THE LEAD CONTENT OF THE URINE AND BLOOD OF CERTAIN OCCUPATIONAL GROUPS WITHIN THE POPULATION OF CINCINNATI, IN RELATION TO THE DISTRIBUTION OF PARTICULATE INORGANIC COMPOUNDS OF LEAD IN THE AMBIENT ATMOSPHERE

INTRODUCTION

In the initial draft of a report entitled, "Survey of Atmospheric Lead in Three Urban Communities," prepared for distribution by and within the Working Group on Atmospheric Lead Contamination, it was pointed out that the investigation of the effects of the general environmental exposure to lead of persons within the population of Cincinnati was to proceed along somewhat different lines than those carried out in either Philadelphia or Los Angeles. (It may be noted incidentally, that the subjects and the procedures of the surveys in the latter two cities were not strictly comparable to each other.)

There were several reasons for this divergence in procedure in Cincinnati. Of primary importance was the fact that many persons in Cincinnati and vicinity had been investigated in this manner previously, on several occasions, the latest of which was in the winter of 1955-1956. In the latter survey approximately 500 persons, engaged in various occupations, had been questioned and examined thoroughly in search of pertinent information, and their blood and urine, as well as their feces, had been sampled and subjected to analysis for lead. Very little more concerning the contribution made by atmospheric contamination to the absorption and excretion of lead, than had been learned in previous investigations of this type, was revealed by this investigation, and the conclusion appeared to be inescapable that if definitive evidence of the influence of air-borne lead upon the absorption of lead by the population of Cincinnati was to be obtained after so short an interval

of time, a different segment of the population would have to be investigated, or the investigative procedure would have to be refined.

With respect to the specific technique of the investigation, the choice of the procedures of sampling and analyzing the urine and blood, as means of measuring the current and, hopefully, the more remote, experience of the individual human subject, with respect to his absorption of lead, had been based upon extensive evidence gained by prolonged and detailed investigation of the metabolism of lead in normal human subjects (1). There was no expectation that these general procedures could be replaced by other and better means of attack on the problem. There was some hope, however, that by a judicious selection of groups of persons in the population, and by the acquisition of certain items of supplementary information, it might be possible to segregate certain individual sources of exposure to lead, and thus to recognize the relative importance of the atmospheric source.

The problem of relating the rate of the urinary excretion of lead by any segment of the population, or the lead content of the blood of such a segment, to the lead in the ambient atmosphere, is complicated by several factors. The most important of these appears to be the intake of lead by the adult with food and beverages. This usually averages 0.20 to 0.30 mg. per day per individual adult over considerable periods of time, but is sufficiently variable from one day to another (ranging from $>$ 0.10 to $<$ 2.00 mg. per day) to induce a considerable degree of variation in the lead output in the urine (with only slight to negligible variation in the concentration of lead in the blood, except during periods of sustained high intake in food and drink).

The next most important factor which tends to mask the specific influence of the air-borne lead to which individuals in the general population (exclusive of those employed in lead-using occupations) are exposed, is the low concentration of lead in the ambient atmosphere. It is now clear that a fairly large proportion of the lead in the ambient atmosphere that reaches the alveolar surface of the lung is likely to be absorbed fairly promptly (25 to 40 per cent (2)). But the absolute quantity of lead so absorbed is minute and is less, under ordinary circumstances, from day to day, than that absorbed from the alimentary tract. Moreover, the lead content of the atmosphere in various areas of Cincinnati is variable, as shown both by the observations described in another part of this report and by those obtained earlier. Inasmuch as this variability has seasonal, diurnal and zonal features, the severity of the exposure of an individual to air-borne lead can be described for experimental purposes, during a specific period of the year, only as the summation of the fractional periods spent from day to day at his place of work, at his home, on the way from one to the other, and at any other place frequented by him. During cold seasons of the year and under other conditions which involve the spending of much time indoors, such factors as indoor ventilation and air-conditioning (especially filtration) can be expected to exert significant influences on the total daily or seasonal exposure. Many other factors, including out-of-the-city travel, have to be taken into account.

The foregoing and other considerations rendered it desirable to seek out groups of subjects whose experience would seem to have yielded more than usually constant opportunities for respiratory exposure to the

principal sources of lead in the ambient atmosphere of Cincinnati. For obvious reasons, the most promising groups were those whose occupations require them to spend most of their working hours regularly in the streets and on the sidewalks of the city (in close relation to its motor traffic). In this category, and with some degree of intrinsic homogeneity as to social and economic status, fell city police generally (traffic officers in particular), postal employees, especially letter carriers on foot and in motor cars, city firemen (reasonably homogeneous but possibly subjected to unusual incidents of exposure to lead in their work), and certain peripatetic, technical employees of the City Health Department (housing inspectors, air pollution inspectors, and sanitary engineers). (Professional drivers of motor vehicles, especially in city traffic, such as taxicab drivers and the drivers of delivery trucks (powered by gasoline engines), were regarded as desirable subjects, but were not readily available through any of the means that seemed feasible of general application, and, after the expenditure of considerable time and effort in obtaining fourteen taxicab drivers as subjects, this group was abandoned. The results of these analyses are given in this report but are not taken to be representative of this occupational group.)

For the purposes of this survey, it is not possible to establish an experimentally valid relationship between the specific environmental conditions to which either the groups, as entities, or the individuals of which the groups were composed, were subjected. That is to say that it is not possible, on the information recorded, to weigh with reasonable precision, the potential exposure to lead of a group or an individual in terms of the time spent per day in one or more of the several areas of

the City of Cincinnati. The search for significant evidence of atmospheric exposure to lead in the accumulated data had to be based, therefore, on the statistical examination of such variability as could be found within and between the several occupational groups, and on plausible interpretations of statistically significant findings.

