Proceedings of a conference to determine whether or not there is a public health question in the manufacture, distribution, or use of tetraethyl lead gasoline / Prepared by direction of the surgeon general.

PUBLIC HEALTH BULLETIN
No. 158

PROCEEDINGS OF A CONFERENCE TO DETERMINE WHETHER OR NOT THERE IS A PUBLIC HEALTH QUESTION IN THE MANUFACTURE, DISTRIBUTION OR USE OF TETRAETHYL LEAD GASOLINE

TREASURY DEPARTMENT
UNITED STATES PUBLIC HEALTH SERVICE

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WASHINGTON, D. C.
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PREPARED BY DIRECTION OF THE SURGEON GENERAL

WASHINGTON
GOVERNMENT PRINTING OFFICE
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TABLE OF CONTENTS

LIST OF ORGANIZATIONS, INDUSTRIAL AGENCIES, AND GOVERNMENT BUREAUS REPRESENTED AT THE CONFERENCE, WITH THE NAMES OF THEIR REPRESENTATIVES

American Federation of Labor:
- A. L. Berres.
- Mrs. Grace M. Burnham, *Director Workers' Health Bureau.*
- Miss Harriet Silverman.

American Institute of Chemical Engineers:
- Dr. D. E. Howe.

American Oil Co.:
- John M. Klein.
- Lee Sonneborn.

American Petroleum Institute:
- Robert Welch.
- F. B. Dow.

American Public Health Association:
- Dr. Henry F. Vaughan.
- J. A. Tobey.

Anglo-American Oil Co.:
- H. S. Tegner.

Baltimore City Department of Health:
- Dr. J. H. Shrader.

Barrett Co.:
- S. R. Church.

Brown University:
- Prof. C. A. Kraus.

Bureau of Chemistry:
- Dr. C. A. Browne, *Chief.*
- Dr. W. W. Skinner, *Assistant Chief.*
- E. W. Schwartze.

Bureau of Labor Statistics:
- Miss Whitney.

Bureau of Mines:
- Dr. H. Foster Bain, *Director.*
- Surg. R. R. Sayers (*detailed from the U. S. Public Health Service*).
- C. A. Taylor.
- Dr. W. J. McConnell.
- William Yant.

Bureau of Standards:
- Dr. H. C. Dickinson.
- Doctor Thompson.

Carnegie Steel Co.:
- B. M. Livezey.

Chemical Warfare Service:
Lieut. Col. Edward B. Vedder, M. C.
Cincinnati College of Medicine:
Dr. Robert A. Kehoe.
Columbia University:
Dr. Haven Emerson.
Dr. Frederick B. Flinn.
Department of the Interior:
Hon. Hubert Work, Secretary.
Deppé Motors Co.:
N. P. Deppé.
E. I. du Pont de Nemours & Co.:
Irenee du Pont.
W. F. Harrington.
Charles K. Weston.
Charles L. Reese (*President American Institute of Chemical Engineering.*
Dr. A. K. Smith.
Ethyl Gasoline Corporation:
W. Gilman Thompson (*Medical Consultant Standard Oil Co. of New Jersey*).
C. F. Kettering.
Thomas Midgley, jr.
Dr. Graham Edgar.
E. W. Webb.
A. W. Maxwell.
Federal Oil Board:
C. W. Waterman, *Manager.*
General Motors Corporation:
C. F. Kettering (*also with Ethyl Gasoline Corporation*).
Geological Survey:
Dr. George Otis Smith, *Director.*
Gulf Refining Co.:
Dr. W. A. Gruse (*of Mellon Institute*).
Harvard University:
Dr. Joseph C. Aub.
Dr. Cecil Drinker.
Dr. David Edsall.
Dr. Alice Hamilton.
Prof. Reid Hunt.
Johns Hopkins University:
Dr. W. H. Howell.
Dr. K. K. Marshall.
National Research Council:
Dr. Ludwig Hektoen.
Dr. E. W. Washburn.
National Safety Council:
Paul Frederick Stricker.
Navy Department, Bureau of Aeronautics:
Lieut. S. B. McMurrain.
New York Academy of Medicine:
Dr. E. H. L. Corwin.

