}_2 + \text{CCl}_4$ - 1.84, CHCl_3 - 1.9; in the second case: CH_3Cl - 2.5, CH_2Cl_2 - 4.2,

TABLE 1.

Checking the method of analysis in which silicagel MSM was used as the adsorbent.

Optimal partition parameters: $\alpha' = 200$, $v = 0.8$; $\eta = 0.012$.

CH_3Cl			$\text{CH}_2\text{Cl}_2 + \text{CCl}_4$			CHCl_3		
q_1	q_2	δ	q_1	q_2	δ	q_1	q_2	δ
6.00	6.2	+3.30	6.30	6.40	+1.59	1.46	1.50	+2.70
14.09	14.0	-0.64	10.50	10.70	-1.90	1.38	1.33	-3.60
10.00	9.9	-1.00	4.33	4.50	+3.90	-	-	-
4.48	4.5	+0.44	4.90	4.96	+1.23	0.76	0.76	0
6.48	6.7	+3.40	3.47	3.50	+0.86	1.54	1.51	-1.95
7.38	7.3	-1.08	3.15	3.20	+1.59	1.40	1.38	-1.13

TABLE 2.

Checking the method of analysis in which vaseline treated kiselgur was used as the adsorbent.

Optimal partition parameters: $\alpha' = 70$, $v = 1.3$; $\eta = 0.058$.

CH_3Cl			CH_2Cl_2			CHCl_3			CCl_4		
q_1	q_2		q_1	q_2		q_1	q_2		q_1	q_2	
4.45	4.5	+1.1	3.80	4.0	+5.20	0.90	0.85	-5.5	0.42	0.39	-7.1
5.30	5.2	-1.8	4.18	4.2	+0.47	1.68	1.60	-1.7	-	-	-
6.00	6.2	+3.3	2.36	2.5	+5.80	0.90	0.90	0.0	0.70	0.68	-2.8
7.05	7.2	+2.1	3.80	4.0	+5.20	2.20	2.10	-5.0	0.42	0.40	-4.7
8.02	8.5	+4.3	4.60	4.4	-4.30	2.78	2.62	-5.7	0.71	0.70	-1.1

CHCl_3 - 4.2, CCl_4 - 4%. The quantities of the samples in the artificial fluid mixture ranged from 0.005 to 0.2 ml; these are indeed small quantities and the above indicated errors could be disregarded.

The above described chromatographic method for the differential determination of chloromethane is presently in use at one of the production plants for the control of the processes of methane chlorination.

Conclusions.

The basic advantage of the chromatographic method to be used in connection with chloromethane analysis is the rapidity (20 - 40 minutes); it also makes possible a differential determination in 0.005 - 0.2 ml of the fluid or in 5 - 30 ml of the gaseous phase; the procedure is strictly objective, since all records of analysis are made automatically in the form of chromatograms.

Bibliography.

- [1] P. F. Urone, M. L. Druschel, *Analyt. Chem.*, **24**, 625 (1952). — [2] R. B. Bernstein, C. P. Semeluk и B. Arends, *Analyt. Chem.*, **25**, 139 (1953). — [3] С. Е. Куприянов, Р. В. Джагацянни, В. М. Тихомиров, Н. И. Туницкий, *ЗЛ*, **21**, 1182 (1953). — [4] А. А. Жуховицкий, В. А. Соколов, О. М. Золотарева, А. М. Туркельтауб, *ДАН СССР*, **77**, 433 (1951). — [5] А. А. Жуховицкий, А. М. Туркельтауб и Т. В. Георгиевская, *ДАН СССР*, **92**, 937 (1953). — [6] И. М. Туркельтауб, В. П. Шварцман, Т. В. Георгиевская, О. В. Золотарева и А. И. Каримова, *ЖФХ*, **27**, 1827 (1953). — [7] Б. В. Айвазов, Д. А. Вяхирев, *ЖПХ*, **XXVI**, 505 (1953). — [8] Д. А. Вяхирев, А. И. Брук, С. А. Гузлина, *ДАН СССР*, **90**, 577 (1953). — [9] Д. А. Вяхирев, А. И. Брук, С. А. Гузлина, *ЗЛ*, **20**, 803 (1954). — [10] М. И. Деметьева, *Анализ углеводородных газов*, Гостоптехиздат, М.—Л. (1953). — [11] A. T. James, A. I. P. Martin, *Bioch. J.* **50**, 679 (1952). — [12] J. H. Purnell, M. S. Spencer, *Nature*, **175**, 988 (1955).

Colorimetric Determination of Benzene Losses.

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Koks i Khimiya, No. 2, 43-44, 1956.

The method herein recommended for the colorimetric determination of benzene losses is based on the comparison of standard colors produced by a solution of C_6H_6 in acetic acid with the color produced by benzene extracted from a gas with the aid of acetic acid. In the studies colorimeter KM-1 of the Leningrad Mechanical Technical Institute was used.

Sample collection. The coke gas was first freed of naphthalene, ammonia, hydrogen sulfide, carbon monoxide. It was then run into a flask of a known volume. Prior to running in the purified coke gas the air in the flask was exhausted to 350 - 400 mm of mercury. The air pressure within the flask was then equalized with the surrounding pressure as indicated by a water manometer. Following this 2 ml of a 50% acetic acid solution, 3 to 4 drops of hydrogen peroxide, and 5 ml of a 10% solution of nitric acid were added to the flask. The flask was then agitated for 5 minutes, and 2 ml of a 40% NaOH solution added and again agitated for 5 minutes. The flask was then allowed to rest for 10 minutes and distilled water added to make a total volume of 20 ml. It was then placed into a colorimetric cup for final colorimetric determination.

Preparation of the standard solution. Add 50 ml of acetic acid to a 100 ml volumetric flask; weigh accurately and add 0.1 ml of pure benzene; weigh again and determine the weight of benzene by difference; add acetic acid to the 100 ml mark. This is the standard benzene solution in acetic acid. It should be prepared anew for each shift. Add 0.25 ml of HNO_3 and 3 - 4 drops of hydrogen peroxide to 3 ml of the standard benzene solution and agitate for 5 minutes. Add 2 ml of 40% NaOH and again shake for 5 minutes. Leave stand for 10 minutes, add distilled water to make a total of 20 ml and place some of it into another colorimetric cup. The color will persist without change for the duration of a single shift. The concentration and light absorption readings of the standard benzene solution serve as the basis for the determination of the tested solution according to formula:

$$C_2 = \frac{C_1 H_1}{H_2 V_0}$$

in which C_2 is the benzene concentration in the gas under study, C_1 is the known concentration of benzene in the standard acetic acid solution, H_1 is the thickness of the reading column of the known solution, H_2 is the thickness of colorimetric reading of the solution tested, V_0 is the gas volume under normal temperature and pressure conditions taken for analysis. Results of tests made by the recommended method are shown in Table 1. Experimental results indicated the closeness of readings obtained by the activated charcoal and the colorimetric methods. Comparative data of actual tests made in August 1955 are presented in Table 2.

TABLE 1.

Comparison of methods for the determination of benzene loss with return gas.

Date	Shift	Cartridge (patron) benzene loss in g/hr/m ³	Aspirator benzene loss by colorimeter in g/hr/m ³					
			Analysis					
			1	2	3	4	5	
12/VIII	III	2.37	2.47	2.42	2.48	2.49	-	
13/VIII	I	2.42	2.43	2.42	2.48	2.44	2.44	
13/VIII	II	2.45	2.40	2.31	2.41	2.40	-	
14/VIII	III	1.98	2.02	1.98	1.97	2.02	1.98	
15/VIII	I	1.98	1.98	2.02	2.00	2.02	2.02	
15/VIII	II	2.49	2.35	2.33	2.36	2.40	2.40	
15/VIII	III	2.41	2.49	2.47	2.52	2.43	2.37	
16/VIII	I	2.21	2.29	2.19	2.33	2.28	2.21	
16/VIII	II	2.27	2.16	2.23	2.19	2.16	-	
16/VIII	III	2.35	2.42	2.32	2.32	2.27	2.34	
17/VIII	I	2.28	2.29	2.23	2.30	2.22	2.25	
17/VIII	II	2.15	1.98	2.06	2.02	2.07	2.10	
17/VIII	III	2.05	2.04	2.07	2.07	2.00	2.02	
18/VIII	I	2.32	2.30	2.34	2.39	2.40	2.31	
18/VIII	II	2.16	2.15	2.15	2.08	2.11	2.06	

Conclusions.

1. The recommended method of analysis can be accomplished within 30 minutes and, therefore, can serve as a better control procedure under industrial production conditions.
2. The colorimetric method for the determination of benzene loss yielded reproducible results.
3. The colorimetric method yielded results comparable with those yielded by the activated charcoal method.

T A B L E 2.

Benzene content in return gas in g/mm^3 as determined colorimetrically
and by the cartridge method.

Date	Shift	Determination method			
		Colorimetric		Activated charcoal cartridge	Differences between activated charcoal and shift averages
		Single test averages	Total shift averages		
13/VIII	I	2.37	2.44	2.42	+0.02
13/VIII	II	2.37	2.39	2.25	+0.14
14/VIII	III	1.92	1.99	1.98	+0.01
15/VIII	I	2.06	2.01	1.98	+0.03
15/VIII	II	2.34	2.32	2.24	+0.08
15/VIII	III	2.44	2.43	2.41	+0.02
16/VIII	I	2.28	2.25	2.21	+0.04
16/VIII	II	2.22	2.15	2.27	-0.12
16/VIII	III	2.35	2.47	2.35	+0.12
17/VIII	I	2.18	2.23	2.28	-0.05
17/VIII	II	2.10	2.11	2.05	+0.06
17/VIII	III	2.11	2.02	2.07	-0.05

Safe Starting of Blast Furnaces.

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This paper presents the results of tests made with a system of safe starting blast furnaces. The particular blast furnace under study had an inside capacity of 1,300 m³ and was inclosed by an all-welded jacket which made the furnace walls almost completely airtight. Conditions of smelting processes were recorded automatically by special devices. A plan of precautionary measures was worked out in advance. Just before starting the blast furnace and the gas purification equipment provision was made for round-the-clock vigilance of the plant's medical personnel and their assistants; some were stationed at the workers' platforms in front of the furnace. At the request of the regional industrial health officer the personnel of the gas rescue station of the plant were stationed at points of suspected danger from gas during the furnace starting. Laboratory tests were frequently made at suspected gas danger points.

The next stage in the precautionary plan for the prevention of occupational (gas) poisoning was a close study of the results checking the airtightness of the gas apparatuses and careful recording of the individual operations in the daily record after preliminary inspection of the system. Personal watching by the staff of the regional public health-epidemiologic station over assembling and preparation of the blast furnace assured early detection of faulty points in the construction of the furnace and made corrections possible long before the furnace was set into operation. Twenty minutes before the furnace was set into actual operation the gas rescue squad tested all points of possible gas hazard and removed persons whose presence was not required. The gas fitter, the blast furnace chief, and members the gas rescue squad remained at the furnace. Fifteen minutes after the furnace was started the gas rescue squad, equipped with KIP-5 apparatuses and torches, began to light up the gas in the tuyeres.

Previous experience with starting blast furnaces had shown that the blowing-in operation was the most crucial in the process, since the slag sealing of the cracks in the brickwork of the furnace proceeded gradually, and during

the first hours there was gas leakage through the furnace lining. The first analyses showed that the carbon monoxide in the air was only slightly in excess of the maximum allowable concentration. This was largely explained by the good quality of the furnace brickwork and also by the all-welded furnace jacket.

The prestarting period was completed satisfactorily, and no carbon monoxide poisoning occurred. Chief points at which systematic laboratory testing was done were the following: the location of the measuring-checking apparatus at the work table and behind the control panel, the Cowper platform, the platform at the cast-iron tap hole, the platforms at the upper and lower slag top holes, and the skip hoist location. Records were kept of several other points of possible gas danger and work at such points was permitted only in cases of extreme emergency, and the workers had to wear appropriate masks. Simultaneously, observations were made of the effects of wind direction and of the technological process on the intensity of carbon monoxide pollution. It was important to determine the correlation between these factors and the carbon monoxide concentrations at the operators' positions and in the region of the blast furnaces. Carbon monoxide determinations were made with the aid of a conductometric apparatus.

Of the 384 air samples taken at the blast furnace operators' platform 94, or 24.7%, were negative for CO. A carbon monoxide concentration of 0.03 - 0.1 mg/li was found in 184 samples, or 47.9%; 0.1 - 0.5 mg/li in 103 (26.8%), and more than 0.5 mg/li in only 2 samples. Air containing the highest CO concentration was found in the tuyere (holes) apertures. Thus, 27 of 36 samples collected in these locations contained carbon monoxide in excess of the permissible limit. In 44 of 86 samples taken in the slag tap holes the carbon monoxide concentration was high. At the Cowper platform the carbon monoxide concentration in 63 out of 89 samples was above the permissible limit. It should be noted that the lowest carbon monoxide concentration was found in the skip-hoist room, where carbon monoxide was found in only 1 sample in a concentration of 0.1 mg/li. The other samples contained no CO, or its concentration did not exceed 0.03 mg/li. One-hundred-and-one air samples were collected in the room containing the measuring-checking apparatus (or pyrometers). The results varied depending on the point of sample collecting.

As a result of measures taken for the prevention of poisoning, such as removal of personnel from the gas-polluted zone, opening door, window ventila-

tors and promptly informing the furnace department of points of suspected hazard, as required by the office of industrial health supervision, no cases of occupational poisoning were recorded.

In studying the degree of gas pollution at the operators' platforms, it was found that the gas pollution was definitely less in the rooms containing the measuring and control apparatus and in the skip-hoist room when the windows were wide open. At operators' platforms near the slag tap holes, cast-iron tap holes, and tuyere apertures, open windows had no effect on the carbon monoxide concentration in the air. The pollution of the air at the Cowper platforms and in the casting yard at the slag and cast-iron tap holes and tuyeres depended largely on the wind direction. Thus, when the wind was blowing from the dust catchers, the carbon monoxide concentration increased, and when it blew from the mine yard, it dropped, as the data in the Table below clearly indicate.

Place of sample collection	Percent of samples with high CO concentrations	
	With wind coming from mine yard direction	With wind coming from dust catchers direction
At the Cowper platform	70.0	84.2
At upper slag tap hole	61.4	100.0
At lower slag tap hole	66.6	100.0
At pig iron tap hole	69.5	100.0
At the tuyeres	72.4	85.7
In the skip-hoist room	50.0	100.0

An analysis of the findings indicated that the carbon monoxide concentration increased considerably during the tapping of the slag at all the points under study, whereas the gas concentration remained constant when the tap holes were closed and also before slag cast iron tapping. The gas pressure in the blast furnace also affected the CO concentration at the operators' platforms. Thus, with a low pressure in the furnace, carbon monoxide was discovered in 54.2% of samples taken in the checking-measuring apparatus room, and with high pressure, in 77.1%. With low pressure, carbon monoxide was discovered in 70% of the samples at the Cowper platform and with high pressure, in 79%. The same picture was observed at all other points at which samples were collected.

On the basis of the findings here presented, the industrial-health office of the regional public health-epidemiologic station recommended that

for the prevention of occupational poisoning and maintenance of sanitary work conditions at blast furnaces, the results of the study here presented should be evaluated and the recommended measures for the safe starting of a new blast furnace should be heeded.

The results of the study also indicated that:

1. The walls (fences) of the foundry yard must be kept open to permit maximum ventilation.
2. Ventilation must be provided on an on-the-spot basis to remove gas from the tuyere apertures and slag tap holes.
3. Cooled air must be supplied to the furnace workers platforms through appropriate air flow channels.
4. The construction of the platforms used for the removal of blast furnace dust should be modified to prevent the dust from being scattered over the blast furnace territory.
5. Windows facing the casting yard and Cowper platforms should be closed at the time blast furnace dust is being removed from the dust collectors.
6. Forced-draft ventilation should be installed in the space beneath the bunkers (bins).

Changes in wind direction at different seasons of the year should be observed and properly accounted for.

Standards for Maximum Permissible Dust Concentrations in the
Air of Working Premises. ^{1/}

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Gigiena i Sanitariya, Vol. 24, No. 12, 63-64, 1959.

A new and important document directed toward future improvement of sanitary-hygienic working conditions has contributed to U.S.S.R. public health legislation in the field of occupational hygiene and sanitation. However, some paragraphs dealing with regulations relative to dust in working premises call for broader and more precise definition. Under actual production conditions air in working premises may become contaminated with semi-dispersed aerosols. The size of dust particles in the air of working areas varies from submicroscopical to micro- and macroscopical. When norms are established as public health requirements, the term "dust" must be clearly defined. This should be done as a prerequisite when the permissible concentrations are established for mixed dusts occurring in the air of textile, cotton cleaning, jute, and like workshops.

Particulate matter suspended in the air of working premises of the above mentioned industries does not fall under the conventional definition of the term "dust". Air at workers' breathing level contains solid particles, the chemical composition and degree of dispersion of which are determined by the following sources of origin: a) soil and loess dust, and b) organic dust from raw cotton fibers, e.g., suspended particles of organic fibrous nature suspended in the air of working areas in cotton cleaning plants of 0.5 - 1 cm or more in diameter.

Studies of upper respiratory mucosa of workers in cotton cleaning plants and special experiments with animals indicated that fibrous particles of 0.5 - 1 cm penetrated into the upper respiratory passages and bronchi. Large organic dust particles comprised 50% of the total suspended dust. Finer dust particles are of mineral origin and the admixture of organic substances contained in them is not in excess of 5%.