An additional point in the methods of the survey is worthy of mention at this point. It has been demonstrated conclusively in balance experiments carried out with human subjects, that, (under appropriate conditions, with respect to respiratory exposure to lead), the lead output in the feces, from day to day, over appreciable periods of time, is clearly indicative of the current intake of lead in the food and beverages ingested (3). It has also been shown that samples of feces, when collected on one occasion from each member of a fairly large group of normal adults, in such a manner as to approximate normal daily evacuations of such individuals, contain quantities of lead which, collectively, are representative of the daily intake of lead in food and beverages by the group. That is to say that the distribution of the frequencies of the quantities of lead found in the samples of feces of such a group, and the mean quantity of lead derived therefrom, correspond very closely in all respects to the results obtained in balance experiments carried out over the period of many months during which the feces are collected as 24-hour samples.

On the basis of these observations, it was thought that a reasonable estimate could be made of the intake of lead in the food of the subjects of the present survey, and that this factor could be so dealt with as to reveal, more clearly, any differences that might exist within or between the various groups of subjects in the severity of their exposure

to air-borne lead. Before undertaking to collect and analyze samples of the feces of these subjects, however, it seemed wise to reexamine the data gathered previously in the 1955-1956 survey from about 500 subjects, so as to assess the usefulness of this procedure in relation to the experimental objective. The criterion for this assessment, which appeared to be crucial, was that of the existence of a significant degree of correlation between the lead content of the feces of the subjects and the lead content of their urine. If such a correlationship should be found to exist in the former group of subjects, it could reasonably be expected to be found in the present survey. Unfortunately, no such correlationship was found, thus demonstrating either that the samples of feces, collected in the manner of the earlier survey, were unsatisfactory, i.e. were not truly representative of the facts with respect to the general level of the ingestion of lead in food and beverages, or that the validity of the correlation between many samples of food and feces, while sustained for a fairly large group, does not extend to the individuals in the group, unless multiple observations on individuals are so made as to reduce the factor of individual variability from day to day. (There are, of course, other possible explanations of this lack of correlation.) In any case, there was no good reason to believe that satisfactory results could be obtained in this manner in the present survey, and this idea was abandoned. (It has been found entirely feasible to obtain samples of feces from a fairly large group of subjects in such a manner as to yield a close approximation of their 24-hour alimentary evacuations. This requires such careful indoctrination of each subject, however, and such close adherence to instructions on their part, as was not thought to be

possible under the conditions of this survey. It is also possible to obtain samples of urine of large volume, or multiple samples of small volume, so as to gain satisfactory information from each subject concerning the general rate of his urinary excretion of lead, thereby dispensing with the relatively large factor of physiological variability in the urinary output of lead from time to time during the day. Such an investigative approach to a large group of subjects, would have extended this survey far beyond its intended scope.)

Selection of Subjects

Pursuant to the objectives indicated above, the groups and numbers of subjects under investigation in the present survey are indicated in Table 1.

Table 1

Groups and Subgroups of Subjects	Numbers	
Policemen	123	
Policemen concerned primarily with traffic		37
Firemen	191	
Post-office personnel	140	
Health Department personnel	37	
Sanitary engineers		21
Air pollution inspectors		9
Housing inspectors		7
Taxicab drivers	14	
Total number of subjects	505	

Three of the groups, i.e. policemen, firemen and post-office personnel, are composed of practically all of the persons who were

available within the periods scheduled for the examinations. Some few were on leave or otherwise temporarily unavailable. The importance of this essentially full coverage of these groups lies in the fact that the effect upon the absorption of lead of any relevant but unusual feature of the life or experience of specific individuals within the group will have left its mark, within the sensitivity of the methods employed for the detection of such effects. (The selection of representative subjects or classes of subjects from a specific category of subjects is likely to be based upon assumptions, and despite the cautious exercise of judgment, grounded in experience, the incompleteness of the coverage becomes a source of concern.)

The assurance as to complete portrayal of the relevant effects of the experience of these three groups does not extend to the selected groups of personnel in the Cincinnati Health Department, but the three subgroups share with the other major groups the geographic coverage of the city.

The drivers of taxicabs, on the other hand, are too few in number to be representative of this highly variable (in geographic, racial and social origin, and in personal characteristics) category of citizens. For the purposes of this survey, they are merely other persons who have yielded additional items of data. No further reference will be made to them, other than to record the data, and to note that the latter fit into the general pattern of the larger body of data.

In order to call attention to other segments of the population of the Cincinnati community, and to include certain additional and seemingly pertinent vocational categories of subjects, it seems

advantageous to broaden this report by recording the results of certain observations made in the winter of 1955-1956 on 478 persons in Cincinnati and vicinity. The methods of questioning and examining these subjects differed radically, in their comprehensiveness, from those (to be described below) employed in this survey. The analytical data, however, augmented by those concerned with samples of feces (as referred to previously), were obtained by the same methods of analysis in the hands of the same members of the staff of the Laboratory, and are comparable, in every respect, to those obtained in this survey. The mere increase in the number of persons investigated, from approximately 500 to approximately 1000, is not in itself, of importance, but the locations and types of employment of the additional groups of subjects, in relation to the factor of the combustion products of automotive engines, provide a significant broadening of the scope of the investigation. The types and numbers of these subjects are listed in Table 2.