New York City Department of Health:
Dr. J. A. Shears.
New York State Department of Health:
Dr. M. Nicoll, jr., *Commissioner of Health.*
Dr. Augustus Wadsworth.
New York, Reconstruction Hospital:
M. DeM. Touart, *Medical Director.*
Ohio State Department of Health:
Dr. E. R. Hayhurst.
Pennsylvania State Department of Labor and Industry:
Dr. Francis D. Patterson, *Chief of the Division of Hygiene and Enginering.*
Philadelphia City Department of Health:
Dr. William C. Robinson.
Standard Oil Co. of Indiana:
Dr. F. R. Morton, *Medical Director.*
Standard Oil Co. of New Jersey:
Dr. C. C. Johns.
E. M. Clark.
R. A. Van Eaton.
F. A. Howard.
State and Provincial Health Authorities:
Abel Wolman, of the Maryland State Health Department (*representing Dr. Johns S. Fulton, State Health Officer.*)
Steel Products Co., Cleveland, Ohio:
C. E. Thompson.
Studebaker Corporation:
A. J. Chanter.
E. J. Miles.
University of Pennsylvania:
Dr. H. F. Smith.
United States Tariff Commission:
Frank Talbot, of the Chemical Staff.
The Texas Co.:
Sherman Ford.
Yale University:
Dr. W. H. Haggard.
Dr. Yandell Henderson.
United States Public Health Service:
Surg. Gen. H. S. Cumming, *Chairman of Conference.*
Asst. Surg. Gen. A. M. Stimson.
Asst. Surg. Gen. J. D. Long.
Surg. L. R. Thompson.
Surg. G. W. McCoy.
Prof. William Mansfield Clark.
Prof. Carl Voegtlin.
Dr. H. D. Gibbs, Senior Chemist.

PROCEEDINGS OF A CONFERENCE TO DETERMINE WHETHER OR NOT THERE IS A PUBLIC HEALTH QUESTION IN THE MANUFACTURE, DISTRIBUTION, OR USE OF TETRAETHYL LEAD GASOLINE

The meeting was called to order at 10 a. m., May 20, 1925, at the Bureau of the United States Public Health Service (Butler Building, Third and B Streets SE.), Washington, D. C., by Surg. Gen. H. S. Cumming, presiding.

The CHAIRMAN. I will ask the meeting to come to order. I wish to introduce to you Assistant Secretary of the Treasury McKenzie Moss, who will open the conference.

Mr. Moss. Ladies and gentlemen, I think I was born with too much sense to endeavor to discuss the questions which will be before you for determination, or even to endeavor to state the issues. I do not know that I would be able even to pronounce some of the words contained in the title. I am merely here to extend, on behalf of the secretary, a welcome to you and to express the confident belief that around this council table you gentlemen will be able to bring to a fair settlement and solution the problems which have brought you together. That is my mission and it has been performed.

The CHAIRMAN. Ladies and gentlemen, I take pleasure in introducing to you Secretary Work, former president of the American Medical Association.

Secretary WORK. Surg. Gen. Cumming and gentlemen of the conference, the applause that followed Secretary Moss's address was partly due, perhaps, to the brevity of it, so I will take notice and be equally brief. This conference has very much to consider from different angles. I became interested in it first from the viewpoint of public health. If this new agent, which it is proposed shall go into general use in every car, is prejudicial to health we should know it and the public should know it. I am interested in it also because of my present position in association with the Bureau of Mines, which is a scientific bureau, as you know. The Bureau of Mines has been making a careful experimental study in this line for several months. A few months ago they put out a statement which was accepted as final. It was not intended to be final. It was really a progress report. Since that time the bureau has been pursuing these studies in the same general direction, and they

will lay before you the results of these studies. This matter that you are called together to discuss, is, I think, a very important one—one of the most important questions up before the public to-day. It has an economic bearing, possibly has a health bearing, and its commercial relations may be very extensive, indeed.