^{1/} Maximum Permissible Concentrations of Poisonous Gases, Vapors, and Dust in the Air of Working Premises, approved by the Chief State Sanitary Inspector of the U.S.S.R., 10 January 1959, No. 279-59.

The silicon dioxide content in the dust of cotton cleaning plants differs with the degree of dispersion of the suspended particles. Thus, if air dust samples collected by standard methods contained 4 - 8% free silicon dioxide, the residual plant air dust content must not be allowed to exceed 4 mg/m^3 as the permissible maximum. Dust fractions having particles of diameters 100μ or less (corresponding to the generally accepted definition of the term "dust") generally contain 16 - 32% free silicon dioxide. In such a case, the maximum permissible dust content in the air of working premises must not exceed 2 mg/m^3 . In this connection it should be added that special studies indicated that dust fractions measuring 5μ and less in diameter, that is silico-organic fractions, contained 8.5% or less of free silicon dioxide. This raises the question, how to determine maximum permissible air concentrations of dusts having a complex chemical composition and containing large organic fibrous particles.

Analysis of dusts collected from the air by usual conventional methods does not accord with the concept of "industrial dust" which ordinarily contains large dust particles; one must use two methods on a parallel basis: 1) the standard method, and 2) a modified method proposed by this author which takes into account only particles of 100μ and less in diameter. It seems logical that future determinations of allowable dust concentrations in the air of shops be approached from the viewpoint of two dust fractions: one in which the particles are 100μ in diameter; and a second fraction the particles of which are less than 100μ in diameter. Standard sanitary requirements for certain dusts which contain large amounts of free SiO_2 and organic material depend upon the chemical composition. Results obtained by the proposed method of air pollution evaluation should offer a rational basis for the calculation of effective and adequate ventilation systems and installations.

Removal of Microorganisms from Air by the Filtration Method.

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Academy of Medical Sciences of the U.S.S.R.).

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Filtration appears to be the simplest method for air purification from microorganisms. Many authors described different methods of air filtration such as gauze, lignin, cinder, cotton, glass wool and other material filters which retain to different degrees air suspended microorganisms and viruses. The present author made a comparative study of the filtering capacity of U.S.S.R. filter type FP-5 and membrane filter No. 3. In the study herein reported membrane filters used in water filtration were tested for their suitability to purify air from suspended microorganisms. The filters were first sterilized by boiling and were then dried; wet filters could not be used because they proved to be practically impermeable to air. In determining the effectiveness of each filter tested, 2 series of investigations were made, each consisting of 20 individual tests. The first series was conducted under a laboratory hood which contained natural airborne microflora (the dust phase of bacterial aerosol). The second series was conducted in an experimental chamber 250 li capacity into which was dispersed 0.1 ml of a culture of Bact. prodigiosum in saline solution. The bacterial suspension contained 200 million of microorganisms per ml (the drop phase of bacterial aerosol). The bacterial aerosol of Bact. prodigiosum was in a fine state of dispersion, since the individual aerosol droplets ranged between 2 and 10 μ in diameter.

The filtration effectiveness (efficiency) in both series was tested as follows: air from the laboratory room, or from the experimental chamber, was aspirated through 2 filters in successive order: the first, or test filter, was of type FP-5 or membrane filter No. 3; the second, or control filter, of membrane No. 3. In this way the air was aspirated either through filter FP-5 and then through control membrane filter No. 3, or it was aspirated through test filter membrane No. 3 and through the same type of control filter. The control membrane filter No. 3 from either set-up was placed over the surface of nutrient agar, incubated, and the number of developed bacteria counted as

an indicator of the efficiency of the test filter. Simultaneously, determinations were made of the normal bacterial content in the air of each of the chambers. Filtration properties of FP-5 and membrane filter No. 3 were tested in each case on a parallel basis throughout a working day. The number of bacteria in the laboratory air examined varied between 600 and 3,500 per m³ of air. The average was 1,500 per m³ of air; sarcina, white and lemon-yellow staphylococci and gram positive spore-bacilli predominated. The concentration of Bact. prodigiosum in the experimental chamber air ranged between 29,000 and 30,000 in 250 li.

Two control analyses were performed in connection with each test for the determination of the total air-suspended bacteria in the laboratory or of the dispersed Bact. prodigiosum in the experimental chamber; in addition duplicate tests were made to determine the filter efficiency of FP-5 and of the membrane filter No. 3. The results of the investigation established that filter type FP-5 and membrane filter No. 3 retained the predominant part of the naturally-suspended or artificially dispersed bacteria in the air, that is, in the dust phase as well as in the bacterial aerosol drop phase. The bacterial retention by filter type FP-5, in the case of the laboratory room, ranged between 99.81 and 100%, with an average of 99.97%. In the majority of cases it amounted to 99.9 and 100%. The bacterial retention capacity of the membrane filters was equally high and ranged between 99.89 and 100%, with an average of 99.66%. In the case of the experimental room, that is, in the case of the artificially dispersed bacteria, the FP-5 filter type retained 100% of the bacteria in 19 of 20 tests; it amounted to 99.995% in the 20th case. Thus, the average was 99.998%. Under similar conditions the membrane filter retained an average of 99.978% of the dispersed Bact. prodigiosum culture. Some differences in the results obtained with the tests made in the open laboratory and in the experimental room may have been due to isolated instances of membrane filter contamination at the time of placing same over the agar medium; it was noted that such contamination had been occurring inadvertently. In filtering air from the open laboratory it was impossible to differentiate accidental contamination from bacteria which may have passed through the first filter. This was not the case with the aerosol drop phase of Bact. prodigiosum, since this specific organism has never been found among the airborne bacteria of the tested room.

The filters studied possessed a high degree retention of bacterial aerosol dust and drop phase contamination. A comparison of the bacterial retention capacity of type FP-5 and membrane No. 3 filters indicated that FP-5 filtration was more convenient, simpler and more of an air volume could be passed through it, because of its lower pressure drop (resistance to air permeability). Membrane filters possessed a high degree of bacterial retention, but their pressure drop (resistance to air permeability) was considerably greater. In addition they were very fragile. On the basis of the above, filter type FP-5 is recommended for use in ventilation conduits and in air conditioning apparatuses wherever air free from microorganisms is an essential requirement.

Conclusions.

1. Air filtration is the simplest method for the removal of air microorganisms.
2. The results of the present study showed that filter type FP-5 and membrane filter No. 3 possessed high retention capacities for bacterial aerosol dust as well as for bacterial drop phase aerosol. Filter type FP-5 retained an average of 99.998 and the membrane filter 99.978% of the Bact. prodigiosum drop phase aerosol and the bacterial dust aerosol.
3. Filters type FP-5 are more conveniently and more simply utilized in practice and are recommended as above indicated.

Bibliography.

- Городинский С. М. Мед. радиол., 1956, № 5, стр. 84—91. — Корняк-Чепурковская Н. Воен.-сан. дело, 1941, № 6—7, стр. 69—71. — Миллявская П. Ф. Труды Центрального дезинфекционного ин-та. М., 1947, в. 3, стр. 18—23. — Резник Я. Б. Врач. дело, 1951, № 6, стр. 533—538. — Шафир А. И., Коузов П. А., Паншинская Н. М. Гиг. и сан., 1953, № 9, стр. 23—28. — Шафир А. И., Паншинская Н. М., Синицкий А. А., Коузов П. А. и др. Тезисы докл. научн. конф. Ленинградского научн.-исследовательского санитарно-гигиенического ин-та по итогам работ института за 1955. Л., 1956, стр. 42—43. — Albrecht J. Arch. Hyg., 1957, Bd. 141, S. 210—216. — Decker H. M., Geile F. A., Harstadt J. B. a oth. J. Bact., 1952, v. 63, p. 377—383. — Goetz A. Ann. J. Pub. Health, 1953, v. 43, p. 150—159. — Kruse H. Gesundheitsingenieur, 1948, Bd. 69, S. 199—201. — McDaniel L. E., Long R. A. J. Appl. Microb., 1954, v. 2, p. 240—242. — Seifert H. E., Callison E. G. Air Condit. Heat a. Ventilal., 1956, v. 53, N. 4, p. 72—73. — Sykes G., Carter D. V. The sterilization of air. J. Appl. Bacter., 1954, 17, 2, 286—294.

Problems of Industrial Hygiene and Occupational Pathology in the
Practice of a Modern Physician.

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The prophylaxis in Soviet health conservation and protection constitutes an important trend in the development of sanitation and hygiene. It is emphasized in the Party's program and expresses the aspirations and hopes of most progressive members of the Russian medical profession. Positive health prophylactic action was the characteristic aspect of the time. Now, when the efforts of the Soviet people (under the guidance of the Communist Party), achieved great successes in the field of disease prevention, in death rate reduction and in the fight for longevity, medical practice should be placed on an even more rational basis so that the high quality medical service given to patients may be the result of a clear understanding of the importance of pertinent environmental factors related to the etiology of diseases, without which no serious work on prevention of diseases is possible. The thousands of Soviet physicians, whose practice is the treatment of sick people, must make prophylactic treatment an inseparable part of their practice.

The extent and character of environmental effects and working conditions on a person are profound. They are first sources of health, physical potency and many-sided harmonious development of man. To insure the proper and beneficial utilization of such effects is the most important task of prophylactic medicine.

Millions of Soviet citizens are working in plants and factories equipped with first-class technical facilities and millions are engaged in the production of farm crops. Achievements of Soviet science and industrial technique combined with untiring care for human welfare made working conditions considerably easier and healthier and safer, thus, lowering workers' morbidity and accidental and traumatic injuries. This is confirmed by statistical reports. The following are data on workers' morbidity in the large Fongauz oil processing plant. If the number of disease cases in 1944 be designated by the index number of 100, then in 1949 it was reduced to 82, in 1954 to 71 and in 1956 to 58. The occurrence of diagnosed diseases on the same index

basis ran as follows: purulent skin diseases reduced from 10.1 in 1944 to 3.1 in 1956; acute gastrointestinal diseases were reduced accordingly from 16.1 to 1.6, and pneumonia from 2.6 to 0.6. Just as convincing are data on the reduction of industrial traumatism in "Azovstal", one of the largest metallurgical plants. In 1949 there were 9.8 cases of traumas and 133 work days lost per 100 workers due to disability; in 1950 there were only 5.6 cases and 75.8 days lost, and in 1957 they were reduced to 3 cases and 47.4 days, according to N. Sementin and T. Terent'eva.

Nevertheless, the December Plenum of the TsK K.P.S.S. made mandatory "further improvement in actual working and sanitary conditions of production establishments, the elimination of causes resulting in traumatism and sickness of workers on a broad national basis". The entire Soviet health protection system should obligate itself to participate in attaining this national goal. It is wrong to assume that only a certain part of our system of health protection, namely the institutions dealing with sanitary-epidemiological problems, should participate in this work. In every field of medical activity, in clinics and rural medical districts, in hospitals and polyclinics, in dispensaries and medico-sanitary stations of industrial enterprises the effect of working conditions on a person's health should be well accounted for as a requisite for the national realization of therapeutic-prophylactic measures. In some cases these measures may be directed toward the improvement of working conditions, in some toward the achievement of higher degrees of the organism's resistance to the effects of environmental factors, and in others, toward forbidding persons highly susceptible to the effect of certain work conditions to be employed on jobs where such work conditions prevailed. The uninterrupted process of scientific and technical development made it possible to eliminate or considerably reduce the effects of series of environmental factors on the workers, or to eliminate almost completely the occurrence of some occupational diseases. There are no more grave cases of overheating, or so-called spastic or convulsive diseases; nystagmus cases have become infrequent among mine workers, etc. However, much more remains to be done for the complete liquidation of occupational afflictions.

Much has been achieved technically which particularly affected labor productivity, eased the toil of workers in many occupations and brought into focus the question of finding means to prevent unfavorable effects of industrial environmental factors. For example, extensive and extremely effective

adaptation by the coal industry of new and perfected machines, such as the coal combines, which immeasurably eased the miners' work; on the other hand, it created the problem of possible effects on workers by the intensive dust formation, vibration, noise, etc. P. I. Tal'yantsev in his dissertation "Basic Problems of Labor Hygiene in Subterranean Mining Operations" (1958) clearly indicated that during the operation of some types of coal combines the dust concentration in the air reached 400 - 500 mg/m³, the noise intensity measured up to 100 - 104 decibels, and the vibration effects were considerable.

The questions with which medical and sanitary authorities are faced are: what environmental and work factors require particular and immediate attention of physicians, what forms of occupational diseases should be considered first? No attempt will be made to present all the possible factors in industrial surroundings which can affect the health of workers where insufficient attention is now being paid by engineers and physicians to health protection problems; only the most essential ones will be mentioned.

Industrial dust. The effect on the organism of industrial dusts have been known to physicians for decades. Despite this and the fact that modern industry had improved the sanitary and work facilitating phases of production, cases suffering from intensive effects of dusts of different composition, in particular, of dust containing free silicon dioxide, are met altogether too frequently. Accordingly, silicosis, as an important lung disease caused by dust, constitutes an acute problem in all industrial countries of the world. In the U.S.A. about six million persons are working under dust conditions and become pathologically affected by the dust; it is estimated that the number of persons affected with silicosis was as high as one million (E. V. Khukhrina). Considerable progress has been achieved in the control of this disease in mining industry of the U.S.S.R. However, the control measures adopted up to the present against deleterious coal dust, including pure silicon dioxide dust, are totally inadequate for the rational protection of workers against the injurious effects of industrial dusts. The increasing occurrence of pulmonary dust disease is more threatening in the mining field than in other fields of industry; in England there are about 5,000 new cases of pneumoconiosis annually, more than 4,000 of which occur among coal miners. The Japanese scientific researcher S. Ishinisi reported that the 1955 - 1956 medical examination of 22,000 coal industry workers disclosed 12.1% cases of

pneumoconiosis. P. I. Tal'yantsev in his dissertation presented the results of a polyclinic examination of miners who worked not less than 8 years in mines under conditions of high air dustiness. Preliminary X-ray examinations showed that about 25% of them had to be classed as pneumoconiosis cases or suspicious cases.

The high degree of unfavorable effect of asbestos dust has been clearly established, as was the possibility of pneumoconiosis development under the effect of dusts of other silicates such as, talcum, olivine, mica, fiber-glass (M. A. Kovnatskii). It has also been established that dust of shales (S. M. Zal'tsman) and of many metals, in particular of aluminum (M. Ostrovskaya), of manganese ore, and dust (or rather smoke) generated by electro-welding operations and containing highly dispersed ferric oxide, may also lead to the development of pulmonary fibrosis. In examining 300 electro-welders in Leningrad, A. A. Egunov noted a group of 143 men whose X-ray pictures showed conditions resembling pneumoconiosis. Results of work conducted by the Labor Hygiene Department of the I. M. Sechenov First Order of Lenin Medical Institute pointed to the possibility of a fibrogenous effect of dust of such metals and their compounds as barium, tungsten, tantalum, etc; symptoms were also detected of pneumosclerosis of different gravity and of different stages of development in persons exposed to dust of vanadium, cadmium, cobalt, etc. aerosols. Recent theories on malignant formations of occupational origin emphasize the role of aerosols, particularly in regard to development of lung cancer and cancer of the upper respiratory tract. This applies particularly to the action of resinous substances as components of smoke particles, the action of dust containing radioactive substances, and the effect of dusts of chromium compounds and of asbestos. An increasing number of publications have appeared lately in the foreign literature on the role of asbestos dust in lung cancer (D. C. Braun, T. D. Truan, E. Holstein, and others).

All this points to the great importance of industrial dust as an environmental factor capable of affecting unfavorably the health of workers.

Toxic substances. Hundreds of thousands of inorganic and organic compounds are manufactured and used in modern industrial plants and laboratories. Their number increases steadily. With developing technique the production methods are improving, and the possibility of workers' health being affected by toxic substances is on the decline in the Soviet factories. Nevertheless,

in the process of future development of the chemical industry, called for by the May Plenum of the TsK, K.P.S.S., a realization of additional progressive occupational safety measures is under consideration. Indeed, many processes and operations in the chemical industry are accompanied by the possibility of toxic vapors and gases escaping into the atmospheric air in the production of non-ferrous metallurgical products, in machine construction, in the atomic and vacuum industries, etc.; the escape of toxic substances and their deleterious effects are now under effective control. Introduction into industry of new types of raw materials, of new processing methods, new equipment, which have not been hygienically evaluated present new dangers from the possible effects of the new substances on the organism. Among these substances are many old industrial toxic metals, such as, lead, mercury, manganese; they should be watched intensely, because they are still causing cases of chronic poisonings. It is very important to guard working conditions in plants using the new highly valuable metals, such as beryllium, cadmium, vanadium, lithium, etc. It is of equal importance to guard working conditions and the health of workers dealing with such organic solvents as benzene, chloro-organic compounds, etc. It is necessary to take into consideration the possible effect on the organism of a number of monomers used in the newly arisen industry of heavy organic synthesis and in the production of plastics. Not of least importance is the possible intoxication during contact with highly toxic poisonous chemicals, such as organic mercury compounds, phosphorus, chlorine, used in agriculture.

Thus, it is the duty of every modern physician to possess basic knowledge of the toxicology of industrial poisons and to assist sanitary control agencies by recognizing initial manifestations (early symptoms) of intoxication.