Table 2

Groups of Subjects	Numbers
Gasoline service station attendants	130
Refinery handlers (tank truck) of gasoline	86
Garage mechanics	152
Car parking attendants	48
Drivers of motor vehicles	45
Cincinnati traffic officers	17
Total number of subjects	478

Methods of Investigation

Each subject was questioned by a member of the clinical team composed of five physicians, assisted by a registered nurse and three clerical assistants, and the results were recorded in a uniform manner, employing the "Environmental, Occupational and Medical History" form of record authorized by the Study Group, a copy of which is reproduced for inclusion below.

A specimen of urine, voided on one occasion directly into a glass container (a chemically clean bottle of approximately 130 ml. capacity, closed tightly by a latex rubber cap), was obtained under the supervision of the examiner, from each subject. Duplicate specimens of blood were also obtained by means of previously cleansed, rubber-capped and evacuated glass tubes and lead-free, metallic needles (the complete B and D Vacutainer equipment). Each specimen, in the container supplied for the purpose by the Kettering Laboratory, was labeled for identification, and returned to the Laboratory for analysis by methods that have been described in the literature and in the preliminary report of the Study Group.

The analytical data were entered into the record of the subject, punch cards were prepared therefrom, and by means of the latter, various statistical arrangements and computations were made in search of relationships of environmental significance.

Results

All of the analytical data of the two surveys (that of 1955-1956, and that of 1963) have been assembled in Tables 3 and 4, according to the

Table 3

Distribution of Persons in Various Vocational Groups According to the Concentration of Lead in Urine

Lead in Urine Mg./L.	Service Station Attend-ants	Refinery Handlers of Gasoline	Park-ing Attend-ants	Garage Mechan-ics	Drivers of Cars		Police			Fire-men	Post-Office Emp.	City Health Dept Emp.
							Traffic Officers		All Police			
					1956	1963	1956	1963	1963			
0-0.009	1	1	1	4	1			2	2			
0.01		1	4	2	28		9		6	47	49	12
0.02	74	49	21	39	11	5	5	13	29	71	52	18
0.03	33	22	12	33	2	4		7	21	36	19	6
0.04	13	9	7	30	2	4	3	8	30	19	9	1
0.05	5		2	21		1		2	12	9	1	
0.06	3	4	1	16				1	7	2		
0.07				4	1			1	3	1		
0.08+	1			3				3	6			
Totals	130	86	48	152	45	14	17	37	116	185	130	37
Mean	0.027	0.028	0.028	0.040	0.020	0.036	0.023	0.039	0.038	0.027	0.022	0.022
S.D.	±0.010	±0.013	±0.011	±0.020	±0.011	±0.010	±0.011	±0.020	±0.018	±0.011	±0.009	±0.007

Table 4

Distribution of Persons in Various Vocational Groups According To the Concentration of Lead in Blood - (Dithizone)

Lead in Blood Mg./ 100 g.	Service Station Attend-ants	Refinery Handlers of Gasoline	Park-ing Attend-ants	Garage Mechan-ics	Drivers of Cars		Police			Fire-men	Post-Office Emp.	City Health Dept. Emp.
							Traffic Officers		All Police			
					1956	1963	1956	1963	1963			
0-0.009												
0.01	1	2				1		3	12	18	22	10
0.02	42	30	1	8	17	4	7	23	78	123	90	24
0.03	71	46	26	43	19	9	9	9	27	44	24	2
0.04	14	8	20	72	9		1	4	5	6	2	
0.05	2			25							1	
0.06			1	4				1	1		1	
Totals	130	86	48	152	45	14	17	40	123	191	140	36
Mean	0.028	0.027	0.034	0.038	0.033	0.031	0.031	0.030	0.025	0.025	0.023	0.021
S.D.	±0.007	±0.006	±0.006	±0.009	±0.006	±0.006	±0.006	±0.009	±0.007	±0.006	±0.007	±0.005

frequencies of occurrence of various ranges of the concentration of lead in the urine and blood, respectively, so as to provide a convenient means of inspecting them in a uniform array, and noting the more obvious similarities and differences in the groups. The impressions gained by observing the differences in the distribution of the results, especially in the frequencies of occurrence of higher values in the data of certain groups, achieve more definitive focus as account is taken of the mean values and their standard deviations.

Bearing in mind that the concentration of lead in the urine of an individual, apart from such a regular and potent physiological variable as the quantity of water available in the body, at any specific time, for excretion in the urine, is dependent primarily (with some lag) upon the current rate of the absorption of lead from the alimentary and respiratory tracts, it is apparent that the degree of variability of the concentration of lead in the specimens of the urine (Table 3) of nearly 1000 persons in these divergent walks of life is remarkably small, the total range extending from 0.005 to 0.11 mg. per liter. When one realizes that there is virtually no physiological obstacle to the excretion of much higher concentrations of lead in the urine (than those recorded in Table 3), under appropriate conditions of exposure and absorption (values in excess of 5 mg. per liter have been observed, while values up to and in excess of 0.5 mg. per liter, in the course of occupational exposure to lead are not uncommon), it is clear that the quantities of lead absorbed by the individuals in these groups, from day to day, while highly variable within low limits, are of a uniformly small order of magnitude.

There are significant differences in the groups, however, of which the outstanding example in the entire series is that of the garage

mechanics. Other groups, notably the police officers of this survey, as an entire group, and a fairly sizable sub-group of traffic officers (including certain other police officers whose duties involve prolonged service on foot and in motor cars in traffic streams of varying density), are in the relatively high zone of the total spectrum of mean values.