This is largely conjecture. None of us knows much about it as yet, so the purpose of this conference is very important, and your deliberations will take, I assume, some days. I can spend only a moment with you, but I am pleased to have had the opportunity to express my appreciation of your assembling here to discuss this question.

The CHAIRMAN. First, I want to express my appreciation to those gentlemen who have accepted an invitation to come to this conference. It is unnecessary for me to enter into any detailed explanation as to the purpose for which you have been asked to come together or the importance of the outcome of the conference. It is, however, perhaps advisable to say a word in the beginning as to the reason for inviting you to a conference and the object which we hope to gain as a result of your advice and counsel.

The Public Health Service, particularly through its division which has to do with the study of problems relating to industrial medicine, has long been interested in lead poisoning in the industries and has made some investigations along this line. We were therefore interested two years ago when we learned that one of the large corporations in this country in its endeavor to increase the efficiency of fuel used in internal combustion engines was experimenting with certain lead compounds to be used in commercial gasoline.

A little later on the question of an investigation as to the effect of these compounds came up, and after a conference with representatives of the Bureau of Mines it was determined, in view of the fact that the Public Health Service had no funds available for the purpose, that the investigation should be made by the Bureau of Mines.

Early in the winter I received letters from several gentlemen who had been interested in the matter, inviting attention to the potential dangers in the general use of tetraethyl lead and suggesting that a conference be called to consider the matter. After correspondence with everyone engaged in such investigations, so far as we could ascertain, it was determined that a conference at that time would be somewhat premature in view of the fact that none of the investigations had been completed.

Upon completion of the preliminary report of the Bureau of Mines, and after a conference with Doctor Sayers and the staff of the Hygienic Laboratory, I decided that it would be advisable to hold a conference as soon as practicable, and found that the report of the medical committee working at Columbia University, together with

other reports, would be available about the middle of May. I therefore took the liberty of requesting you to be present at this time.

It seems unnecessary to inform you that this is in no sense a legal hearing; in fact, there are no Federal laws which authorize the Public Health Service to take jurisdiction regarding the interstate shipment of substances such as tetraethyl lead, even should it be determined that they are injurious to public health. On the other hand, it is the duty of the Public Health Service to investigate such questions and to inform the public as to the result of its investigations, restrictive measures being part of the police power of the several States and municipalities. However, I am quite certain, from assurances given both to me and to the public, that no police measures will be necessary in the premises should the use of tetraethyl lead be determined to be detrimental to the public health.

It is earnestly desired that we shall confine our conference as nearly as possible to the determination of such facts and to the reporting of such investigations and experiences as may lead to a definite determination as to the hazards, if any, which follow the manufacture, distribution, and use of tetraethyl lead and similar substances, not only to those who are engaged in the manufacture and distribution of the compound, but, more particularly, perhaps from my standpoint, to the public at large. The Public Health Service asks your cooperation in arriving at the proper solution of the problems.

I fully realize the responsibility imposed and the confidence that has been given to me, and I am quite sure you are all going to help me and help each other arrive at a solution of this problem.

I am sorry that we are not all around a small table. In our first study we had the advantage of the psychology of sitting around a conference table—we have grown a little larger than any available table—but I hope you will feel you are around a common council board.

I have thought it would be interesting, at least to some of us, if we begin this conference by asking someone to give us the history of the development of this tetraethyl lead in its relations to gas engines, and Mr. Kettering, the president of the Ethyl Gasoline Corporation, will give us the historical account.

Before he does so, may I say that I thought we would all be interested in seeing the working of one of the engines at a proper time. That will be demonstrated to you later.