In the attainment of uninterrupted work records of industrial employees prevention of chronic intoxications and of latent symptoms produced by toxic substances should play a primary role. The seriousness of the problem of pneumosclerosis development assumes graver aspects in workers with records of many years of work under effects of so-called irritating gases, as a consequence of periodic exposure to light, yet acute, intoxications, or as a consequence of a prolonged exposure to low concentrations of such gases. Soviet occupational pathologist B. I. Martsinkovskii, and others, brought the im-

portance of this problem in the fight for workers' health into sharp focus. Many modern products of chemical industry such as the monomers and sometimes the polymers possess allergy-producing properties. Allergic conditions in workers of the chemical industry might be caused by high-molecular complete antigens and, under certain circumstances, by semi-antigens having a simple molecular structure and forming links with the proteins of the organism, as is the case with phenol-cresol compounds, paraphenylene-diamine, etc.

Industrial vibration. Modern industry is increasingly employing machines, equipment, devices and tools, the operation of which causes vibrations, that is, oscillations transferred directly from the equipment and tools to the bodies of workers, or the vibrations of the floor, foundation, etc. Vibration can be local, i.e., transferred directly to the hands or arms of the workman, or general, oscillating the surfaces on which the worker is standing. Some processes generate both general and local vibrations, as in work on vibro-platforms of concrete plants. Soviet scientists, notably E. Ts. Andreeva-Galanina, L. N. Gratsianskaya, Z. M. Butkovskaya and others, studied the character and degree of pathologic effects of occupational vibrations. Among the factors of importance were the frequency and amplitude of the created periodic oscillations and characteristics of the pneumatic instruments used.

The effect of vibration may produce a complex syndrome, now known as vibration disease. This disease is reminiscent of Reynaud's disease. It has much in common with traumatic neuritis of infectious origin (spasm of peripheral vessels, loss of sensitivity, pain in the wrists, numbness, etc.). In more clearly expressed cases there are also arterial hypotonia, bradycardia; changes in electrocardiogram may appear in more clearly expressed cases. Work with pneumatic instruments may cause changes in the osteo-muscular motor apparatus. The timely recognition of early disturbances is of utmost importance in order to effectively adapt therapeutic prophylactic methods and to bring to the attention of authorities the importance of improving the production processes. The high number of people exposed to the effects of vibration places the problem of vibration disease prevention in the forefront.

High-frequency currents. Among the most important achievements of modern science and technique are the widely used high-frequency currents in a wide range of wave lengths. High-frequency currents are used in heating metals,

soldering, drying, etc. The electric and magnetic fields generated when high-frequency currents are used, affect the functional conditions of the organism; the degree of effects depends upon the specific properties of the generators in use, and of the generated electromagnetic fields. Considerable information has been accumulated as the result of studies related to workers' health and to the physiological condition of the organism, relative to the clear-cut manifestations of the effects of the short waves and of the less obvious effects of the longer waves.

The Ukrainian Institute of Labor Hygiene studied 128 employees who worked mainly on metal hardening with high-frequency currents; no symptoms were revealed in 30 persons; others manifested different functional disturbances of the nervous and cardiovascular systems (V. G. Piskunova, V. S. Androvskaya, and others). Studies of the Institute of Labor Hygiene and Occupational Diseases A.M.S., U.S.S.R. indicated that workers stationed within the action zone of centimeters-long waves showed more clearly expressed asthenic conditions with definite vascular-vegetative endocrine changes (M. N. Sadchikova, A. A. Orlova). According to results of foreign authors, workers of this category might develop crystalline lens cloudiness or hemopoietic changes. These disturbances were basically reversible. In view of the above the early diagnosis and timely application of therapeutic-prophylactic measures became of particular importance.

Ionizing radiation. During the last decade the use of atomic energy for peaceful purposes in the U.S.S.R. reached vast dimensions. The world's first atomic electric power station was built in the U.S.S.R. Radioactive substances are extensively used in different fields of national economy (metallurgical, chemical, machine building, etc.). Isotopes are being utilized in geological explorations, in agriculture, in biological investigations, in medicine, etc. Accordingly, persons engaged in a variety of occupations are subject to considerable exposure to α -, β -, γ -rays and neutron ionizing radiation. The chances for the penetration into the organism of radioactive dusts, vapors and gases are potent in many occupations, thereby creating specific conditions for active radiation effects.

It is known that radiation of low intensity had no serious effects on the living organisms, but in large doses it can cause specific diseases of different degrees of gravity. Practically no acute cases of radiation disease had been observed among industrial workers; nevertheless, there is al-

ways the possibility of chronic disease development as a result of exposure to low radiation over a long period of time. The onset of such a disease is not easily recognized; it is characterized by a variety of complaints connected with functional disturbances of the central nervous system and internal organs, such as weakness, fatiguability, headaches, loss of appetite, high irritability, etc. This is followed by the appearance of other symptoms which will not be described here. However, it should be strongly emphasized that persons who by virtue of their occupations might be exposed to the effects of ionizing radiation should be kept under constant observation of competent and experienced professional personnel. An early detection of shifts in physiological indexes might be decisive in instituting measures for the protection of the workers' health. Nobody questions the necessity to formulate and to enforce sanitary "Rules for Transportation, Storage and Follow-Up Work with Radioactive Substances", published in 1957 (G. M. Parkhomenko).

Work under conditions of assembly line production. Improvement of work tools and production methods is one of the requisites of technical progress in socialist industry. It affects the character of the industrial process and of the operations performed by the workers. At present assembly line production is used extensively; if well organized it presents considerable economic advantages. In this connection it should be recalled that specialized reports by Soviet physiologists, by the Party press ("Communist", 1958, No. 10) emphasized the fact that "under present production procedures each worker is engaged in one definite occupation within the scope of which he performs one specific operation throughout the entire work day, month, year, or many years; accordingly he exercises only one group of muscles the coordination of which is controlled by specific nerve centers. This explains why productivity follows a variable course throughout the working day: with increased fatigue the productivity curve decreases". Many industrial administrators look at this as a normal phenomenon and do not utilize the pertinent means suggested by experienced practice in Soviet enterprises, namely "decrease of conveyer speed at certain hours, 5-minute breaks for physical exercise, alternate work with rest periods" (D. Kaidalov). Statements of this character emphasize the importance of medical supervision over work processes organized along modern trends and the need for incessant watchfulness over the health of workers performing limited specialized work func-

tions. Here, as in instances previously mentioned, early diagnosis and timely treatment of disease symptoms are of vital importance.

The significance of many new environmental factors in the etiology of specific occupational diseases has been studied extensively. However, the modern physician must not fail to consider that the specific characteristics of conditions and organizational factors of occupational activities can and do effect the development of general morbid conditions of different etiological character. The possible effects of industrial occupational factors on the development of the present-day widely spread diseases of the cardio-vascular system should be taken into account seriously. In his recent report Professor L. K. Khotsyanov specifically stated: "There is no doubt that widely differing industrial factors participated in eliciting and stimulating the development of individual nosologic forms, and in particular in arterial, venous and lymphatic vascular diseases. They may enhance the development of hypertonic diseases".

Thus, modern (industrial) physicians are faced with the problem of correct understanding and interpreting the significance of individual factors of the industrial environment and production organization in relation to the etiology of occupational diseases and of the need to adopt necessary prophylactic measures. Physicians of institutions for medical treatment, especially those attached to industrial production plants, must make certain that:

1. The detection of early manifestations (symptoms) of occupational diseases was based on the latest developments in diagnostic medicine.

2. Therapeutic and prophylactic measures should be instituted at the earliest possible stages of occupational diseases.

3. Qualified medical supervision over the state of health of persons working under industrial production conditions should be in effect at all times, especially where such conditions may be potential factors in the future development of occupational diseases.

4. Employees suffering from such general conditions, as chronic disease of the cardio-vascular, nervous, blood systems, and the like, should be assigned to jobs recommended for such persons by industrial physicians.

5. Total morbidity of a production plant or industry and its prevailing diagnostic phases should be studied (analyzed) in relation to specific production characteristics of the plant or industry.

Bibliography.

Андреева-Галанина Е. Ц. Вибрация и ее значение в гигиене труда. Л., 1956. — Кайдалов Д. Коммунист, 1958, № 10, стр. 8. — Ковнацкий М. А. Силкатозы. Л., 1957. — Малинская Н. Н. Гиг. труда и проф. заболевания, 1957, № 1, стр. 14. — Марцинковский Б. И. Клиника, патогенез и терапия профессиональных отравлений удушающими газами. М.—Л., 1940. — Пархоменко Г. М. Гиг. и сан., 1958, № 1, стр. 43. — Пискунова В. Г., Азатовская В. С., Трутень М. Д. и др. Гиг. труда и проф. заболевания, 1957, № 6, стр. 27. — Садчикова М. Н., Орлова А. А. Гиг. труда и проф. заболевания, 1958, № 1, стр. 16. — Сементин Н., Терентьева Т. Охр. труда и соц. страх., 1958, № 2, стр. 28. — Тальянцев П. И. Основные вопросы гигиены труда в подземных работах в шахтах Подмосковн. угольн. бассейна. Автореферат дисс. М., 1958. — Хоцянов Л. К. Гиг. и сан., 1958, № 9, стр. 22. — Хухрина Е. В. Гиг. труда и проф. заболевания, 1957, № 3, стр. 59. — Фонгауз М. И. Гиг. труда и проф. заболевания, 1957, № 5, стр. 25. — Braun D. C., Truan T. D., Arch. of Industrial Health, v. 17, 1958, N. 6. — Holstein E., Grandriss der Arbeitsmedizin. Leipzig, 1958. — Ishinishi S., Miyazaki T., Zbl. f. Arbeitsmedizin, 1958, Bd. 8, S. 87.

Population Mortality in the U.S.S.R. and in Capitalist Countries.

A. M. Merkov.

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Total U.S.S.R. population mortality in 1956 was 7.5 per 1000 compared with the 1913 pre-revolutionary ratio of 30.2 per 1000, i.e., it decreased 4.3 times. The present total U.S.S.R. mortality appears to be the lowest in the world. However, fall in the total population mortality alone presents only a partial picture of health advances in the U.S.S.R. This can be attained only by a well organized statistical analysis of the many aspects of total population mortality in the U.S.S.R. and comparing the results of similar analyses made in the capitalist countries. Mortality rates differ at different historic periods. High mortality characterized the period of European feudalism, resulting in a low population increase despite the high birth rate; the primary causes of such high mortality were: incessant wars, frequent famines and serious epidemics, such as the plague, cholera, smallpox, typhus, etc. The Soviet demographer B. Ts. Urianis, specialist in European population growth, estimated the death rates in the XV - XVII centuries at 40 - 45 per 1000 of population.

The coming into being of industrial development, known as capitalism, was accompanied by rapid and pronounced deterioration of sanitary conditions in populated areas. Tens of thousands of peasants and small craftsman lost their usual means of livelihood and flocked to the cities causing congestion; water, air and soil became polluted with industrial wastes and in the absence of the concept of labor legislation, working conditions were unbearable. As a result morbidity was on the increase, epidemics continued, all of which led to an increase in population mortality. Increasing epidemics endangered not only the health of the working class and the peasants, but of the so-called ruling classes as well.

"As soon as this was scientifically established," writes F. Engels, "the humane bourgeois was impelled to initiate noble competition in caring for their workers' health". ^{1/} As a result, a study of sanitary conditions in the populated areas and industrial enterprises was organized and, since sanitary-police measures were not sufficient for the control of epidemics, a series of community sanitary health improvement measures were carried out in the XIX century, which led to a decrease in morbidity due to epidemics. The decrease in infectious diseases resulted in decreased population mortality in progressive capitalistic countries. However, this mortality decrease did not take place in the colonies held by the imperialistic countries, and even in the large cities the mortality rate among the workers was considerably greater than among members of the so-called bourgeoisie.

Although in the XIX century the death rate in the principal European countries was below that of the XV - XVII centuries, it still remained high, amounting to 20 - 28 per 1000. Only at the end of the XIX and the beginning of the XX century did the mortality in these countries begin to fall rapidly, reaching at the beginning of the Second World War a relatively low level. Mortality data in some of the European countries per 1000 persons of population are presented in Table 1.

The considerable decrease in mortality indicated in Table 1 was manifested only in the progressive, technically and economically developed capitalistic countries. In the backward capitalistic countries and in the colonies high level mortality persisted. Thus, the death rate in the 1930's

^{1/} F. Engels. Housing Problem, M. Gospolitizdat, 1954, p. 41.

T A B L E 1.

Population mortality in European countries.

Year	England	France	Germany (Prussia)	Belgium
1841 - 1850	22.4	23.4	28.6	24.4
1851 - 1860	22.3	24.0	28.6	22.5
1861 - 1870	22.5	23.7	27.4	23.4
1871 - 1880	21.0	23.7	27.2	22.6
1881 - 1890	20.6	22.1	25.2	20.6
1891 - 1900	18.8	21.5	22.3	17.7
1901 - 1910	16.9	19.4	18.8	16.6
1911 - 1914	13.9	18.6	16.7	15.0
1915 - 1920	15.1	19.2	19.4	15.4
1921 - 1925	12.4	17.2	13.2	13.5
1926 - 1930	12.7	16.9	11.8	13.6
1931 - 1935	12.6	15.7	11.2	12.9
1936 - 1939	12.9	15.4	11.8	13.1
1940 - 1944	13.3	17.9	12.2	15.1
1945 - 1949	12.0	13.8	11.2 (FPG)	13.5
1950 - 1954	11.6	12.7	10.5 (FPG)	12.2
1956	11.7	12.4	11.0 (FPG)	12.6

in India, a British colony at that time, was 33 - 39, in Egypt 40 - 45, in Chile 33 - 40, in Uruguay 20 - 25 and in Argentina 24 - 30 per 1000 of population.

The lower mortality in the progressive capitalistic countries is partially and in a sense only a seeming decrease. It is known that lower birth rates reduced mortality rate as compared with actual rates, and that the birth rate in the progressive capitalistic countries has been falling since the beginning of imperialism. Thus, the general mortality dropped in France during the 1855 - 1939 period by 27.4%, in England during the same period by 47%, in Belgium by 23.7%. However, the drop in birth rate during the same periods was: in France 41.2%, in England 48.1%, in Germany 47.2%, in Belgium 48.5%. Consequently, the general mortality percentages under the circumstances, are actually too low; the true population mortality level in progressive capitalistic countries must be higher than presented in Table 1.

Mortality at the age of over one year shows that during the indicated period the death rate in France dropped not by 27.4% but by 12.8%; in England not by 48.1%, but only by 25.2%; in Germany not by 47.2%, but only by 25.7%; in Belgium not by 48.5%, but by 9.7% only. This decrease was caused basically

by the lower rate of death from infectious diseases, the control of which was brought about by the personal interest of the bourgeoisie; at the same time, the death rate caused by heart diseases, malignant neoformations, cerebral hemorrhages, arteriosclerosis and a number of other non-infectious diseases did not drop but increased.

Lower mortality among children is another cause of lower general mortality in capitalistic countries. To a certain degree it depends also on lower birth rate and the small number of children per family. The lower mortality among children was also the result of some measures directed specifically toward preservation of children's life. The considerable drop in birth rate in imperialistic countries, particularly at the end of the XIX and the beginning of the XX century, raised the threat of loss of population and, as a consequence, of the threat of diminishing numbers in the imperialistic armies. (This is an outmoded argument of early socialism. B.S.L.). Aggravated imperialistic conflicts and intensive preparation for the First and later the Second World War impelled the governments of imperialistic countries to pay attention to this threat. Unable to stop the reduction in birth rate, stimulated by basic character of the imperialistic era, the governments of such countries began to pay particular interest to lowering mortality among children, in an attempt to maintain life of born children and thereby assure their survival to the conscription age. Lloyd George eloquently expressed these tendencies of the imperialistic bourgeoisie when he said once in Parliament: "Had we taken better care of the nation's health, we could have increased our military force by at least one million men".

Thus, the drop in total mortality, which took place as a result of anti-epidemic measures, as well as the reduction in mortality among children were not the consequence of humanitarian tendencies of the bourgeoisie, as described by bourgeois statisticians and social hygienists, but the result of bourgeoisie selfish interest to protect itself against infectious diseases, and maintain the necessary imperialistic armies. Sanitary-hygienic measures which reduced general mortality were introduced largely in metropolitan territories of imperialistic countries; they were not applied to populations of colonial and semi-colonial countries in which mortality persisted at high levels. For example, in 1941, the death rate in Hong-Kong was 37.4 per 1000; in Egypt in 1945, 27.7; in India, the same year, 22.1; in Guatemala in 1947, 24.7, etc.

In all these and many other countries the death rate was 2 - 3 times higher than in the basic imperialistic countries. Only in the U.S.S.R. and in people's democracies was the reduction in mortality and increased longevity the result of true concern of the state over the health of the population as a whole. Mortality rate of pre-revolutionary tsarist Russia was the highest among advanced countries, as indicated by the fact that in 1913 it was 30.2 per 1000. Development of capitalism on the basis of feudal exploitation of peasants contributed to the persistence of high mortality rate in pre-revolutionary Russia. A slight reduction was noted at the beginning of the XX century, which was rapidly wiped away by the first imperialistic war. War, foreign intervention and the resulting economic collapse, aided by famine, greatly increased total mortality; only since 1923, the first year of normal conditions in the field of economic development which followed the liquidation of famine and economic collapse, did the death rate in the U.S.S.R. drop significantly below the pre-war level and continued to drop since that time.

By 1926 mortality in the U.S.S.R. dropped to 20.3 per 1000, while the population's longevity increased (in comparison with 1896 - 1897) by 11 years for men and by 14 years for women. In 1940 the death rate in the U.S.S.R. dropped to 18.3 per 1000 of population. During the period of 1913 - 1940, including the war and intervention years, death rate in the U.S.S.R. dropped by 40%, as compared with a drop of 9% during 1886 to 1913, a period of 27 years. The U.S.S.R. superiority to capitalistic countries in mortality rate reduction can be judged by the fact that in relatively few years it has achieved a death rate drop comparable to the one attained by the U.S.A., Japan and France in over 100 years, Sweden in 70 - 75 years, and England in 60 years. The rapid tempo of mortality rate reduction in the U.S.S.R. has not been equalled by any capitalistic country. This is clearly illustrated by the data listed in Table 2.