In considering the results of the analyses of the blood in Table 4, it should be pointed out that those represented in these tabulations were obtained by the use of the "dithizone" method of analysis. (The results obtained as a precaution against contamination or manipulative error, by the application, in parallel with the dithizone method, of the spectrographic method of analysis, were consistently confirmatory, in the sense that there was no instance of a deviation of the one from the other beyond the range of the known precision of the two methods. There were, therefore, no contaminated samples of blood and no unaccountable errors in the analytical procedures. Since, however, the variability of the results obtained by the parallel employment of the two methods is of lesser degree in the instance of the procedure involving dithizone, the results so obtained are preferable for statistical purposes.)

In Table 4 as in Table 3, but in somewhat lesser degree, the groups are divergent, and again the outstanding example, on the high side, is that of the garage mechanics. A small group of men employed in several parking garages and parking lots (investigated in 1955-1956) is next in order on the high side, and a correspondingly small group of regular drivers of motor cars (also investigated in 1955-1956) come next and are almost paralleled (for whatever meaning the fact may have) by the small and unsatisfactory group of taxicab drivers included in the

present survey. Next in descending order come the traffic officers (of the 1955-1956 survey) and, with insignificant difference, the larger group of policemen of which (in the present survey) they are a part. From here on down, from the mid-point in the sequence of mean values, come, in minutely staged differences of no apparent statistical or physiological significance, firemen, post-office personnel and the peripatetic technical personnel (inspectors of various kinds) of the City Health Department. It is obvious, despite the narrow range of the individual findings (0.01 to 0.06 mg. of lead per 100 grams of whole blood), and the small range of the mean concentration of lead in the blood of the several groups (0.021 to 0.038 mg. of lead per 100 grams of whole blood), that the differences between the groups reach statistical significance at several intervals from the lowest to the highest, in view of the fact that the intrinsic variability within the group is of nearly the same low order of magnitude throughout, as shown by the distribution of the frequencies and by the mathematical expression of their variability in the standard deviations. The significance of these differences, in relation to the primary environmental factor under examination - namely, air-borne lead - is not so readily evident. As indicated previously, the situation is complicated by the quantities, and variability of the quantities, of lead ingested day by day with food and beverages. Many opportunities are afforded, daily, to individuals in our general population, to take in unusual quantities of lead. Cooking utensils, tableware, simple and not unusual incidents involving the handling of food (and other objects introduced into the mouth) with unclean hands play their part in the environment in which lead is always present in

some form and quantity. An important feature that operates to limit the variety of human experience in these matters, and to promote a certain homogeneity of excitation and response, is the regular, daily, almost inescapable pattern in the highly organized life of the modern urban community. Common sources of food, water and other beverages, common avenues for the distribution of these products, and the common equipment and routines of life in a large proportion of households, tend to limit the variety of experience. One may postulate, under these conditions, that such a variable as the atmospheric content of lead, if distributed in sufficiently distinctive orders of magnitude in well-defined areas of a city, would reveal its effects in a distinctly variable manner, through the responses of the residents of these areas. Accordingly, in order to determine the significance of one factor which might contribute to the differentiation of the exposure to air-borne lead of individuals within the several groups, the subjects were classified according to the four general areas in which their home addresses were situated, as industrial, commercial, residential or rural (refer to the aerometric survey in Cincinnati). The results of the examination of the analytical data arranged in this manner are shown in Tables 5 and 6. The failure to find any valid or consistent relationship between these areas and the lead content of the urine and blood is evident.

Another variable in the experience of the subjects - namely, their habits of smoking - in its hypothetical relationship to their absorption of lead, was examined in considerable detail because of its possible effect in masking or distorting the physiological response to the lead in the general (ambient) atmosphere. For reasons which have

Table 5

The Mean Levels (and Their Standard Deviations) of the Concentration of Lead in the Urine of Four Vocational Groups of Subjects Distributed According to the Location of Their Home Addresses Within Certain Designated Areas of the Community

Vocational Groups of Subjects	Industrial Area			Commercial Area			Residential Area			R
	Number of Subjects	Mean Value Mg./L.	S.D.	Number of Subjects	Mean Value Mg./L.	S.D.	Number of Subjects	Mean Value Mg./L.	S.D.	Number of Subjects
Policemen	9	0.048	±0.019	12	0.037	±0.024	80	0.037	±0.017	10
Firemen	5	0.027	±0.008	21	0.026	±0.011	143	0.027	±0.011	16
Post-Office Employees	18	0.020	±0.005	14	0.020	±0.010	63	0.023	±0.009	15
Health Department Employees	1	0.020		6	0.020	±0.004	23	0.022	±0.008	3
All Groups	33	0.028		53	0.026		309	0.028		44

Table 6

The Mean Levels (and Their Standard Deviations) of the Concentration of Lead in the Blood of Four Vocational Groups of Subjects Distributed According to the Location of Their Home Addresses Within Certain Designated Areas of the Community

Vocational Groups of Subjects	Industrial Area			Commercial Area			Residential Area			Rur
	Number of Subjects	Mean Value Mg./ 100 g.	S.D.	Number of Subjects	Mean Value Mg./ 100 g.	S.D.	Number of Subjects	Mean Value Mg./ 100 g.	S.D.	Number of Subjects
Policemen	10	0.026	±0.007	12	0.029	±0.011	85	0.024	±0.006	10
Firemen	5	0.026	±0.004	22	0.026	±0.007	148	0.025	±0.006	16
Post-Office Employees	20	0.022	±0.005	14	0.026	±0.011	68	0.024	±0.007	17
Health Department Employees	1	0.025		6	0.021	±0.005	24	0.021	±0.005	3
All Groups	36	0.023		54	0.025		325	0.024		46