MR. C. F. KETTERING

President, Ethyl Gasoline Corporation

Mr. Chairman, ladies and gentlemen, about 1914 we undertook to determine what were the essential factors in an internal-combustion engine which prevented us from getting more economy. As you perhaps know, it is possible to build internal-combustion engines which, when at full load, show very good percentage of efficiency. That has been pushed up to as high as 30 per cent, but inasmuch as in the automobile we very seldom drive at anything but a very small portion of the load, the efficiency falls off quite markedly with a decrease in the load. We undertook to study why it was, or what could be done that would assist in giving us more efficiency at the point where the public drive their cars.

We are getting to-day about 5 per cent of the energy out of gasoline; 95 per cent of it is thrown away. As I said before, it is possible, however, to push up on full load so that with the airplane engine or the motor-boat engine, we obtain up to a maximum of 30 per cent, and you can get fairly normal operation at around 20 per cent.

In that study there were a great many problems brought out because the instrumentation that was necessary to make these determinations had not been thoroughly developed, so we were confronted as we went along with continually having to stop our work on the actual study in order to develop instruments whereby we could make determinations that would have an actual quantitative value. There was as a rule abundant qualitative information about this, but none of it had been reduced to a quantitative basis.

After a preliminary study we discovered that with the fuels, as they now exist, one of the things necessary was to increase the compression of the motor. To explain what that is, I will say this: In the ordinary automobile motor as we have it to-day, and we will consider just a single-cylinder engine, here is the way the thing works. There is a cylinder in which is fitted a piston and there are two valves in that cylinder. We will say that our engine is standing still. The piston moves down, and as it moves down a valve opens which allows a mixture of gasoline and air to flow into that cylinder. That valve then closes, the piston goes up and compresses that mixture until it reaches nearly top center, then a spark is introduced into it and the mixture burns and an explosion of the gas is obtained; near the bottom of the stroke the other valve is opened and when the piston goes up those exhaust gases are ejected, save what was in the space above the piston. That thing is repeated. In other words, a cylinder in the ordinary gas engine, as it is known in the automobile to-day, gives you one explosion for every two revolutions, the

sequence being, first, a drawing in of the mixture; second, a compression of it; third, a firing and expansion of it; and fourth, an exhalation, and that is the way they got the term, "a 4-cycle motor," a cycle being the passing of the piston once over the cylinder.

Now the amount of the exhaust gas which is retained in the cylinder is the function entirely of that space which is above the piston, so that when you have a full load or a full charge in this engine, the per cent of the mixture which is retained in the engine is relatively small compared with the total amount taken in, but when you are taking only a little bit of mixture in, as for a quarter or half load of the engine, that dilution factor becomes relatively large. So it is desirable to cut the space down above the piston, and that is what, in engineering technology, we call raising the compression. In other words, it is simply reducing the space into which that mixture is compressed just previous to firing.

There are two or three factors which obtain when you raise the compression—two or three things which happen. First of all, you get a better burning efficiency; second, the dilution factor is reduced because the amount of exhaust gas which is retained there is smaller; and third, there is a smaller amount of surface exposed to the very hot gases at the time of combustion; so you gain in three different factors by raising the compression.

In the Diesel engine—this is simply by way of explanation—its result is accomplished not by taking the mixture into the cylinder in the way we do in the ordinary gas engine but by taking in the air and then compressing it; and then, after it has reached compression, the fuel is put into the engine at the definite rate at which it is to be burned. That is a differentiation from the ordinary automobile engine in that we take into the cylinder both the gasoline and the air, and they are compressed together, so that the Diesel engine has accomplished the raising of compression by keeping the fuel out of the mixture before you want it to burn.