Death rate reduction in 1956, as compared with 1913, amounted to 31.9% in the U.S.A., 18.2% in England, 29.9% in France, and 75.2% in the U.S.S.R. Total mortality data have an essential shortcoming: they are expressed in terms of 1000 persons of the total general population without consideration of age and sex; numerically the latter differ in different countries, and in the same country at different periods; leaving such factors out of consideration conceivably can conceal important trends in death rate. Thus, with the

T A B L E 2.

Mortality drop in the U.S.S.R. and in some capitalistic countries.

Country	Mortality per 1000 population		
	1913	1927	1956
U.S.A.	13.8	11.3	9.4
England	14.3	12.5	11.7
France	17.7	16.5	12.4
U.S.S.R.	30.2	20.3 (1926)	7.5

drop in the birth rate and an increase in the number of middle-aged persons the total mortality indicator drops irrespective of changes in the population's sanitary life conditions. And vice versa, an increase in the number of young children and of old people, i.e., age groups of usually highest mortality,

leads to a higher total mortality indicator, regardless of changes in the population's sanitary life conditions. The most rational method of interpreting mortality data should be based on age group analysis supplemented, if need be, by an analysis of the total undifferentiated data.

Lack of published age group mortality data for the U.S.S.R. during recent years, makes impossible the presentation of the mortality rate picture as suggested above, and hence, no comparison can be made between the mortality rate of the U.S.S.R. and capitalist countries. However, the advanced position held by the U.S.S.R. with regard to mortality rates can be brought into focus by different methods. One such method is a comparison of population mortality rates for the age group of over one year without taking into consideration the effects of birth rate characteristics of the countries studied, as is shown in Table 3, per 1000 of over one year of age. (See note at end of paper).

T A B L E 3.

Mortality among those over one year old.

Year	U.S.A.	England	France	Sweden	Germany	Italy	U.S.S.R.
1910	-	11.2	15.9	12.4	11.8	15.2	19.9 (1913)
1925	10.5	11.0	16.0	11.0	9.9	14.2	13.2 (1926)
1940	10.2	13.8	17.8	11.0	11.8	11.5	12.9
1950	9.1	11.3	11.9	9.9	9.6	8.7	7.7
1955	8.8	11.5	11.7	9.2	10.3	8.6	5.7 (1956)

Table 3 indicates that before the First World War pre-revolutionary Russia had considerably higher mortality rates at the age of over one year than the advanced capitalistic countries. In 1926 and 1940 the situation in this

regard improved considerably, but even then the general mortality rates in the U.S.S.R. for the age group of over one year were higher than in many of the advanced capitalistic countries. In 1950 and 1956 the situation changed drastically, and the mortality rates of the U.S.S.R. population for the age group of over one year dropped to a level lower than in the advanced capitalistic countries. Thus, the drop in the death rate in the U.S.S.R. was the direct result of a realistic improvement in the sanitary-hygienic conditions of the population and not an indirect reflection of the fall in birth rate.

In addition to age group mortality statistics use is frequently made of the so-called mortality coefficients of stationary population, the formula for which is the reciprocal of average longevity times one thousand. Such coefficients are based on longevity data (mortality tables). The average longevity of population in England in 1954 was 67.6 years for men and 73.1 for women. Accordingly, the table coefficients of population mortality that year in England were for men $1/67.6 \times 1000 = 14.8$ and for women $1/73.1 \times 1000 = 13.7$. The values of these indicators are, as a rule, slightly higher than the ordinary mortality rate indicators (in England the ordinary rate indicator in 1954 was 11.3); this difference depends upon the characteristics inherent in the calculation method and can be disregarded. It is no surprise that due to a variety of computation methods mortality rate indicators should differ. Therefore, ordinary mortality rate indicators can not be compared with table indicators; however, a comparison between mortality rate table indicators of different countries constitutes a valid procedure. The advantage of such comparison rests in the fact that, as in the case of standard mortality rate indicators, the effect of population age groups is eliminated, enabling and validating comparison of population mortality rate indicators of countries whose population consists of different age groups. This also brings into relief effect of sanitary-hygienic improvement of mortality rate indicators independent of changes in the age groupings of the population. Comparison of mortality rate table indicators of the population in the U.S.S.R. and in other countries again brought out the fact that the considerable and rapid drop in death rates in the U.S.S.R., as compared with other countries, was independent of changes in the population age grouping, and that it was the direct result of the general improvement of sanitary life conditions.

Thus, designating 1900 mortality rate, or that of the nearest year, as 100, the 1955 indicators and those of the nearest year will be:

	<u>Men</u>	<u>Women</u>
U.S.S.R.	49.2	47.9
England	65.2	65.5
France	71.0	70.2
Austria	61.1	59.4
Belgium	73.2	72.7
Finland	71.3	66.2
Germany	77.6	76.7
U.S.A.	71.8	70.1

Population mortality table indicators in the U.S.S.R. dropped more than 50%, i.e., considerably more than the corresponding indicators of the above mentioned countries and, as mentioned before, this drop was the result of changes in the population's age groups. In 1926 values of population mortality table indicators in the U.S.S.R. even in the light of comparison with pre-revolutionary values were still higher than in the advanced capitalistic countries. However, in 1955 these indicators dropped to below that of analogous indicators in many other countries. This meant that the longevity of the U.S.S.R. population increased, as illustrated by the data shown in Table 4.

T A B L E 4.

Longevity among U.S.S.R. population.

Years	Total population	<u>Including</u>	
		Males	Females
1896 - 1897	32	31	33
1926 - 1927	44	42	47
1955 - 1956	67	63	69

The above indicated drop in mortality rate was accompanied by an increase in average longevity of the U.S.S.R. population so that in 1955 - 1956 it exceeded more than twice average longevity of pre-revolutionary Russia, and 1-1/2 times average life expectancy in the

U.S.S.R. during 1926 - 1927.

In summarizing, it can be stated that the U.S.S.R., with a birth rate higher than in all leading capitalist countries, has a lower population mortality and an increased average survival expectancy. It was shown that the above progressive population changes were the direct result of sanitary-hygienic and general living conditions and not the indirect reflections of age group differences.

Note: Computation of population mortality indicators for the age group of over one year has been carried out according to the method suggested by S. A. Novosel'skii, i.e., according to approximate formula:

$$M_1 = \frac{1000M - ND}{1000 - N}$$

where M is the total mortality indicator; M_1 is the mortality indicator for the age group of over one year; N is the birth rate indicator; D the indicator of child mortality. All the indicators, with the exception of child mortality coefficient, are taken per 1000 persons, and the indicator of child mortality is calculated per 1000 children born.

Bibliography.

Достижения Советской власти за 40 лет в цифрах. М., Госстатиздат. 1957.—
Buncle H. Le mouvement naturel de la population dans le monde de 1936 à 1936.
Paris, 1954.—Demographic Yearbook (1949—1952).—Statistique internationale du
mouvement de la population d'après les registres d'état civil. Résumé rétrospective
depuis des Statistiques de l'état civil jusqu'au 1905. Paris, 1907.—Summary of inter-
national vital Statistics. 1937—1944. Washington, 1947.

Industrial Sanitary Supervision.

Editorial.

Meditsinskii Rabotnik, 13 May 1956.

The Soviet State continuously devotes attention to the improvement of labor conditions, safety measures and the cultural refinement of industrial establishments. Great sums of money are allotted annually for these purposes. It is sufficient to mention that on labor protection and safety measures alone, more than 11 billion rubles were spent during the past 5 years. Progressive improvement in labor conditions, prevention of injuries and reduction in morbidity were emphatically considered as state problems of urgent importance in the decisions of the December Plenum of the Central Committee of the Communist Party of the Soviet Union. It was the duty of leaders of commercial enterprises and professional organizations to make sure that safe sanitary-hygienic conditions be mandatorily instituted in all industrial departments. In this connection the role of hospitals and polyclinics, medical-sanitary organizations, health stations and sanitary-epidemiological stations was regarded of paramount importance.

Industrial-sanitary physicians were urged to assume the role of direct organizers of extensive sanitation projects. The activities of such physicians could be made rewarding and satisfying by working closely with appropriate social organizations, by maintaining daily contact with polyclinics, hospitals, sanitary-epidemiological stations, shop interns, councils for social insurance, and safety engineers, active members of the trade union, Red Cross and Red Crescent of the Moon Societies.

It should be noted that wherever physicians fully exercised the authority granted them, morbidity decreased and labor production increased. It is in this manner that A. M. Kochenova, a physician at the Sanitary-Epidemiological Station in the city of Pavlovskii Posad, organized her work. In shops of different enterprises she worked in cooperation with the shop interns, outlining the sanitary measures and gradually solving the complex problems of public welfare.

A. P. Flerovskii worked for nearly 20 years in the "Sickle and Hammer" plant in Moscow. Working in close cooperation with the plant administration and the public, the hygienist made many contributions to the sanitary improve-

ment in the largest plants of the capital city. In the steel wire shop, where rustproof wires were processed, an alkali bath was substituted for the lead-bath at the suggestion of the physician, because the latter had a deleterious effect on the health of the workers. Air conditioning was installed in overheated shops and the shower rooms in the open-hearth and rod-rolling shops were completely rebuilt under the direct supervision of the physicians.

Persistence and precision in the realization of sanitary improvement measures should characterize every hygienist. However, there are physicians who perform their supervision in name only, and who prefer to take no note of violators of the sanitary regulations. G. B. Maksimova, a physician at the Sanitary-Epidemiological Station of the Proletarskii Region in Rostov-on-the-Don, is such a physician. She failed to assume the initiative in instituting health improving measures in the establishments under her supervision; she chose to disregard shortcomings and was tolerant toward persons who either did not wish to, or could not put into practice plants outlined for the improvements of every-day labor conditions approved by the entire organization. As a result, medical examinations of workers in the leading branches of a radiator manufacturing plant were rare. No X-ray films were taken over long periods of time at the "Red Banner" factory. The authority of a sanitary physician never comes automatically. It must be acquired by skillful organization of sanitary control and a concern for people's health and welfare. A physician-hygienist should analyze and appraise all the facts within the scope of his observation; he should study occupational diseases and contribute to the furthering of the sanitary improvement of labor conditions.

M. A. Plesetskaya, a physician at the Sanitary-Epidemiological Station of the Leningradskii Region in Moscow, studied the effect of high temperature upon the furnace attendants at the "Izolyator" plant. She reported on the results of her observations at a technical conference held at the plant and proposed changes in the working conditions for furnace attendants. The proposed changes were accepted. It is to be regretted that in a number of ministries of the Republic, as well as in the regional and city divisions of the Health Ministry, the physician-hygienists are still underrated. It is for this reason that many, and even some very large enterprises, still have no industrial-sanitary physicians.

The technical progress in industry and the wide use of radioactive isotopes in various branches of the peoples' economy, confronted the hygienist with new

and serious problems. The industrial physicians may find proper solutions for these problems only with the participation of the scientific-research establishments. The institutes of hygiene and sanitation, labor hygiene, and departments of medicine in the higher educational institutions were urged to instruct all sanitary physicians in the knowledge of the newer and more perfect methods of water and air analysis under all possible industrial conditions. The rapid methods which enable a physician to make required analyses directly in an industrial establishment without the assistance of chemists or other laboratory personnel should be introduced more broadly. Sanitary physicians must be allowed to use modern apparatuses adapted to certain conditions to determine the content of chemical substances in the environment.

Progressive refinement and improvement in labor conditions is one of the most important problems of the State. The successful solution of this problem calls for a concerted effort on the part of the members of trade unions and the workers in public health services, but principally on the part of the workers in the sanitary services, i.e., the industrial physicians.

Soviet Health Protection Legislation Is Based on Scientific Findings.

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and of History of Medicine).

Sovetskoye Zdravookhranenie, Vol. 17, No. 20, 24-30, 1958.

Medical and sanitary legislation of the U.S.S.R. plays an important role in the protection of workers' health. Such legislation is based on the principles of Soviet law, of which it is a constituent part, and for this reason plays an equally important part in the protection and improvement of the population's health and of the country as a whole. Soviet medical and sanitary legislation has its roots in the basic national economic and cultural problems; therefore, it reflects the medical and sanitary needs of the population; this,

in turn, determines the content of the basic legislative acts, which regulate and control the activities of the Soviet health protecting organizations and institutions. At the same time Soviet medical and sanitary legislation reflects the advanced practical experience gained in serving the population and the basic achievements of Soviet and foreign medical science. In the Soviet Union this finds its expression in the form of health and sanitation standards, systems of rules and regulations related to established practical therapeutic and prophylactic measures. Soviet medical legislation is based on the Marxist-Leninist concept of the State, its problems and functions during the period of building socialism and during the period of transition to the communist society. Soviet medical legislation differed sharply from similar legislation in non-socialist countries; the latter in principle aims to preserve the social status quo.

The concept of prevailing prophylaxis and provision of free qualified medical help to the population are alien to the medical and sanitary legislation of foreign non-socialist countries. The 1946 health protection law adopted by the laborite government of England was widely publicized as the medical service of complete coverage; however, it did not meet the medical needs of the working masses.

A new and extensive medical and sanitary legislation was enacted in the Soviet Union recently which sharply differed from the legislation of most foreign countries and of pre-revolutionary Russia. The Medical Code and its constituent, the Code of Medical Police (Vol. XIII of the Code of Laws), which existed in pre-revolutionary Russia, merely specified some primitive sanitary requirements related principally to the rank and file and applicable mainly to the field of epidemic disease control. The standards of sanitary protection of air, soil, food products, and organization of medical assistance, contained in this Code, were very general and devoid of basic principles. Most of the standards and requirements included in that Code were far below the level achieved by medical science of the twentieth century. The measures provided by that Code were mostly in the nature of sanitary-police measures.

The question of necessary replacement of the obsolete Medical Code by a new health-protecting Code was repeatedly placed on the agenda at conventions of the Pirogov Medical Society, but all decisions and pleas resulted in no appropriate action. Even the Commission organized in 1912 under the chairman-

ship of P. G. Rein for the revision of medical and sanitary legislation, which in other respects performed significant tasks, was unable to secure the modification of the old Code. Nor were any basic changes introduced into the medical and sanitary legislation in Russia after the February revolution or during the existence of the provisional government. Health protection laws began to appear immediately after the Great October socialist revolution; they were aimed at the care and improvement of the health of the working people. The laws were directed at the prevention of spread of diseases, particularly of infectious diseases, at the creation of sanitary working and living conditions, at providing maximum easily available and free qualified medical help, and measures for the improvement of the sanitary conditions in populated areas including health education. Considerable importance was ascribed to these laws, since they dealt with the basic conditions essential to the successful building of socialism.

The foundation of Soviet medical and sanitary legislation rests on principles laid down by the Communist Party program and by the U.S.S.R. Constitution. The health laws define the basic aspects of health protection of workers in a socialistic country: its national scope, qualified free medical service to the entire population, intimate relationship between health protection and the economic and cultural development, planned preventive Soviet medicine, wide participation of all agencies concerned, economic organizations, trade unions and communal activity in the realization of health protection measures. The development of Soviet medical-sanitary legislation is closely associated with the work of Soviet health protection institutions and the achievements of medical science. The imperative need to satisfy some requirements of the population for a variety of medical assistance and to institute suitable measures resulted in the issuance of government proclamations and decrees; such action appeared particularly appropriate when there was need to define the rights and responsibilities of some organizations empowered with authority. The decrees dealt with the control of such diseases as: tuberculosis, malaria, smallpox, typhus, typhoid fever, and various other infectious diseases, medical help organizations, laws related to sanitary organization of the republic, state sanitary inspection, sanitary protection of air and water supplies, sanitary condition of populated areas, etc., and the protection of motherhood and childhood. A series of laws dealt with the improvement of the quality of

medical service for rural areas and specified certain standards established by scientific research. There is hardly a field of Soviet health protection of any importance which is not covered by the medical and sanitary code of laws.

The health protection during one period or another of the country's development affected the character of the medical and sanitary legislation. For example, during the years of civil war, of the intervention and of the blockade, legislative acts were aimed at helping the front lines, at controlling epidemics, at maintaining sanitary conditions in the rear, and at protecting the health of children. Accordingly, laws of that period were directed toward satisfying the country's basic needs in the field of health protection. An analogous situation occurred during the Great Fatherland War. The necessity to broaden preventive sanitary supervision during the years when construction of many new industrial enterprises and new settlements was begun, prompted the issuance of laws governing sanitary inspection and the broad authority given state sanitary inspectors for the efficient performance of their responsibilities; these laws also defined the functions of economic organizations in the process of instituting sanitary requirements. In this connection the achievements of medical science formed the basis for many government decrees not only in relation to health protection, but also in relation to problems of national economy; for example, the results of hygienic research were thoroughly studied prior to issuing laws on provisional standards and rules controlling the sanitary condition of towns, villages, sovkhoses, schools and other institutions for children, public buildings, etc., as well as in making timely provision to prevent pollution of air, water, soil, etc.