been set forth in the initial draft of a report of the Study Group entitled, "Survey of Atmospheric Lead in Three Urban Communities" dated January 15, 1963, it was not anticipated that this effect would be striking or even certainly discernible. On the other hand, the entire contribution made by the inhalation of lead to the absorption and excretion of lead by representative persons in the general population can hardly be detected readily, and the reduction of any part of it to discernible size might well be helpful in the appraisal of the other part (or parts) of it. The data that are available in sufficient numbers to be worthy of statistical examination are assembled in Table 7. (The division of all of the subjects or of certain of the groups of subjects into sub-groups, especially those concerned with varying degrees of intensity of cigarette smoking, resulted in such small numbers in certain categories as to be of highly dubious or obviously negligible representative significance.) It will be evident at a glance that the differences between the smokers and the non-smokers of cigarettes in the several groups of subjects, while very small and statistically insignificant, are, with one exception - that of the concentration of lead in the urine of policemen - in the right direction. That is, they tend to show, if anything, a trend toward the occurrence of larger quantities of lead in the urine and blood of smokers, as compared with non-smokers. This trend, not remarkably, in view of its essential uniformity within the group, is sustained when all of the groups are combined, and all of the smokers are compared with all of the non-smokers. Because of the larger number of subjects in the two categories, the difference seems to have greater validity, but it is small indeed,

Table 7

The Mean Levels (and Their Standard Deviations) of the Concentration of Lead in the Urine and Blood of Four Vocational Groups of Subjects Distributed as Smokers and Non-Smokers, and According to Certain Predilections of the Smokers, of Cigarettes

Group of Subjects	Sub-group	Lead in Urine (Mg./L.)			Lead in Blood (Mg./100 g.)		
		Number	Mean Value	Standard Deviation	Number	Mean Value	Standar Deviati
Policemen	Smokers	104	0.038	±0.019	107	0.025	±0.007
	Non-Smokers	8	0.039	±0.013	11	0.023	±0.006
Firemen	Smokers	158	0.027	±0.012	163	0.025	±0.006
	Non-Smokers	26	0.026	±0.008	27	0.024	±0.006
Post-Office Employees	Smokers	109	0.023	±0.009	118	0.024	±0.006
	Non-Smokers	19	0.019	±0.007	20	0.022	±0.010
Health Department Employees	Smokers	29	0.023	±0.007	30	0.022	±0.005
	Non-Smokers	5	0.018	±0.004	5	0.016	±0.002
All Subjects 1963	Smokers	400	0.028	±0.014	418	0.024	±0.006
	Non-Smokers	58	0.025	±0.010	63	0.022	±0.007
All Smokers	Inhale	282	0.029	±0.012	294	0.024	±0.006
	Do Not Inhale	43	0.025	±0.010	46	0.022	±0.005
All Smokers of Cigarettes	Unfiltered	168	0.037	±0.017	173	0.022	±0.005
	Filtered	123	0.023	±0.010	131	0.024	±0.006

and cannot be taken very seriously, from the aspect of the one specific, but uncontrolled, variable. To the extent of the significance that may be attributed to this trend, it introduces a complicating factor into the interpretation of certain other statistical findings. It is important to recognize, however, that the differences between the vocational groups are influenced either slightly or not at all by the factor of smoking. Obviously, therefore, the factor which differentiates policemen from post-office employees, whatever it may be, is much more potent than the factor of smoking. It may be worthy of note, perhaps, (as much as is any other feature of these inconclusive findings) that the difference between smokers, with respect to whether or not they inhale, while minute, is favorable to the hypothesis that more lead is absorbed by those who inhale. Just what can be made, other than as the intervention of chance, of the contradictory findings yielded by the urine and blood of men who smoke unfiltered, as compared to filtered, cigarettes, is not apparent.

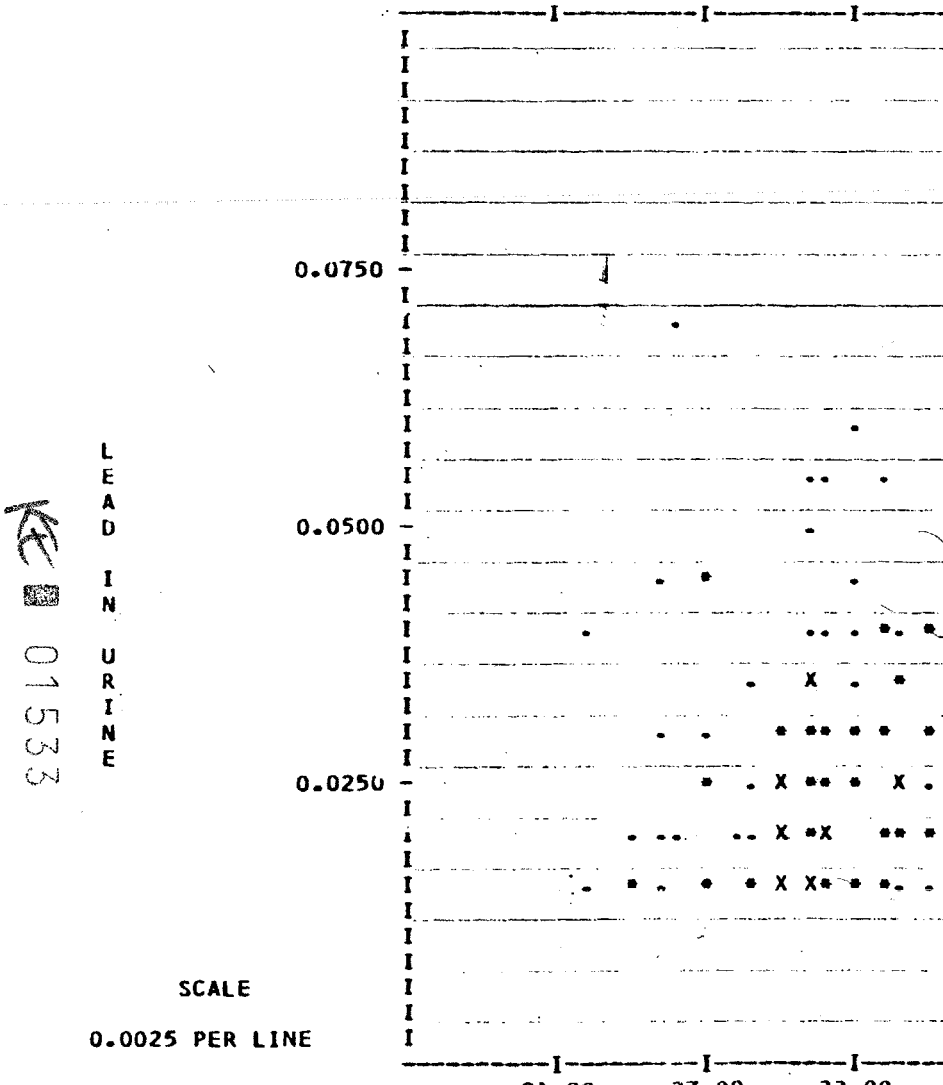
A series of additional relationships between the levels of the concentration of lead in the urine and blood of the subjects in vocational and combined groupings, and various features of their experience or environment, were investigated statistically. Included in these were such factors as the age of the subjects, the duration of their employment in their specific vocational categories, the source of their water supply, the type of heating and cooking devices in their homes or quarters, certain physical ailments (specifically, pulmonary, renal and hepatic diseases), and the frequency and severity of such suggestive effects of exposure to significant concentrations of carbon monoxide as headaches, dizziness and the feeling of undue tiredness, singly and in combination. Attempts to discover correlations

between these factors and the data indicative of variable levels of absorption of lead, were of no avail. Two charts portraying the product of the handling, in the computers, of the data with respect to the age of members of one of the groups, versus the concentration of lead in the urine, (Figure I), and the concentration of lead in the blood, (Figure II), will serve to illustrate the statistical procedure, as well as the lack of correlation that characterized this group of variables. This lack is so obvious in a mere glance at these two charts (as it was in all of the others) that there was no need to calculate correlation coefficients.

Discussion

The data as assembled systematically, for comparative purposes, in the preceding tables and figures, together with the explanations and discussions that have accompanied them, have conveyed the information obtained in this survey in a seemingly satisfactory manner. Some additional comments, however, may render this information more pertinent and responsive to the primary issues of the survey.

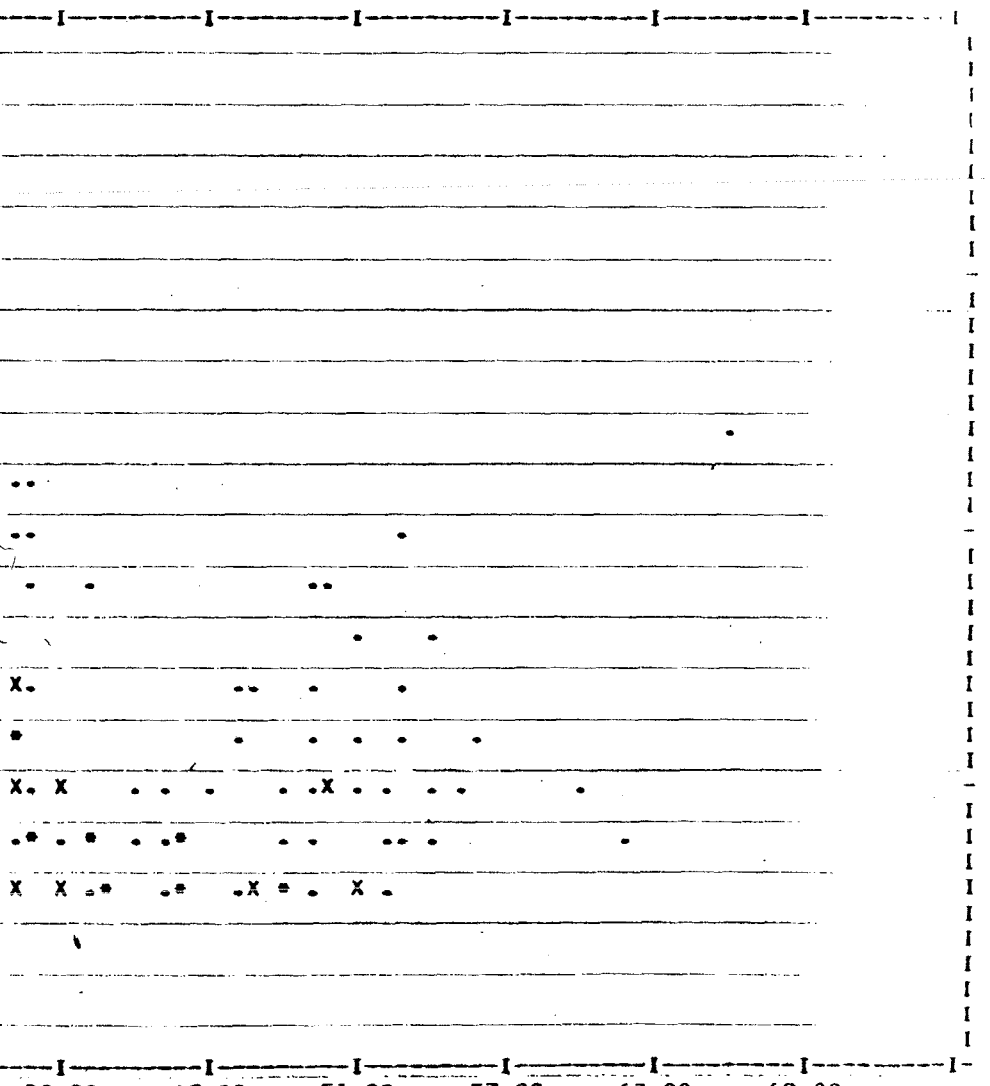
It is all too apparent that the evidence which points to the influence of the lead content of the atmosphere in any part of Cincinnati upon the levels of the concentration of lead in the urine or blood of the subjects of this survey, as well as that of 1955-1956, is dubious at best. From the physiological viewpoint there can be no doubt that this factor exerts an effect upon the composite absorption and excretion of lead by the individuals in the population. But the best, and in fact the only, findings that contribute any actual weight of evidence to the detection of effects which vary with varying degrees