Results of sanitary inspection of populated areas, of studies of population morbidity and of measures for its prevention or decrease, formed the basis for the issuance of corresponding laws. Legislative acts issued during the first decade of the Soviet regime for the control and regulation of standards of sanitary protection of water reservoirs (chlorination, sanitary protection zones), sewage disposal, planning of cities and towns, etc., were based on scientific research of different hygienic institutions. Systematic investigations of atmospheric air, conducted in recent years in many cities, established a number of trends with regard to the origin and spread of dif-

ferent kinds of air pollution by dust, smoke and harmful gases of industrial origin, motor-transport exhaust, boiler room emissions, etc. Results of investigations conducted under various meteorological and topographical conditions helped to clarify the effect of above factors on the population's health. Results of such investigations lead to the establishment of statutes related to measures for the control of atmospheric air pollution, to the formulation of hygienic requirements for the degree of industrial smoke and waste gas purification, prior to their being discharged into the atmospheric air.

Intensive research carried out by hygienic institutes of Moscow, Leningrad, Perm', Gor'kii and in the Ukraine and in departments of hygiene in medical institutes played an important role in determining maximum permissible concentrations in the air for many noxious chemical substances. Results of such studies were instrumental in the formulation of sanitary requirements which must be mandatorily provided for in the construction of new industrial plants. Rules for sanitary conditions in populated areas were based on similar studies. Many investigations were conducted with the participation of academies of architecture and municipal bodies. The SNK R.S.F.S.R. decree of April 14, 1932, "Measures for the Improvement of Sanitary Conditions in Cities", was based on a series of scientifically developed sanitary requirements, particularly in regard to problems of water supply.

Results of scientific research on water hygiene and the sanitary protection of water reservoirs were carefully studied prior to issuing the decrees of TsIK and SNK U.S.S.R. of April 17, 1937 on the sanitary protection of water reservoirs and sources of water supply; following that, legislation was enacted on "Measures for the Elimination of the Pollution and for the Sanitary Protection of Sources of Water". These laws contain hygienic standards and describe means for the protection of water supply sources against sewage pollution. The standards above referred to were based on the results of previous numerous investigations of sanitary conditions of rivers Volga, Dnieper, Amu Dar'ya, and others; a number of water reservoirs and canals, such as the Moscow-Volga, Volga-Don, etc.; these investigations were conducted primarily to determine the manner and extent of their pollution and the processes and degree of their self-purification, and to find means for the elimination and prevention of such pollution. The same can be said regarding the 1947 law related to these problems.

Investigations in industrial toxicology led to legislation related to maximum permissible concentrations of toxic industrial by-products in the air of industrial working premises. In this connection it should be noted, that the maximum permissible concentrations of noxious substances established in the U.S.S.R. were many times lower than in the U.S.A., where they amount to 0.03 mg/li for aniline, 0.012 mg/li for hydrogen cyanide and 1.29 mg/li for acetone. ^{1/} In the U.S.S.R. they are correspondingly: 0.005, 0.0003, and 0.2 mg/li, i.e., six, forty and six-and-one-half times lower.

Results of scientific investigations in industrial hygiene were taken into consideration in issuing the decrees which established hygienic standards in industrial surroundings and work conditions in high-temperature workshops, and a system of prophylactic measures for drinking fountains, ventilation of premises, etc. Hygienic investigations also formed the basis of a series of other legislative acts, for example, national standards (GOST) mandatory throughout the Soviet Union. Some of these standards are of great scientific and practical significance, as for example, the GOST 2874-54, approved January 14, 1954, regarding requirements in water quality and means for its control.

Results of hygienic investigations in the field of community hygiene, industrial and food sanitation formed the basis for the N 101-54 standard, or the "Sanitary Standards for Industrial Enterprise Project", approved November 4, 1954 by the National Committee on Construction of the Council of Ministers of the U.S.S.R. N 101-54 makes mandatory the inclusion of required sanitary provisions in the plan of construction, such as sanitary-protection zones, sanitary clearance between buildings, safe water supply, sewage disposal, sanitary facilities for individual industrial buildings and workshops, including ventilation, maintenance of correct temperature, humidity, heating, natural and artificial light; the same applies to private dwellings. N 101-54 contains rules governing the protection of public reservoirs against pollution with sewage water, the maximum permissible concentrations of toxic substances in industrial discharges, concentrations of vapors and dust in the air of working rooms of industrial production plants and maximum permissible concentrations of non-toxic dust.

^{1/} N. I. Grashchenko. Achievements of Soviet Medicine and Problems of Its Further Development.

The comprehensive scientific research going on in hygienic institutes and departments related to water sanitation follows planned programs and methods directed toward the solution of many practical sanitary problems, particularly toward the attainment of a nation-wide safe water supply. Experimental clinical investigations carried out at the Obukh Institute, at the Gor'kii Institute of Labor Hygiene, at medical and sanitary departments and at the industrial-sanitary inspection service related to the effect of tetraethyl lead on the organism, the mechanism of its poisonous action, including sanitary-technical and prophylactic measures, were also taken into consideration in the final adoption of standards and requirements for plants producing or working with tetraethyl lead. Studies were conducted at the Leningrad and Moscow Labor Hygiene, and other institutes, related to the clinical and prophylactic aspects of mercury vapor intoxication.

The developing science of hygiene made it possible to include into the "Building Standards and Requirements", which control the construction of buildings, a series of regulations related to standards of natural and artificial light in industrial and public buildings. Achievements of medical science formed the foundation of many other legislative acts containing a wide variety of sanitary regulations and requirements on a broad national scale. Among such are the "Sanitary Regulations for the Sanitary and Hygienic Maintenance of Industrial Enterprises", issued June 9, 1951 and regulations for the control of sanitary conditions in public eating places and sovkhos and kolkhoz markets, sanitary regulations for industries producing or processing harmful substances, etc., issued November 20, 1953.

Hygienic standards, developed by scientific institutes of hygiene related to the construction of residences, hospitals, polyclinics, etc., were included in sanitary hygienic codes and approved by the Architectural Committee at the Council of Ministers of the U.S.S.R. Government decrees dealing with the mandatory compliance with the National Sanitary Inspection of Building and Construction Plans for Populated Areas, production plants, sovkhoses, drinking fountains, sewage discharges, etc., played an important role in the application of scientific sanitary achievements to the development of the natural economy in the U.S.S.R.

Scientific investigations in the field of epidemiology and clinical aspects of infectious diseases contributed immeasurably to the development of

practical epidemic control measures. This is particularly true of the control of smallpox, malaria, typhoid fever, typhus, etc. Rules and regulations contained in manuals issued by the Ministry of Health of the U.S.S.R. related to the diagnosis, prophylaxis and treatment of infectious diseases, production of vaccines, control of bacilli carriers, methods of active immunization, disinfection, duration of hospitalization and isolation periods, etc., contributed considerably to the improvement of the country's sanitary-hygienic condition.

Standards of ambulatory and fixed centers of first aid to the population and a considerable part of legislative acts were issued by the Ministry of Health in the form of decrees, orders, instructions which controlled the purely organizational aspects of national phases of hygiene, sanitation and medicine. Such decrees and orders were based on the results of analyses of practical experience and of series of scientific investigations. Thus, the results of research studies carried out in the Moscow oblast in 1924 by P. I. Kurkin, Ya. I. Nekrasov, S. I. Mikhailov, P. P. Sletov, I. V. Novokhatnyi, and others ^{1/} proved of great practical help in organizing medical help in the U.S.S.R.

Investigations of the N. A. Semashko Institute of Health Protection Organization and History of Medicine served as the basis for letters (circulars) issued by the Ministry of Health of the U.S.S.R. January 28, 1954 dealing with the use of dispensary methods in municipal hospitals and medical-sanitary departments, and for the letter (circular) of instructions issued April 12, 1954, dealing with the administration of rural dispensaries, medical centers of workers' organizations, medical help for workers engaged in building hydraulic power dams, workers of the oil industry, etc. Many scientific studies conducted at the health protection department of the Central Institute of Post-Graduate Medicine and of many medical institutes, such as Central Tuberculosis Institute, Institutes of Oncology, Central Pediatric Institute, Venerological Institute, Neuropsychiatric Institute and other scientific-research institutions provided scientific data for the development of forms, methods and standards useful to the practice of medicine, which were later officially adopted by the Ministry of Health, of the U.S.S.R.

Numerous mandatory legislative acts issued by the Ministry of Health pertaining to problems of prophylaxis of enteric infections, rickettsias,

^{1/} Methodology of Standards in Developing Medical Help. M. 1930.

malaria, tuberculosis, droplet infection, zoonoses, and to the use of disinfectants, were based on pertinent investigations of many scientific-hygiene institutes, institutes of epidemiology and microbiology, clinical institutes and clinics at medical schools. ^{1/} An important role in the scientific solution of health problems, subject to regulation, was played by scientific sanitary-epidemiological and clinical conventions, as well as by scientific sessions of the Academy of Medical Sciences of the U.S.S.R., whose decisions were taken into consideration by the Ministry of Health of the U.S.S.R.; by the decision of the 1947 - XII Convention of Hygienists, Epidemiologists and Infectious Diseases Specialists, on prophylactic inspection; by the decisions of the Academy of Medical Sciences on problems of rural health protection during its session in Krasnodar and Novosibirsk on problems of medical service to workers of Stalingrad hydroconstruction, etc. The above mentioned legislative acts aided in improving the sanitary conditions in populated areas, raised the quality of medical service, lowered the rate of morbidity and improved general health conditions.

Soviet legislation related to health protection is developing on a basis parallel with the socialist national economy in the interests of working people. It is based on scientific principles developed by Soviet medical science and accords with the predominantly prophylactic trend of Soviet health protection, and is up-to-date. The legislation regulates medical service to the population in accordance with its needs. It is not only of great importance for further successful organization of the health protection of U.S.S.R. population, but is also of great international value as a demonstration of health achievements which can be attained under a socialist government such as exists in the U.S.S.R.

Note by B.S.L.: In the last paragraph, which has not been translated, the author presents many suggestions for future sanitary, hygienic and medical legislation based on principles and to be directed along channels which are in essence no different from the principles and channels variously dealt with in the main body of this paper.

^{1/} Collection of Most Important Official Materials on Sanitary and Epidemic Control Problems. Book 3. Medgiz, M. 1954.

Futile Efforts to Control Air Pollution in English and American Cities.
(A Survey of Foreign Literature).

M. S. Gol'dberg.

Gigiena i Sanitariya, No. 11, 48-52, 1950.

In recent years the English and American professional and public press has been issuing increasing numbers of articles on efforts to control air pollution by smoke, dust, and noxious gases, thus testifying to the urgency of the problem, which has evidently begun to threaten the health of bourgeois residential areas. At the same time the foreign publications clearly reveal the hopelessness of all attempts to solve the air pollution problem under prevailing capitalist conditions.

Every year there appear in the press descriptions of the harm caused by air pollution, corrosion of metals, etc., and the need to combat such evil. For many years past the Department of Scientific and Industrial Research and the Royal Institute of Public Health have been spending public funds on observations of air pollution of English cities, issuing voluminous annual reports and monographs. They propose "possible future measures to alleviate the situation inflicted on London by smoke". ^{1/} A special report on the same subject, "Proposals for the Control of Atmospheric Pollution in the Future" was presented in 1948 at a smoke control conference in Wolverhampton. ^{2/} In answer to an inquiry raised in the House of Commons, the Minister of Health declared that "the Department of Scientific and Industrial Research had no recent data showing substantial changes in atmospheric pollution by soot and smoke in the country". ^{3/}

In an address delivered at the annual conference of the Natural Society for Smoke Abatement (Brighton, 1946) the prominent Labor leader H. Morrison estimated the total quantity of fly-ash and unburned coal emitted into the atmosphere at 3 million tons, two-thirds of which did not settle owing to the high dispersion of the particles. Such fly-ash kept the air in England con-

^{1/} Regan, C. J. "The Air of London", Journal of the Royal Institute of Public Health, December, 1946.

^{2/} "Proposals for the Control of Atmospheric Pollution in the Future", Colliery Guardian, 176: 196, 197, February 6, 1948.

^{3/} "Atmospheric Pollution", Chemical Trade Journal, 119: 554, November 8, 1946.

stantly polluted, reduced the amount of light, and cut the farm crop yield by 20 to 30%. Morrison appealed to the participants of the conference "to combat it for the sake of the national economy" (i.e., to increase the profits of the monopolists. M.G.). According to Monkhouse (1947), the total volume of sulfuric acid emitted into the air of English cities was about 10 million tons a year, nearly 60% of which was attributed to industry, the remainder to home furnaces. A satisfactory method of ridding gases of the acid has not been found.

Press dispatches testify that air pollution in England was on the increase. For example, the emission of soot in the industrial regions of Sheffield and Rotterdam increased six times between 1939 and 1944. The four Don-Valley electric power stations, which discharged daily about 214 tons of sulfurous anhydride into the air constituted a source of continuous complaints. In Newcastle the Municipal Sanitary Committee of Newcastle noted that air pollution in 1947 increased by 30% as compared with 1946. The 1947 report of the National Society for Smoke Abatement mentioned a substantial increase in the number of complaints about fly-ashes.

Addressing the House of Commons on February 12, 1948, the Minister of Fuel and Power declared that all new electric power stations would be using the latest methods of preventing air pollution. ^{1/} These assurances made in Parliament resulted in no positive action, as can be judged by press dispatches on the state of gas purification in the major English power stations. For example, in December 1948, the Times published an open letter from two members of Parliament in which they complained about putting into operation in London the powerful Bankside oil-burning power station without installing sulfur-absorbing equipment. Another important London power station at Fulham was still operating without ash-catchers, as a result, a representative of the British Electrical Association had to receive a delegation of Londoners in 1949 who complained about extensive pollution of the air by fly-ash emitted by this station and the delay in installing air pollution abating equipment. ^{2/} On May 9, 1949, Reeves directed the attention of Parliament to numerous com-

^{1/} Air Pollution by Coal Burning Power Stations. Hansard, House of Commons, February 19, 1948, 447, 1323-1324.

^{2/} Fulham Grit Nuisance. Local deputation received by the British Electrical Association officials, Electrical Times, February 24, 1949, 115, 250.

plaints by people living in the vicinity of the Greenwich power station about fly-ash, eye injuries, and the harmful effect of the emissions on the health of children attending a nearby school. ^{1/}

The Sheffield public health committee sent a resolution in April 1949 to the British Electrical Association requesting that steps be taken to halt pollution of the air caused by fly-ash and sulfurous anhydride emitted from the Neapsend and Blackburn Meadows power stations. Fly-ash air pollution was quadrupled as compared with 1932, while pollution by sulfurous anhydride was 56% over that of 1932. At times pollution was so intense that people had to wear eye protectors.

On February 10, 1932, the House of Commons was promised that steps would be taken against air pollution in the industrial regions of Stock. Ten years later the House asked the Minister of Health when the promise would be kept and whether he intended to request information about pollution in the region. Minister Beven replied to the first question by saying that the promise would be kept when the legislative agenda permitted. He answered the second question thus: "An investigation is now in progress and such measures will be taken as are feasible with our current shortage of funds". ^{2/} Any comment on these answers would be superfluous.

In recent years there have been a number of cases of fluorosis among the people and cattle in the vicinity of aluminum and other plants which emitted fluorides into the air. In 1946 there were poisonings in Lincolnshire, the location of metallurgical works which operated open iron ore roasting hearths accompanied by emission of silicon fluoride. The fluoride content in the urine of affected animals amounted to 26 to 29 parts per million. The water of nearby farms had a fluorine content of 0.5 parts per million, whereas the areas on which the cattle fed in some places exceeded 2000 parts per million. An analysis of the urine of 9 men showed 1.3 to 4.2 parts of fluorine per million. "It is assumed," said the head of the investigation, "that the danger zone is no more than 3 km wide." ^{3/} In another articles on fluoride poisoning, the authors pointed out that these catastrophes could be easily avoided by roasting the ore

^{1/} Atmospheric Pollution Bulletin 17, No. 6, September 1949.

^{2/} Smoke Abatement. Hansard, House of Commons, February 5, 1948, 446, 312.

^{3/} Journal of Industrial Hygiene and Toxicology, 29: 40, March 1947.

in closed hearths and by purifying the emissions of fluorine; however, according to the authors "such methods of combatting atmospheric pollution by fluorine compounds are at present infrequently used in England, due to the lack of awareness of fluoride poisoning danger. Actually, the reasons for this are different. The 83rd annual report of the Chief Inspector for Enterprises Deleterious to Health stated that these measures "would place a heavy burden on industry". In our opinion protection of the inviolability of profits for the capitalistic masters is the real reason for the bourgeois type of "supervision" over enterprises dangerous to health. The Chief Inspector prefers to ignore completely the problems of air pollution by fluorides emitted by aluminum plants, despite the fact that these emissions were highly concentrated and dangerous to the health of the population.

In 1949 severe poisonings occurred in Scotland by toxic aerosols (a mixture of tar and fluoride fumes) emitted into the air by the big aluminum works near Fort William. ^{1/} Cattle died, vegetation was ruined, etc. Despite the incontrovertible claims of the suffering residents and the decision in their favor by the immediate court, the court of appeals decided to defer the decision to close the plant in view of the fact that "more important public interests were involved" and that representatives of the company gave oral promises that they would "effect with all possible speed the necessary changes in the plant at Fort William". Such court decisions made a mockery of the famous English laws dealing with smoke "abatement" which so strongly support the interests of the investors. It is not without reason that the authors of the latest textbook on public health for English sanitary inspectors urge them to act on the basis of friendly contact with plant owners. ^{2/}

English legislation dealing with control of air pollution is highly circumscribed. According to the latest law on public health (1936), measures to control industrial exhausts "do not apply to the ore-mining industry if such laws interfere with the efficiency of operation; nor do such laws apply to the extraction of metals from ores, smelting of minerals, roasting, puddling, and rolling of iron and other metals, reprocessing of pig iron into wrought iron,

^{1/} Industrial Fluorosis. Study of Hazard to Man and Animals near Fort William, Scotland. London, Med. Research Council, Memo No. 22, 1949.

^{2/} W. M. Frazer and C. O. Stallybrass, Edinburgh, 1946.

or annealing, tempering, hardening, forging, reprocessing and carburization of iron and other metals, if they prevent or impede any of these processes. ^{1/} Such interpretation of the law obviously gives industrialists the full right to avoid taking any steps to control their industrial discharges. The chapter dealing with atmospheric pollution in the textbook referred to above reveals the extreme backwardness, the blind alley, in which bourgeois air hygiene now finds itself. With such ramifications attached to the law, the question of the effect of air pollutants on the human organism, standards of permissible pollutant concentrations, principles of aerosol diffusion, sanitary protection zones between industries and residential areas, etc., or any of the new developments with which Soviet air hygiene has enriched science can not be seriously or effectively taken into consideration. The "lofty level" of this "textbook" is revealed by the authors' recommendation that sanitary inspectors determine the intensity of smoke by the method of visual comparison with the long discarded Ringelmann Charts.

One of the loudly acclaimed "achievements" of English bourgeois hygiene is the attempt to create so-called "smokeless zones" where only gas, electricity, coke or other smokeless fuel may be used. The failure of such measures is emphasized by the "Protest of Bradford Against the Bill for Smoke Abatement". ^{2/}

At a session of the Chamber of Commerce, which took place in Bradford, one of the oldest textile centers of England, the secretary of the Association of Coal Merchants requested the Chamber to back their protest against a bill introduced in the corporation of Bradford which threatened the owners with great losses. The speaker reported that should the bill be enacted into law it would affect the entire central region, meaning that plant owners would either have to remodel the existing boilers or install new ones adapted to burning smokeless fuel, which would entail heavy expenses. The Bradford Association of Owners and the Chamber of Commerce passed a resolution endorsing the coal merchants' protest.

The commonest type of heating systems in England is the overly obsolete smoke-producing coal-burning fireplace. A question was raised in the House

^{1/} W. M. Frazer and C. O. Stallybrass, Edinburgh, 1946.

^{2/} Coal Merchant Shipping, November 3, 1948.

of Commons, in December 1948, on the intentions of the Prime Minister with respect to issuing instructions to the appropriate ministers to carry out a policy aiming at replacing the obsolete home fireplaces with better heating equipment within a specific period of time. Mr. Attlee replied that "the importance of effecting such replacement within a reasonable time was readily admitted by the ministers concerned, but that this was a problem which could only be solved over many years, depending, as it did, on many factors, such as industrial capacity, policy of capital investments, and financial considerations". ^{1/}

It should be added at this point that the requirements of the public health law of 1936 on abating smoke did not apply to private homes. Consequently, regardless of any ordinances passed in various cities to create "smokeless zones", the imperial law did not hold home owners responsible if they did not wish to go to the expense of installing better heating facilities. Such is the hopelessness of the problem of providing English cities with clean air.

The development of regional central heating in England is on a low level. According to the Times, it was only in October 1946 that the Westminster Municipal Council agreed in principle to supply heat from the Battersea power station to homes in three streets, "the first attempt at localized central heating in London". The conference on fuel utilization (1946) had good reason for admitting that "the U.S.S.R. was the first in the world in the broad adoption of localized central heating". On July 29, 1947, Shinwell, Minister of Fuel and Power, in answer to a query in the House of Commons on the measures taken by the government to develop localized central heating in the country, mentioned a special committee "which has already approved plans which were being implemented in Armston, Salsburg, and Bonny Ridge; 23 other plans were in process of development in various inhabited areas, none of them at the point where operating costs and amount of fuel saved could be reliably determined". ^{2/} Even this modest activity seemed excessive to the House of Lords. A special committee chosen by the House of Lords concluded its report by stating that the plan adopted in London "should be limited to obtaining

^{1/} Hansard, House of Commons, July 29, 1947.-

^{2/} Hansard, House of Commons, July 29, 1947.

heat from the Battersea station and should not serve as a precedent for general application". In January 1948, the Illustrated London News called localized central heating for some of the homes in Armston, Lancashire "the first plan for regional central heating to be executed in England". In December of the same year, Minister of Health Beven told a session of Parliament that he objected to a proposed bill empowering all local municipalities to introduce centralized heating of homes on the grounds that it was still in the experimental stage and implementation progress was impeded by inadequate resources, particularly steel, which was needed for more urgent products. ^{1/} An obstacle in the way of developing central district heating in England, as may be seen from Fitzgerald's report to the 37th annual conference of the National Association for District Heating, was the fierce struggle between the various monopolies, such as the coal companies struggling to hold their markets against smokeless fuel competition and the two against the electric heat and power stations.

The situation is no better in the United States. There is no lack here for possible legislative enactment since every state has its own legislative body and various national associations, leagues, conferences on smoke abatement, etc. However, the practical results are the same as in England. Press reports indicate that atmospheric air pollution in the main industrial centers of the country such as New York, Chicago, Pittsburgh, Philadelphia, Cleveland, etc. is steadily increasing. The irreconcilable contradictions inherent to the capitalist system are responsible for the chaos in building the main industrial centers and the gross violations of elementary hygienic requirements in planning cities. Now that, as a result of indifference to hygienic requirements, pollution has reached the point of threatening imposing homes and villas, American city planners are vainly searching for ways of "restoring the health" of cities, leaving untouched the capitalist basis of their society. As an example mention can be made of the Conference on Prevention of Smoke and Economy of Fuel. In a paper entitled "The Significance of Smoke-Control in City Planning", Olson pointed out that "in Minneapolis, as in other cities, the wealthier classes, and the industries were being forced to leave the central areas of the city due to extreme air pollution." ^{2/}

^{1/} Atmospheric Pollution Bulletin, September, 1949.

^{2/} Industrial Hygiene Digest, March, 1947.

Pollution of city air by exhausts from oil-heating systems burning sulfur-rich crude oil was peculiar to America. The annual conference of the American Association for Smoke Prevention in 1947 heard a report on the subject. The speaker stated in effect that theoretically smoke from oil burners could be completely eliminated, but that it would be impossible to effect the necessary measures because of the conflicts among the various monopolies which were not interested in the problems of public hygiene.

The lack of gas-cleaning equipment in the major oil refineries and other industrial plants recently led to a sharp increase in air pollution in Los Angeles, a leading industrial area in the U.S. The concentration of smog at times was so great as to cause eye, nose and throat irritation. Lowered visibility frequently hindered normal air communications, and at times even disrupted automotive traffic. Topographic and meteorological conditions, unfavorable for aerosol dissipation and the location of industries and residences in complete disregard of these factors were responsible for the intense atmospheric pollution in the presence of high mountain ranges; temperature inversions usually occurred at 300 to 900 m; the prevailing southwesterly and westerly winds carrying the pollutants from the industrial into the residential sections began immediately after sunrise and continued throughout the day. The eyes, nose and throat became irritated during stagnant weather when the base of the inversion fell to the ground level. The strongest lacrimation often occurred when the air temperature was high and the relative humidity was considerably below 100%, which did not prevent the formation of smog accompanied by low visibility. The author pointed out that in spite of numerous investigations of pollution in Los Angeles, nothing was known about the dimensions and composition of the particles in the dispersion phase of this aerosol, the etiology of lacrimation, the effect of temperature and humidity on the concentration and chemical composition of the smog. The author ascribed the harmful effects to different sulfur compounds such as SO_2 , SO_3 , H_2S , aromatic sulfo acids, the ammonium sulfite aerosol formed by the interaction of ammonia emitted by the cracking plants with SO_2 and water vapors, the partial oxidation products of the mercaptans, paraffinic and aromatic derivatives of sulfanic acid, etc.

During the past 15 years the author of the article, Professor Johnstone of the University of Illinois, a pioneer in the field of purification of in-

dustrial gases from sulfur oxides, has worked out many sulfur purification plans under laboratory conditions. However, capitalist America has not seen fit to apply the results of his studies. They are not wanted by the oil monopolies which are receiving huge dividends without them. ^{1/} The struggle against air pollution in Los Angeles has been going on for several decades. A special committee set up in 1947 brought in scientists to solve the problem. The result was a resolution that "implementation of severe compulsory measures might be difficult because: 1) the specific causes of smog formation have not been fully elucidated; 2) standard methods of collecting and analyzing smokes have not been developed; 3) the proposed measures for smoke abatement have been frequently inefficient; 4) satisfying the demands of the people without adequate scientific data could result in unwise and ineffectual decisions". The author cautions against "excessive haste that would lead only to half measures" and sets great hopes on the results of new scientific research, broad scientific and engineering consultation, and close contact with the owners of smoke-producing enterprises (! M.G.). ^{2/} On October 1947 the New York Times was compelled to admit that "effective steps to control smoke in the U.S. have thus far been hindered by the diversity of jurisdictions in the country in relation to air pollution in a country which consisted of 45 states with independent municipal administrations, and of the opposition of business concerns confronted with the need to spend large sums of money to install gas-cleaning equipment".

These facts, as reported by the capitalist press, testify to the futility of all attempts to solve the problem of clean city air under the conditions of capitalism in contemporary England and America.

^{1/} Journal of Industrial Hygiene and Toxicology, November, 1948.

^{2/} Atmospheric Pollution Bulletin, July 1949.

Problems in Planning and Building Cities and Protecting the Air in England.
(U.S.S.R. Appraisal).

K. G. Beryushev.

Gigiena i Sanitariya, Vol. 23, No. 7, 72-79, 1958.

A Soviet delegation consisting of V. M. Zhdanov, S. M. Bessonov, and K. G. Beryushev participated in the International Congress of the Royal Society of Public Health in Great Britain held in Folkestone in the spring of 1957. The program included a broad range of problems, chiefly city planning, housing construction, hospital facilities, and air pollution. One of the tasks of the U.S.S.R. delegation was to become familiar with the planning and construction of new cities, new housing, and measures to provide sanitary protection for the atmospheric air in England. A second task was to acquaint those participating in the Congress with measures employed in Soviet cities for the protection of atmospheric air and with recent achievements in this field.

The Soviet delegation also visited a number of scientific institutes, different organizations, etc. Sir Charles, Deputy Minister of Health, Prof. Bradley, Head of the Anti-Epidemic Department, Dr. S. Laff, Specialist in Hygiene, and Dr. L. Crome, Chairman of VOKS were most cooperative in making arrangements for the visits to these institutions (for which we are deeply grateful). Several of the reports presented at the sessions of the Congress merit special attention. In a report entitled "City Planning and Location of Industry", Peter Stock, Chairman of the Imperial Chemical Industry, expressed the view that once authorization was granted for the construction of industrial enterprises, the planning and construction ought to be free from preliminary and future demands and control, since such action would impede the development of industries badly needed by the state. Demands upon industry to incorporate certain sanitary-hygienic measures could be presented later. Persons who are responsible for the development of industries should participate in the committee engaged in drafting general city plans.

Stock's suggestion met with sharp disapproval. Engineers, sanitary physicians, and other congress members insisted on retaining the system of preliminary examination of plans for the allocation of industrial manufacturing plants and of presenting demands for compliance with certain standard condi-

tions; some members of the Conference voiced the opinion that standard requirements for the allocation of industrial manufacturing plants be enacted into law.

Two reports on housing were of particular interest: C. N. Craig, Chief Scientist in the Department of Scientific Research, in his paper "The Cost of Housing" cited economic data which supported the advisability of constructing multi-story apartment houses instead of detached two-story homes or cottages. This report stimulated a lively discussion. Dr. Greffen C. Clayton from Doncaster, Mr. Watts from Ashford, and others objected to the idea of basing housing solely on economic considerations. They contended that while economic considerations were important the convenience of the people must also be taken into account, especially in instances where economics conflicted with hygienic requirements and with comfort. It is necessary to take cognizance of the results of a mass questionnaire which indicated that the English preferred detached houses to multi-story apartments. Detached houses can be built at a cost no higher than the units in multi-story buildings. Participants in the discussion noted that the building of houses must be based on acceptable conditions and decisions. In large cities, such as London, multi-story houses of moderate height were allowable, whereas, in small and average-size cities two-story detached homes might be built in block formation so as to reduce construction costs.

A report on "Slum Clearance" was presented by F. G. Brown, Chief Inspector of the Ministry of Housing and Local Government. He noted that the problem of ensuring adequate housing is still in its early stages. The word "slums" first appeared in official documents and English legislation on March 28, 1956, in the law dealing with construction subsidies, and again August 2, 1956, in the law dealing with "slum" clearance. The word "slums" is currently applied to substandard homes which were to be demolished as being no longer habitable.

The law of 1954 dealing with rent and repair of homes indicated that 850,000 homes in England and Wales were recognized as substandard and were to be razed at the earliest possible time. Local municipal authorities determined that 375,000 homes should be razed and replaced during the next 5 years. If 75,000 of the 850,000 homes slated to be razed were demolished annually, the slum clearance project would take 11 years. However, this pro-

posals has not been approved. The annual bulletin of the Ministry of Housing stated that in 1955 only 25,229 homes were to have been demolished or closed. The outlook for 1956 was no better. Thus, the hopes expressed for a rapid slum clearance were not realistic.

The Assistant to the Director of the Southeast Council of the Gas Industry, I. D. C. Woodall, in his paper "Atmospheric Pollution and the Requirement of Smokeless Combustion of Fuel" emphasized that safeguarding the purity of the air in the country was a national problem. The fuel and gas industries must play a major role in executing the law of 1956 related to the prevention of air pollution. Approximately half of all the smoke in England was produced by home furnaces. Conversion to gas would help reduce such pollution. More than 11 million houses have already been converted to gas heating. To supply the population with coke, the speaker maintained, would require the reconstruction and modernization of coke units for 19 million tons of coal to be replaced by coke. However, coke production in England was limited and it could not provide for the total replacement of coal in home furnaces and fireplaces; on the other hand, the production of gas from coal was more expensive than the production of coke.

Central heating of homes and the resultant elimination of many smoke emitting points has not progressed in English cities due to the people's lack of interest, which is rooted in the tradition of fireplaces for home heating. Furthermore, conversion of the existing heating units into a central system is time-consuming; it would also present technological and economic difficulties. These were the considerations advanced by Woodall following the report presented by the Soviet delegate K. G. Beryushev on the measures widely enacted by the Soviet Union to protect the atmospheric air. Thus, efforts to safeguard the air in English cities must perforce continue to lag behind the efforts of the U.S.S.R.

Information was received from the Sanitary Administration of the Ministry of Health on air pollution and methods to control it. The Deputy Director of the Central Scientific Station for Fuel, Mr. MacDougall and his scientific staff acquainted the U.S.S.R. delegates with their work. It seemed that research was carried on without the participation of hygienic institutions and sanitary physicians. Air pollution research was conducted at some 2500 observation points throughout England. Observations at many of the points were made irregularly, and at some points only during fogs. These points

are partially under the direction of local governments, partially under the jurisdiction of industrial enterprises, on whose grounds the observation points were located. Some of them were operated by volunteers. Nevertheless, all the data were collected, processed and published annually by the Central Scientific Station for Fuel (A. Parker, Director).

The Central Station for Fuel is a major research organization with many laboratories and semi-factory installations located in different buildings over a wide area in the East End industrial regions of London. The basic studies were devoted to developing and recommending methods, procedures and equipment for better and more complete fuel combustion. Work was conducted on the preliminary purification of coal from iron pyrites. Different methods and devices were tested to free smoke emission from suspended particles. In addition, several laboratories outlined and recommended methods of research in atmospheric pollution, constructed and tested devices for the study of dust and sulfur dioxide in the air. Dust is still collected, for the most part, by the old but inadequate standard sedimentation method using a vessel resembling a rain gauge and the calculations were expressed in grams per m^2 .

The aspiration method - drawing air through paper filters - was also in use. The amount of dust (in mg/m^3) was determined visually from a standard scale by the black intensity of the filter. Use was also made of a reflectometer, a more accurate device, which enabled the determination of the degree of the filter paper blackness by measuring the intensity of the reflected light and then referring to a special table of smoke concentration in the air, expressed in mg/m^3 .

There were no criteria for the hygienic evaluation of the data obtained, nor were there standards for maximum permissible concentrations of pollutants in the air. None of the hygienic specialists of the Ministry of Health or of the workers in the Central Scientific Station were familiar with the hygienic indexes of atmospheric pollution adopted in the Soviet Union. The U.S.S.R. delegates presented them with pertinent collections of papers by Soviet specialists.

Cazell's thermic precipitator for the determination of dust dispersion properties was valueless. There was no research on air pollution in relation to sanitary clearance zones around industrial establishments, to which Soviet hygienists were paying considerable attention. The English regarded such in-

vestigations as highly complicated due to difficulties involved in examining emissions of individual enterprises and to the complexities involved in calculating meteorological factors. A study of an isolated electric power station by setting up stationary points around it had been initiated, but as yet no results have been announced. There was no classification of industries on the basis of hygienic indexes in relation to widths of sanitary clearance zones.

In order to reduce the dust concentration in the atmosphere, the Central Station was working on and testing different kinds of dust extractors to free flue gas of ashes emitted by electric power stations. England was presently using two-stage combination ash-catchers in the form of extractors and electrostatic filters, which operated at 96 to 98% efficiency. Smoke purification in small, boiler-operated plants was not required. Instead, a search is being made for methods and procedures for better and more complete fuel combustion by regulating the furnace air supply, overhauling the furnaces, etc. The U.S.S.R. delegates commented that these measures did not eliminate ash-created pollution, to which the scientists of the Station replied that installation of ash-catchers for small boilers was not feasible.