NUMBER OF PIECES OF DATA

Figure I

FIREMEN
BY AGE

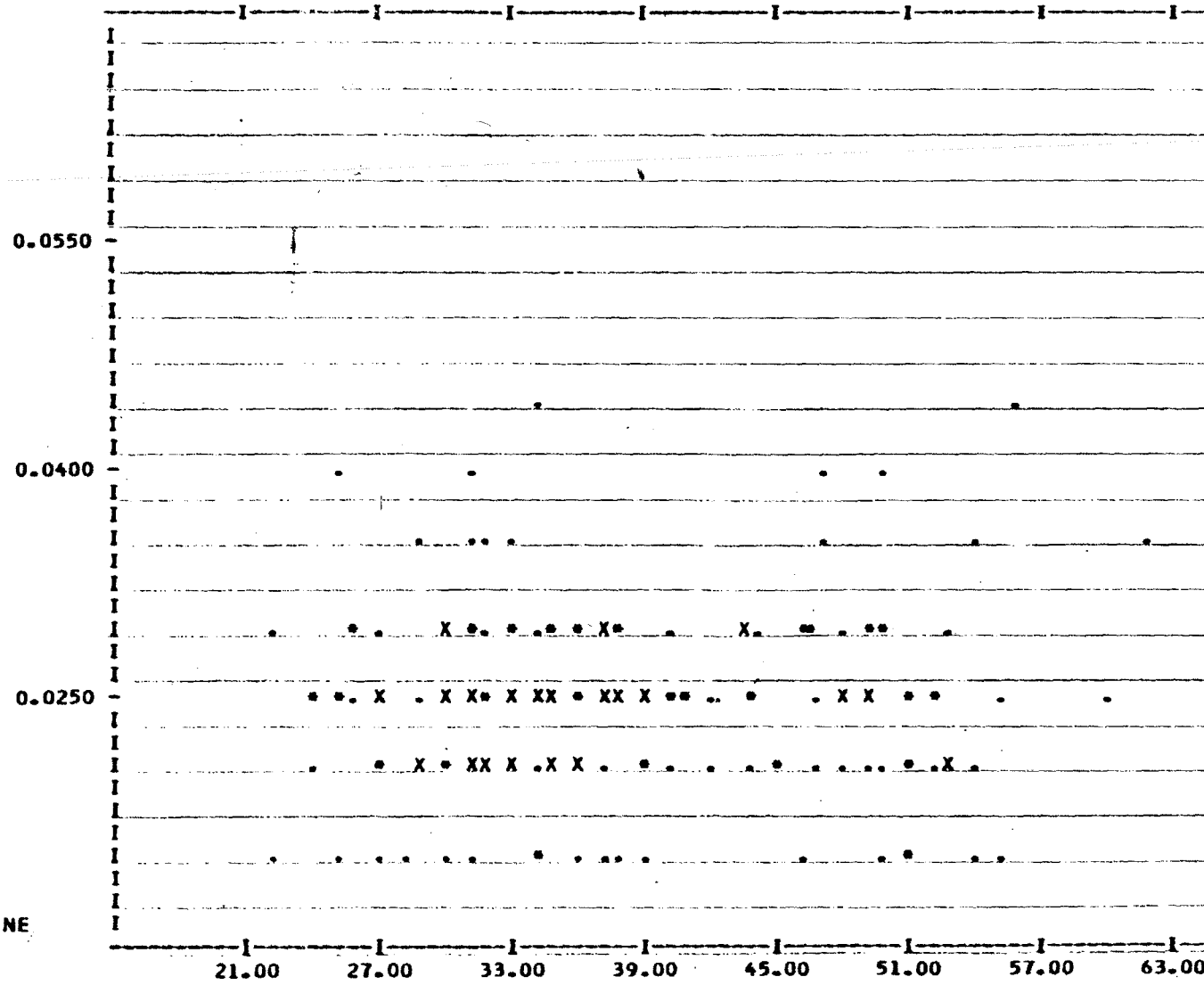


SCALE 0.60 PER SPACE
AGE

SYMBOL TABLE

Figure II

FIREMEN
BY AGE



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SYMBOL TABLE

of severity of exposure to air-borne lead, lie in the somewhat greater extent of the current (and less recent) absorption of lead (as revealed by the level of the urinary excretion of lead and the lead content of the blood) by certain groups of subjects who would seem to have undergone somewhat more than the usual exposure to air-borne lead, - namely, the garage mechanics and car parking attendants of the 1955-1956 survey, and the policemen (including traffic officers), of the present survey. There is no doubt that many of the individuals in these groups have absorbed more lead than have corresponding numbers of persons in any of the other groups. Further, there is no doubt that there had been a significant gradation of the total exposure to and absorption of lead within the several groups of subjects, from the highest mean values recorded in Tables 3 and 4 to the lowest. The question at issue, of course, is whether these differences are due to differences in the exposure of the individuals within these groups to air-borne lead. It is tempting to conclude that this was the case, especially since this was the assumption on which certain of the groups of persons were selected. But the matter is not so simple in terms of valid evidence, primarily because the experimental design of the survey included no control of other environmental sources of lead, one of which, at least, must be regarded as no less than equivalent in magnitude and variability to that of lead in the air - namely, the lead in the food and beverages of the individual and grouped subjects. There is no direct evidence in these data on which the actual order of magnitude of the absorption of air-borne lead by these subjects can be estimated. Moreover, as indicated above, there

is no valid direct or indirect evidence on which the differences between the various groups can certainly, or even probably, be ascribed to differences in their respiratory exposure to lead.