In addition to dust studies, the Central Station and several observation points make periodic determinations of sulfur dioxide air pollution. In this connection use was made of a standard absorber containing a solution of hydrogen peroxide. A new automatic apparatus for experimental purposes, the "German automatic" was being tested at the station for the continuous, around-the-clock study of sulfur dioxide. This device proved more sensitive than the American "Thomas autometer", which is able to determine concentrations beginning with one million and up. Preliminary purification of coal from iron pyrites was recommended as a means for sulfur dioxide air pollution reduction. The coal contained 1% sulfur after purification.

Experiments were conducted to free smoke discharges from sulfur dioxide. Ammonium sulfite was obtained at the Nottingham electric power station by passing flue gases through an ammonia solution. The Battersea power station in London, operating on coal, and the Bankside station, operating on fuel oil, conducted experiments in freeing flue gases of sulfurous anhydride by means of Thames water. Preliminary results did not justify a blanket recommendation of any one method due to low efficiency and high cost.

Taking into consideration the low efficiency of SO₂ removing devices and the lack of any prospect of such devices being adapted on a broad scale, the Central Scientific Station was attempting to find means for the individual and group protection of inhabitants against the harmful effect of this gas. It was proposed that in the event of abnormal amounts of sulfur dioxide in the air, use should be made of individual "collars" which would liberate ammonia fumes, and hospital wards should be sprayed with ammonia water. The Central Station was designing masks for mass use. Persons suffering of cardiovascular and respiratory diseases will be supplied with such masks, gauze and bandages during heavy fogs.

The activities of the health organization in the field of air pollution protection were quite limited. The law of July 5, 1956, on reducing air pollution granted municipal governments and health organizations the right to prohibit filling the regions of a city with smoke. However, for all practical purposes this authority cannot be used extensively because of the above-noted shortage of coke. Preliminary hygienic inspection consisted in the city sanitary physicians sitting in during the municipal committee's consideration of applications by industries for locations in the city.

Reference should also be made to the fact that the National Institute of Medical Research was investigating illnesses related to air pollution. The physicians were able to establish that the increase in bronchitic diseases was due to the excessive concentration of sulfur dioxide in the air. It was noted that northeastern London had many cases of lung cancer, attributed to smoke drifting into this part of the city from the industrial area. Research was begun on the chronic effect of sulfur and sulfur dioxide on the human organism.

The U.S.S.R. delegates were able to obtain information on planning new cities and mass house construction during a visit to the new town of Crowley, a suburb of Greater London, and during an inspection of the rebuilt town of Folkestone. Crowley is located some 40 to 50 km from the center of London, it is being built on the grounds of a small village and adjacent free uninhabited land, partly covered by arbors. The town is being built according to a plan proposed in 1947, and is intended to draw some industries from London and to resettle their employees. The Deputy Chief Administrator of the town, Mr. Goepel made arrangements which permitted the U.S.S.R. delegates to inspect the town, obtain explanations and illustrative material.

The town occupies an area of about 6000 acres; it is planned to accomodate 50,000 to 60,000 inhabitants. About 40,000 persons have already settled there. Eighty percent of the present inhabitants work in the local industries, the others are in business, schools, and service establishments. The local government did most of the construction, the industries only a part of it. A feature of the planning of Crowley and of the other 12 new towns (Harlow, Basledon, Steavhenge, etc.) is the system of breaking up the entire settled area into small sections. Crowley has 9 such sections of 150 to 280 acres each. Population density ranges from 60 to 110 persons per hectare; inhabitants occupied chiefly two-story and occasionally three-story houses. The center of each section had an elementary school for children 7 to 11 years old. One secondary school for children 11 to 15 years old was generally planned for 2 or 3 sections having a service radius of about 1 km. Six-acre plots were reserved for such schools with an expected capacity of 600 children. School buildings were one-story for the younger children, and two-story for the older ones.

Sections which for the most part had no apartment blocks featured picturesque cul-de-sac approaches to groups of homes. The main roads dividing the sections looked like park lanes lined with trees and shrubbery. In the center of each section there was a building for public meetings. There were few small shops supplying goods for everyday use. Home construction in the sections was in a free style with open space ensuring adequate ventilation and privacy. Most of the buildings were facing the street and had landscaped green strips 8, 10 or 15 m wide extending from the buildings to the sidewalks. Each apartment was assigned a small plot in the rear for gardening and other uses. Each section or two adjacent sections had a park and large lawns suitable for children's games, for school children, and for general relaxation. The center of the town was encircled by a broad thoroughfare, parking places, and gas stations.

In the non-residential areas industries were located having no objectionable anti-sanitary aspects; they produced electrical and electronic equipment, printing, wood processing, food, etc. The minimum distance between the industrial and residential areas was 200 m and sometimes 600 m. The industrial areas were separated from the highways by a broad strip of lawn and trees. The entire network of subterranean systems, such as central water supply pipes,

sewer pipes, electric cables were preplanned and laid out over the entire area including sections already built up. The streets were well paved with asphalt, concrete blocks, and granite chips. Empty tracts, set aside for eventual construction in accordance with the city master plan, were temporarily grass seeded. A typical two-story house in Crowley has 4 to 6 apartments, each having a first and second floor and a front and rear entrance. The first floor has a foyer, living room, dining room (or a living-dining room combined), kitchen, and a staircase leading from the foyer to the second floor, which has 2 to 4 bedrooms, bath and toilet having windows to the outside, thus providing them with natural light.

The common type of 3-room apartment (living-dining room and 2 bedrooms) has an average of 40 m^2 living space in addition to the 11 m^2 kitchen and other secondary areas; it is usually occupied by a family of 3 or 4. The rooms are 2.5 m high which makes an unpleasant impression. All apartments have cross ventilation. The sections have small detached one-story houses for old people to whom authorities may allot 2-room apartments with secondary (service) areas. Homes are constructed of light brick. The inside walls are covered with dry plaster. The windows are single glass pane frames. The warm climate makes it possible to ventilate the houses by opening the windows. There is no central heating. Only the living room has a fireplace. Before retiring, the people warm their beds with heaters. Outwardly the Crowley row houses are generally unattractive, monotonous, long structures with low windows.

Plan for the rebuilding of the small resort town of Folkestone also provides for separated sections. However, the houses are of better construction. Most of the houses have only two apartments; occasionally two-story apartments are joined together in which case they will contain 5 to 6 apartments. The houses are more appealing on the outside than the houses in Crowley. The houses are fronted by wide gardens (8 to 12 m) ornamentally landscaped with well-tended flowers or shrubs.

New cottages in London were also inspected. After the war, whole areas on the outskirts of the city were built up by two-story, architecturally attractive cottages. The houses are separated by open spaces the width being about half the height of the houses. The houses are fronted by large lawns and have small gardens in the rear. Entrances to the houses are not as convenient as they should be. One-car garages were attached to some of the

houses and had entrances directly from the street. The interior layout was similar to the ones previously described, differing in that they have better trimming and higher ceilings (2.7 to 2.8 m). Some houses had central heating; but the traditional fireplace was found in every living room.

In summary it must be emphasized that the measures to protect atmospheric air in English cities are rather limited and local in scope. The research of Soviet hygienists and the practical preventive inspection by Soviet physicians is more advanced and far more practical in the effort to control atmospheric pollution.

As for the planning and construction of cities and housing, Soviet planners might well profit by studying the methods used in the new cities of England. Worth considering are: 1) the system of sectional planning of residential areas with detached building of small, well-located homes; 2) setting the building line of homes a considerable distance away from the sidewalks and roads; 3) the large number of arbor and general landscaping in the sections, open breaks between houses, wide streets, and recreational areas; 4) lower population density in the city blocks and sections; 5) construction of all underground municipal systems before building was started, the roads well paved; 6) strict adherence to the city master plan and no use of land except as planned; 7) the basic idea of home construction is to provide a separate apartment for each family; 8) each apartment to have cross ventilation and insulation; 9) introduction of more advanced techniques to ensure proper soundproofing and adequate heating.

**Urgent Problems in Industrial Hygiene of Women Workers.
(A Report).**

(Conference of the Scientific Council of the Institute of Obstetrics and Gynecology of the U.S.S.R. Academy of Medical Sciences, in Cooperation with the Committee on Problems and with Provincial Scientific Institutes).

Vestnik Akademii Meditsinskikh Nauk, U.S.S.R., Vol. 15, No. 7, 53-56, 1960.

The Seven-Year Plan for the extension of U.S.S.R. national economy emphasizes the basic importance of a nation-wide prophylactic plan for the prevention of disease. In this connection the effect which harmful industrial emissions and dusts may have on the sex and reproductive systems of women workers employed in the various branches of the national economy has become of pressing importance. Harmful effects may arise in women workers when industries fail to provide necessary health-protecting and safety measures, especially where the employed women come into contact with new chemical substances, the toxicological action of which has not been studied adequately. The Scientific Council of the Institute of Obstetrics and Gynecology of the Academy of Medical Sciences of the U.S.S.R. in cooperation with an investigating committee and with representatives of provincial scientific institutes met at a special conference to consider problems of hygiene in women's working conditions and to propose plans for the future expansion of pertinent scientific research.

The principal speaker on this problem, M. A. Petrov-Maslakov, called attention to the necessity of studying as soon as possible problems concerning the sanitary-hygienic and health aspects of women workers and the mode of life which faced them as the new Seven-Year Plan was unfolding. Workers in the Institutes of Obstetrics and Gynecology of the Academy of Medical Sciences of the U.S.S.R. and of the Ministry of Health of the R.S.F.S.R., the Departments of Obstetrics and Gynecology of the Ivanovsk Institute of Medicine, in cooperation with hygiene institutes, studied the problems pertaining to work conditions, gynecological diseases, and the sex functions of women engaged in the textile and tobacco industries, and in factories using lead, benzene, phosphorus, mercury, gasoline, as well as other harmful agents. Results of such research established that one of the factors mentioned produced a definite syndrome of a distinct occupational disease; other disclosed factors produced no such effect by themselves; however, they synergistically affected

the course of different existing or incipient pathological processes. It has been generally recognized that by virtue of many anatomical and physiological peculiarities the organism of women was affected by adverse environmental (and other) factors more directly and more profoundly than the organism of men.

The introduction of mechanization and automation into the industry of production and processing continues to attract increasing numbers of women to participate in all branches of the national economy. On the other hand, the introduction of many new synthetic materials that have been put into production and new sources of energy, particularly atomic, which came into use, carry the promise of increasing the deleterious effect of the many new industrial introductions on the reproductive system of women workers. This emphasizes the need of intensive and thorough studies of the effect of the new production processes on the organism of women workers and of developing appropriate and effective prophylactic measures; in its turn, this requires that research methods presently in practice be improved or changed so that early symptoms of pathological processes could be more easily detected. Study of possible harmful effects of working conditions on the female organism must be made cooperatively by a group of specialists including occupational disease pathologists and hygienists.

Detection of certain occupational hazards can be solved and prophylactic and protective measures developed only through a thorough study of industrial conditions, their sanitary and hygienic characteristics, accompanied by a full determination of reactions arising in the organism of working women. In this connection Dr. R. S. Mirsagatov of Khar'kov, who had extensive experience in the gynecological care of women in different industrial enterprises, recommended that prophylactic examinations of workers of all ages be made at least once a year, and that methods and forms presently used for recording morbidity be revised. B. L. Shol'nikov of Stalinsk reported on the positive results yielded by sanitation measures instituted during the current year in the machine construction industry, emphasizing the dispensary system as the most effective means for lowering gynecological morbidities.

Ye. I. Rodkevicha of Stalinsk reported on the occurrence of atrophic changes in the sex organs of women workers in an aluminum plant, which she thought were the result of the harmful effect of aluminum oxide. Ya. A. Dul'tsin of Leningrad presented data on the effect of certain working condi-

tions of gynecological pathology and on the reproductive system of women workers in the viscose industry. The data pointed to premature childbirth, toxic states in the first, and especially in the second half of pregnancy which occurred more frequently in women working in rooms, the air of which had a high content of carbon bisulfide. D. D. Przhedetskii of Moscow reported on several specific conditions prevailing at work in textile plants and the effect of such conditions on the course of pregnancy. He recommended that women workers with child should be assigned to appropriate processes and machines according to the stage of pregnancy.

I. I. Klimets of Leningrad presented some clinical-statistical results of experimental studies on the basis of which he came to the conclusion that industrial vibrations, to which textile workers were subjected in the course of their work, could not be regarded with certainty as the cause of abortions. However, he believed that industrial vibration contributed to the pathology of the ovarian-menstrual and reproductive system of predisposed women with underdeveloped sex organs, with miscarriages and inflammations in anamnesis, etc. Timely discovery of such women, vigilant watch over them, and prompt resort to appropriate prophylactic measures were recommended as the most effective means in reducing the percent of premature births among textile women workers. I. D. Arist of Chelysbinsk pointed to the need for the development of recommendations pertaining to working conditions for women with gynecological affections and for pregnant workers in the different production and processing industries. He reported on the unfavorable effect on pregnancy of vibration to which women were exposed in heavy machine construction plants, and recommended that pregnant women be released from work entailing vibrations long before the onset of childbirth. K. V. Migai of Leningrad stated that determination of the effect of heavy physical work on the health of women workers constituted a pressing problem requiring immediate solution. Ya. S. Elenitskii spoke in favor of creating a scientific center affiliated with the Academy of Medical Sciences of the U.S.S.R. for the methodological direction and supervision of all research in the field of hygiene of women workers.

V. G. Khrenov of Moscow called attention to the lack of scientific data required for changing existing legislation related to industrial women workers, and suggested that such information be obtained as soon as possible. K. M. Bazhenov of Leningrad discussed the pressing need for organizing examining

rooms for women in the large industrial plants independent of the existing gynecological consulting rooms. Bastina of Leningrad presented data relative to the harmful effect on the organism of present-day conditions in ship painting and particularly on women's sex organs. Ye. P. Maizel of Leningrad stated that industrial physician-pathologists should initiate studies of the effect of occupational hazards on female workers organism, and expressed the opinion that obstetricians and gynecologists should be drawn into this work at least as consultants. He was also of the opinion that maternity leave for women workers in different occupations should not be of a single stereotype but differentiated. P. A. Beloshapko also expressed the opinion that the problem will find its solution only if specialists in different fields studied it intensely under the guidance and direction of institutes of labor hygiene and occupational pathology.

In the final resolution it was noted that the problem related to the effect of different deleterious occupational factors on the condition of the sex organs and the reproductive system of women workers received scant attention in the past, while opportunities to employ women have been ever increasing in different branches of the national economy. Public health bodies are facing urgent problems in their efforts to determine the effect of specific occupations on female sex organs and the need to create industrial and hygienic conditions in industrial enterprises under which employed women would work without injury or harm to their health and without damage to the health of their progeny. The Scientific Council of the Institute of Obstetrics and Gynecology of the Academy of Medical Sciences of the U.S.S.R. in cooperation with the Investigation Commission recommended that the following measures be instituted as soon as possible, in order that the discussed problems may be appropriately and timely resolved:

1. To extend and intensify scientific efforts in the study of the effect of occupations on women workers and on their sex system by conducting group investigations cooperatively, so that concrete recommendations may be developed for health measures for women workers in different occupations.

2. Special attention should be paid to the condition of the sex system and the reproductive organs of women employed in chemical, textile, and machine construction industries, and of women exposed over long periods of time to small doses of penetrating (ionized) radiation, bearing in mind the plans

proposed for the future development of new types of industry in the next Seven-Year Plan.

3. The following steps should be taken as soon as possible to improve the medical care of women workers:

a) Industrial obstetrician-gynecologists should make a thorough study of working conditions with reference to the appropriate re-allocation of pregnant women and women who have gynecological affections;

b) The prophylactic phase of public health stations should be intensified; women applicants should be carefully examined before being assigned to special jobs, and should be thoroughly examined medically, regardless of age, at least once annually; the recommendation should become mandatory;

c) All women workers having gynecological diseases should be covered by a complete dispensary and clinical history, so that they can be observed systematically and necessary prophylaxis and treatment may be instituted promptly, including correction of working equipment;

d) Efforts to prevent premature birth and still-birth should be stepped up; a special report should be made of all workers predisposed to abortion or those who have complicated obstetrical anamnesis;

e) Workers should be taught proper hygienic habits with the view to effecting different forms of proper health education.

Reported by M. A. Petrov-Maslakov.

I. P. Pavlov, Dialectical Materialism, Conditioned Reflexes and Signal Systems Based on a Series of Excerpts Taken from Pavlov's Book "Lectures on Conditioned Reflexes. Twenty Years of Objective Study of Higher Nervous Activity of Animals".

Selected and arranged into a continuous exposition as a supplement to the introduction to Survey Volume 5, O.T.S. No. 61-11149.