The uncertainties with respect to the meaning of the variable results of the analytical findings from person to person and from group to group among the subjects, may indicate to some persons who are interested in the outcome of this investigation, that little or nothing of significance has been contributed toward an understanding of the hygienic significance of lead in the ambient atmosphere. Such a view of the matter misses the main point of the findings, from the aspect of the potential hazard of air-borne lead to the public health. The fact is that the order of magnitude of the respiratory exposure to lead in Cincinnati is small - so small, in fact, that it cannot be distinguished, with reasonable certainty, from other sources of the exposure to lead, on the part of the general population, even by the refinements of statistical analysis.* The importance of this fact is exceeded only by that of the further fact that the composite exposure of the general population of Cincinnati to lead, from all ordinary and general sources, is small, and that while such exposure is variable, from day to day, the limits of variability are such, and the frequencies of occurrence of the

*The magnitude of the respiratory exposure and of the physiological response to it can be defined indirectly, but accurately, in well designed experiments in the laboratory, in which the several sources of exposure can be measured individually. It is possible also that a survey could now be designed in such manner as to yield valid information concerning the extent of the contribution made by individual sources to the composite exposure to lead of representative groups in the general population. Such a survey would be more elaborate and more costly than any that have been carried out previously.

higher ranges of exposure are such, as to pose no hazard to the public health.

Summary

1. Observations have been made this year (1963) on 505 persons in five different, active, vocational groups of males in the general population of Cincinnati, in search of evidence of the effects (upon the absorption and excretion of lead) of their exposure to lead in the ambient air of the city. The results of these observations have been combined or compared, so far as possible, with those obtained eight years earlier (in the winter of 1955-1956).

2. The specific groups of subjects (gasoline service station attendants, gasoline tank truck handlers and transporters of gasoline, automobile parking attendants, drivers of motor cars, and garage mechanics, in 1955-1956; and policemen, post-office employees (mostly letter and mail carriers), firemen, technical personnel (peripatetic inspectors) of the Health Department of Cincinnati, and a small group of taxicab drivers, in 1963) were selected for investigation for the reason that each group offered some prospect of including within its ranks a goodly number of persons the greater portion of whose working days were spent in proximate relationship to the motor traffic in the streets or within the confined spaces of repair or parking garages.

3. The subjects were also investigated from the aspect of the relative contribution which might be made to their respiratory absorption of lead through their use of tobacco (primarily in smoking cigarettes).

4. The subjects were questioned as to matters which appeared to be relevant in some degree to their past and present opportunities for the absorption of lead from any source, but with specific emphasis on respiratory sources. Other seemingly pertinent items of historical, occupational or medical information were recorded. Specimens of urine and blood were obtained from each subject for analysis for lead.

5. The historical and analytical data were coded and assembled in a variety of strategic arrangements, combinations and juxtapositions for statistical comparisons and computations, and both the significant and insignificant relationships were examined and commented upon in the text of this report.

6. The essential conclusions derived from the combined data of the two surveys may be stated in much abbreviated form as follows:

(a) Among the several vocational groups of subjects, garage mechanics may definitely be singled out as having given evidence of their subjection to greater exposure to and absorption of lead than have any of the other groups. Several other groups, namely the automobile parking attendants, the drivers of motor cars, and traffic policemen, have yielded suggestive but not consistent and definitive evidence of having absorbed somewhat more lead than the remaining vocational groups. Listed in the decreasing order of the mean levels of the concentration of lead in the urine and blood of the other groups are, interchangeably, service station attendants and refinery handlers of gasoline, firemen and postmen, and finally, a group of peripatetic inspectors in the City Health Department.

7. The mean levels of the concentration of lead in the urine

of the several groups range from 0.022 to 0.040 mg. per liter, while those in the blood range from 0.021 to 0.038 mg. per 100 grams. These ranges are small and well within the limits of the normal range as it has been defined in balance experiments conducted on normal, healthy individual subjects in this Laboratory (1), and the successive differences from the highest to the lowest are significant statistically at only two points between the extremes. From physiologic or hygienic viewpoints these differences are of little significance, and from the aspect of the differentiation of the effects of the absorption of airborne lead, from that of ingested lead (which was not measured independently in these observations), they are too small to be informative.

8. The combined data derived from these surveys serve to demonstrate that the composite exposure to lead and the absorption thereof, by the several groups of subjects investigated, is too small to be separated into its component parts by the methods that have been employed.

References

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(2) Kehoe, Robert A.: The Harben Lectures, 1960 - The metabolism of lead in man in health and disease. Lecture II. The metabolism of lead under abnormal conditions. Journal of the Royal Institute of Public Health and Hygiene, 24:101-20, 129-43, 1961.

(3) Kehoe, Robert A. et al.: Experimental studies on the ingestion of lead compounds. Journal of Industrial Hygiene and Toxicology, 22:381-400, 1940.

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