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Despite the incessant efforts of members of the ruling political party of the U.S.S.R. to include I. P. Pavlov into the realm of their socio-ideological influence or bent of mind, Pavlov remained a free scientist with an open and free mind to the last day of his life. He was a true and ardent exponent of the non-vitalistic and monistic viewpoint prevailing during his time among progressive bioscientists to the same extent as were many of his predecessors and contemporaries in Russia, Germany, France, England, the U.S.A., and other countries. In none of his writings or lectures could one detect any indication of Pavlov having been affected or impressed by the Hegelian adjuncts of philosophical thinking which Karl Marx adopted as the basic principles of his interpretation of the dynamics of historical economics; nowhere in Pavlov's lectures, or other writings, is there any reference to the concept of historical materialism or dialectical materialism based on the trinity so sacred to the ruling communists, as the Thesis, Synthesis and Antithesis. It was stated by some of Pavlov's students, foreign as well as Russian, that Pavlov never addressed his audiences by the salutation of "Comrades" (Tovarishchi), but always by the traditional Russian congenial and polite "Ladies and Gentlemen", or by its equivalent. In support of the above the following excerpt from one of Pavlov's lectures is presented:

"It is clear that contemporary, so-called, vitalism, or shall we say, animism, confuses different points of view of the naturalist and of the philosopher. All the accomplishments of the former have been founded on investigations of objective facts and their comparisons; ignoring the questions of essence and final causes. The philosopher, personifying the highest human aspirations to coordinate or to synthesize, though fruitlessly up to the present, has been searching for an answer to manifestations which concern man; now, even the philosopher must create the totality by going from the objective to the subjective. The naturalist perceives life phenomena through the meth-

od, by means of which he strives to attain a basic lasting truth; to the naturalist the concept of a soul is a stumbling block and a factor which delimits and arrests his courage to delve into depths attainable by his analytical methods".

Occasionally, I. P. Pavlov indicated in his purely physiological lectures that he was not unaware of the existence of certain sociological manifestations. However, such awareness of Pavlov was of interest to him only to the extent to which he could use it as an additional illustration of some point related to his basic thesis of conditioned reflexes; it bore no relation to the ill-defined and diffuse concept of dialectical materialism, as originally advanced by Karl Marx and later revised by V. I. Lenin, and others. This is well illustrated by the following excerpt from one of I. P. Pavlov's lectures:

"All life is more than a realization of a single purpose, namely, the preservation of life itself, the tireless labor of which may be called the general instinct of life. This general instinct, or reflex, consists of a number of separate instincts or reflexes. The greater part of these reflexes are positive movement reflexes toward the conditions favorable to life, reflexes the object of which is to seize and appropriate such conditions for the given organism, grasping and catching reflexes . . . We again insist on the necessity to describe and enumerate the elementary inborn reflexes in order to gradually understand the whole conduct of the animal. Without such classification we have only the usual empty conceptions and words; "the animal forms and breaks habits, remembers, forgets, etc.", instead we arrive at a scientific study of the complex activity of life. There is no doubt that a systematic study of the fund of inborn reactions of the animal will greatly favor an understanding of ourselves and the development in us of the ability of self-guidance. It is clear that with the reflex of freedom there is also the reflex of slavish submission. It is a well known fact that puppies and small dogs often fall on their backs in the presence of larger ones. This is the surrendering of self to the wishes of the strong, the analogy of man's falling on his knees, or prone on his face, the reflex of slavery. This has a use in life. The intentional passive attitude of the weak which leads to a natural decrease of the aggressive action of the strong, whereas even an ineffective resistance tends to increase the destructive ambition of the strong".

This is no expression of a fighting revolutionary reflex, such as the Bol'shevik wing of the Russian fighters for freedom inscribed on their banner

before they took full, absolute, unilateral and monolithic possession of all the privileges and facilities of a group governing not only Russia proper but its, so-called, satellites as well. The Pavlovian concept of the "slavish submission reflex" approaches more nearly the neo-Christian Tolstoyan and Ghandian concepts of non-resistance to force or evil. With regard to reflexes as such Pavlov stated:

" . . . here is a certain agent (external stimulation, B.S.L.) which calls forth in living matter a definite reaction (reflex response B.S.L.). It is a typical example of adaptation and fitness. Let us consider somewhat closer the facts which play such an important part in present-day physiological thought. What does such adaptation consist of? As we have seen, it was nothing more than the exact coordination of the elements of a complex system, and of their complexes, in relation to the external world. . . The external world perpetually calls out, on the one hand, conditioned reflexes, and, on the other hand, continually suppresses them, submerges them through the action of other vital phenomena. This rising and sinking of conditioned reflexes responds at any given moment to the demand of the fundamental law of life - equilibration with surrounding nature. This is accomplished and adjusted through the different kinds of inhibition of the conditioned reflexes. . . From our viewpoint all nervous activity of the animal could be considered as reflex activity of one or two forms - the usual reflex, which had been studied previously for many decades, which we called an unconditioned reflex, and a second, new reflex which embraces the entire remaining nervous activity, and which we designate as the conditioned reflex. . . From the standpoint of objective research we hold that all the nervous activity (of the dog), without reservation, is a reflex activity, a reaction of the animal to the external world effected through the nervous system. In this reaction we can distinguish two kinds of reflexes. The simple and well-known reflex, which we call "unconditioned", is one in which certain phenomena of the external world are associated with definite responses of the organism through a constant and unchanging connection in the central nervous system. For example, if a mechanical body impinges on the eyelid, or every time a foreign body enters the larynx and irritates it, coughing results. From these old reflexes we can differentiate a new group in which the connection of the external phenomena with the responsive reaction of the organism is only of a temporary nature.

This connection forms only under certain conditions, and disappears under definite conditions. Thus, we distinguish between constant and temporary reflexes. In this way we can comprehend and understand many complicated relations (of the dog) to the outside world as temporary reflexes."

"... Considering the phenomena more closely, I can not fail to see the following distinction between these two kinds of reflexes: the unconditioned reflexes, those properties of the substance to which saliva is physiologically adapted act as the stimulus, for example, the hardness, the dryness, the definite chemical properties, etc.; on the other hand, in the conditioned reflex, those properties which bear no direct relation to the physiological role of the saliva, act as stimuli, for example, color, form, and the like. These last properties receive their physiological importance as signals for the first ones, i.e., for the essential properties. In their response one can not but notice a more advanced and more delicate adaptation to the external world. . . . The designation "reflex" which we have given to these complex nervous phenomena is entirely logical. The phenomena are always the result of the stimulation of the peripheral endings of various centripetal nerves, and this stimulation spreads through the centrifugal nerves to the salivary glands (or other receptors, B.S.L.). "... For the building up of conditioned reflexes certain cortical connections from different specific receptors are necessary, for instance, from the eye, the ear, the nose, the skin. There is ground for assuming that the same is true for all other conditioned reflexes. Thus, we have a right to state that the cerebral hemispheres are the organs of conditioned reflexes." "... In different experiments by many workers the fact was constantly met that the temporary reflexes occurred only in presence of the whole or part of the hemispheres. Consequently, we may accept without misgivings the statement that the most essential function of the hemispheres is the elaboration of the conditioned reflexes, just as the main work of the lower part of the nervous system is concerned with the simple, or, according to our terminology, the unconditioned reflexes."

"... The second mechanism belonging to the cerebral hemispheres is the mechanism of the, so-called, analyzers. In this case we started from the old and well-known facts, somewhat changing the conception of them. We designate as analyzer that apparatus the function of which is to break down the complexity of the outer world into its separate elements or constituents; for example,

the eye analyzer consists of the peripheral part of the retina, the optic nerve, and the brain cells in which this nerve ends. The union of all these parts into one functional mechanism, called analyzer, has its justification, because physiology at present has no data for an exact division of the work of the analyzer as a whole. We can not assert that a certain part of its function is performed by the peripheral section, and other parts by the central end. . . . Thus, the cerebral hemispheres, according to our understanding of the matter, consist of a number of analyzers: of the eye, ear, skin, nose and the mouth analyzers. An examination of these analyzers brought us to the conclusion that their number must be increased, that beside the above cited ones relating to external phenomena, to the outer world, there must be recognized in the cerebrum special analyzers the function of which it is to decompose the enormous complexity of the inner phenomena, which arise within the organism itself. Certainly, not only an analysis of the external world is important for the organism, but of same value is an ascending signaling, an analysis of everything happening within the organism itself. Besides the external analyzers there must be internal analyzers. The most important of these inner analyzers is the analyzer of movement, or the motor analyzer. It is known that from all parts of the motor apparatus, from the joints and their surfaces, from the tendons, ligaments, etc., there originate centripetal nerves which signalize every movement, the exact details of the act of movement. All these nerves unite above in the cells of the hemispheres. The most diverse peripheral endings of these nerves, together with the nerves themselves and their terminal cells in the great hemispheres, form a special analyzer, which breaks down the complex motor act into a large number of finest elements or components, thereby attaining the multiplicity and exactness of our skeletal movements".

". . . The analyzer is a complex nervous mechanism which begins with the external receiving apparatus and ending in the brain, now in its lower, now in its higher sections; in the latter case it is much more complex. The facts on which the physiology is based, is that every principal apparatus is nothing more than a special transformer of a certain given external energy into a nervous process. The following questions arise in this connection: what processes are involved in this transformation? Which part of the activity of the analyzer is to be attributed to the construction and process in the

peripheral apparatus, and which part to the construction and process in the cerebral ending of the analyzer? What consecutive phases does this analyzer manifest, starting from its simplest and proceeding to its highest stages? And finally, what are the general laws governing this analysis? In establishing a temporary connection between a given phenomenon of nature and an organism, it is easy to determine to what extent the corresponding analyzer of the animal is able to break the external world into its simple elements".

". . . Now, as to the work of the analyzers. These are nervous mechanisms the function of which it is to decompose the complexity of the external world into its elements, and to receive these elements as well as all their combinations. . . From all our experiments we can say that the cerebral hemispheres represent a central station of all analyzers, which may serve as do the eye and ear analyzers for the analysis of the external world, or as the motor analyzer for the analysis of the internal world, for example, movement. (Many other analyzers still remain undiscovered, and the scope of their analytical activity remains to be defined)." ". . . The basic activities of the higher parts of the central nervous system are: first, the coupling or linking of new temporary connections between certain external phenomena and the functions of the different organs; and secondly, the decomposition of the entire complexity of the external world into its units, briefly, the activity of a coupling or synthesizing mechanism and of an analyzing mechanism. Through these two activities there are established exact and fine adjustments of the animal organism to the outside world, or, in other words, a complete equilibration of the systems of energy and matter constituting the animal organism with the system of energy and matter of the environment." ". . . The main point of the nervous activity is located, I believe, in the receptor part of the central station; at this point is to be found the impetus for the full development of the central nervous system, realized in the central hemispheres of the brain; because these constitute the basic organ of that most perfect equilibrium with the external world which is incarnate in the higher animal organism. The centrifugal portion of the reflex path is purely executive; this latter apparatus conditions what functional combinations will be formed by the cells of one or another motor nerve".

In the paper on Pavlov published in Survey Volume 5 of O.T.S. No. 61-11149 a brief discussion was presented on the processes of differentiation and inhibition. In connection with these phases of the central nervous activity

Pavlov states: "The process of analysis and the process of differentiation must be presented thus: if our chosen special agent is brought for the first time into connection with a physiological function, then the stimulation called out by this agent, coming to certain point in the cortex, irradiates or spreads over the corresponding receptor centers, and, thus, not only the single point in the brain and of the given analyzer enters into definite connection, but the entire analyzer, or a greater or smaller part of it. And only later, owing to the opposition of the inhibitory process, does the field of stimulation-influence become smaller, until at last an isolated action is obtained" . . . "And further, if inhibition lies at the basis of the process of differentiation, then it should be possible to reinforce, accumulate, and summate this inhibition. How? By several successive repetitions of the differentiated stimulus. . . (And) here is another fact following from this: if inhibition lies at the base of differentiation, then the more difficult the task of differentiation, the greater will be the inhibition. It is obvious that it is more difficult to distinguish between two tones differing in pitch by only one-eighth of a note than it is to distinguish between two tones differing by two full notes. One may suppose that the intensity of the inhibition will also differ. The more delicate the differentiation, the stronger will be the inhibition, and vice versa".

" . . . There arises an interesting question: where does this inhibition, which lies at the basis of differentiation, take place? Naturally, one thinks that it develops in the corresponding analyzer, i.e., in that place where the stimulations are analyzed. . . (In fact) we have (other) experiments which prove directly that the inhibition takes place in the analyzer of the differential stimulus. . . (It was shown in) foregoing reports (that) the nervous processes in the highest part of the central nervous system constantly flow, irradiate, and concentrate. This is the reason for believing that inhibitory processes coming from a given analyzer may spread over the entire hemisphere. . . . When you behold a series of such facts (as were presented in the preceding paragraphs), I believe you will arrive at the conception which for me is the only true one. . . The study of reflex mechanism, which forms the basis of the activity of the central nervous system, is here reduced in its essence to a study of space relations, of the definition of paths along which the excitation at first spreads, and then concentrates. If this is so, then it is comprehensible that a sure probability of mastering the subject in all its

extent is given only by conceptions characterized by space ideas. This is the reason why it must be perfectly clear that it is impossible, by means of physiological conceptions, to penetrate into the mechanism of these unusual connections. You must be able, so to speak, to point to the seat where the excitation process was at a given moment, and where it has gone. If you conceive of these reactions as they are in reality, then you will understand the truth and power of that science which we are indicating and developing, the science of conditioned reflexes. It has absolutely excluded from its domain psychological conceptions, and has to do always only with objective facts, facts existing in time and space."

. . . (In the course of our experimental investigations) "it became clear that a definite agent in the outer world may condition the state of rest of the animal and the suppression of the higher nervous activity affecting in the same sure way, as other agents evoke, one or another manifestation of the animal's complex nervous functions. In other words, besides the different active reflexes there is also a passive sleep reflex . . . The sleep reflex is only one kind of inhibition of conditioned reflexes. Inhibition which is induced by the sleep reflex is called by us general inhibition." I. P. Pavlov also speaks of orienting or focusing reflex and many other reflexes. In fact, according to Pavlov, every reaction to a stimulating effect is basically a reflex reaction, direct, or unconditioned, or indirect, or conditioned. General inhibition, according to I. P. Pavlov, is in fact a complex property of central neuro-reactivity. Pavlov states: "Three kinds of inhibition have been established: simple inhibition, extinguishing inhibition, and conditioned inhibition, which as a group form external inhibition. . . There are (still other) cases of internal inhibition. In new experiments another important phase of the problem has become crystallized. It has been demonstrated that besides stimulation and inhibition of stimulation there is often an inhibition of inhibition, in other words, "dis-inhibition". It is not possible to assert which of these three reflex manifestations is the most important. One can merely state simply that the highest nervous activity, as it manifests itself in the form of conditioned reflexes, consists of a continual change of these three fundamental processes: excitation (stimulation), inhibition and disinhibition. I now proceed with the second of these fundamental mechanisms, the mechanism of the analyzer." . . . "Internal inhibition has its origin in the mutual interrelation between new (conditioned) reflexes and the old (uncondi-

tioned) reflexes by means of which the conditioned reflex was formed. This type of inhibition always develops when the conditioned stimulus temporarily or constantly (if constantly, then only under definite and specific conditions, B.S.L.) is not accompanied by the unconditioned stimulus with which it was elaborated."

For the better understanding of the principles which form the basis for the utilization of Pavlovian methods of conditioned reflex studies to practical determination of limits of allowable air pollutant concentrations (and other toxic substances, mostly in gaseous or vapor form), the following excerpts are presented: "Besides external inhibition there exists another group of inhibition phenomena the mechanism of which is quite different. The conditioned reflex, which is a temporary connection of some external, previously indifferent agent, with a certain function of the organism, originates because the action of this indifferent agent on the receptor surface of the animal repeatedly coincides in time with the action of an already existing reflex stimulus of one or another activity. All our experiments have been performed in connection with the salivary gland, which, as you know, reacts to psychical stimulation, using the old terminology, and consequently, is in constant complicated relation to the external world. Food and other stimulating substances, entering into the mouth of the animal, elicit an unconditioned reflex; a conditioned reflex, however, may be called out by any agent of the external world, if it is capable of acting on any receiving surface of the organism. It is clear that a preformed reflex must exist as the basis of formation of the new reflex. Now, if the conditioned stimulus acts for some time alone, unaccompanied by the unconditioned stimulus, with the help of which it had been formed, then the action of the conditioned stimulus becomes weaker, in other words, it is inhibited. . . Finally, the last type of inhibition. We take some indifferent agent, having no marked effect on the animal and add this to a well elaborated conditioned stimulus, not accompanying this combination of the two agents by the unconditioned stimulus (food, for instance). The indifferent agent will gradually become an inhibitor of the conditioned stimulus, i.e., the combination of the conditioned stimulus with the indifferent agent is always null, although the combined stimulus used alone is as active as before. This phenomenon we called conditioned inhibition. Here, too, we have an after effect of the inhibition, just the same as we have described in the case of differentiation of the stimuli."

Research scientists who are engaged in the study of the physiological, toxicological and pharmacological phases of air pollution may be interested in the application of Pavlovian principles of conditioned reflex technics to the practical determination of limits of allowable concentrations of certain types of air pollutants. Their attention is called to the fact that the latent period of conditioned reflex response to stimulation constitutes an important index in evaluating the effect of a studied air pollutant on the organism's state of neuro-mechanism. The latent period of response may be delayed or shortened, accordingly as the pollutant depresses or enhances the reactivity of the nerve apparatus which transmits the stimulation to the central points, and/or depresses or exaggerates the rate of stimulation transmission to the different receptor apparatuses. In this connection the following brief and last excerpt from Pavlov's book is presented: (Under certain conditions) "there is formed the, so-called, retarded or delayed conditioned reflex (response) or latent excitation (of any given receptor). . . What is the basis for this latent stimulation? One might think that the stimulation did not reach an intensity sufficient to produce an effect (due to the poisoning effect of the air pollutant on the receptor and on the transmission neuro-mechanisms in the direction of depression or oversensitization and overstimulation, B.S.L.). Certainly, this can and must be true, even though it does not adequately answer the basic question. One can surmise that there may be an apparent internal inhibition (or overstimulation through nerve sensitization) which up to a definite moment blocks the activity of the (pertinent) center, (or renders the center supersensitive to the stimulus) as manifested (by changes in the latent periods of conditioned reflex response)."

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