Any attempt we were able to make to raise the compression was always accompanied by a corresponding gain in efficiency, but it was not accepted by the public because of the fact that when you tried to use the engine at full load you got what we call a "knock." That is the familiar sound known to everybody who drives an automobile when he tries to climb a hill. He gets a little carbon in the motor. In other words, we could not supply to the public the gain possible by engine alterations because of that very undesirable knock, and it was undesirable from two standpoints, first, because it might cause injury to the motor, and second, because the driver thinks there is something wrong with his motor. Therefore it was noncommercial from that standpoint.

So, after we had developed the possibilities of what might be done by the use of increase in engine efficiency, we then attacked the problem of whether we could introduce anything into the fuel which would stop this knocking. At that time none of us had any very definite knowledge of what was happening to such an engine. I do not know that to-day we know definitely what happens. In other words, we have found that those things like combustion, things we have known about the longest, the simple burning of a fuel and air, explained so simply, still have a lot of very technical things related to them, and are not as simple as the words might indicate.

At this point we developed quite a number of instruments which helped us to determine to a certain extent what was happening physically inside the engine cylinder. We found out that with ordinary natural gas we could produce certain results and with the higher-gravity gasolines, the aromatic series of compounds, alcohols, etc., we could get the high compression without the knock, but in the great volume of fuel of the paraffin series we could not do that. But we did prove that if we could use the motor at those compressions our efficiencies could be very greatly increased. So we started to try different materials which might, if put into the fuel, produce the desired results.

One of the first things that we used, and which has always been regarded as a sort of bench mark from which we reckon, is ordinary iodine, which when added to the fuel will completely stop the knocking. By way of explaining what the knock is, it has been proved by experiments in this country and abroad that the normal rate of burning of gasoline and air can proceed at quite different rates and that if the ordinarily efficient work be represented by 1 these rates are some place between sixty and seventy times as high, so that the change of rate is very much greater; in other words, sixty or seventy times greater; that the rate of burning is so rapid that the temperature goes very high, the radiation is very high. I might explain at this point that when we got to those very high pressures and to those very high temperatures the radiation rate from the flame is exceedingly great, and inasmuch as radiation can pass entirely through those gases without doing any heating it does not do a bit of work. It is just like having the mixture full of holes; and the radiation does no work until it strikes the cylinder wall and heats it.

After introducing the iodine we were first of the impression that perhaps it was the color added to the fuel that did something, because we felt that perhaps the color of the fuel did something in the way of absorption of radiant energy, very much as the early plants paint themselves red on the underside to absorb radiation and help their growth, but we disproved that supposition by using some

forms of iodine which are colorless. We found it was purely a molecular proposition and had nothing to do with the color, and we also demonstrated it by the use of some other colored materials that supplied the color but did not produce the other results. So finally we had this one material which we could introduce, which was a starting point from which we could make comparisons.

It took about 3 per cent iodine to be equivalent to 40 per cent benzol, and our methods of rating gasoline have been based on this line. We were taking a certain standard gasoline and adding 40 per cent benzol to it. That permits a certain raising of compression and a certain operation of the motor. We accepted that as a standard of compressions. Of course, iodine was out of the question from a commercial standpoint because of its not being obtainable.

Another very interesting thing in the use of benzol, or of iodine, was that it helped to produce carbon. So your cylinder would fill up very quickly with a very flaky type of carbon. I mention the word carbon. In the ordinary garage they will say, "Get the carbon cleaned out of your motor." The reason for that is that the carbon is one of the best heat insulators we have.

A small cake of carbon on the inside of the motor takes up space, it raises compression, and it slows the conduction of heat from the residual gases to the cylinder wall, and the difference between a satisfactory burn and an abnormal burn is very delicate when it comes to the point of temperature. A few degrees plus or minus will throw the thing from a satisfactory operation to an impossible operation.

I have seen that tried out on airplane motors, and it is rather interesting. Take a motor and a fuel condition which you can make normal; get up in the air and level off, fly along definitely, and finally open your throttle to a point where you ought to get an abnormal rate of burn. You go along and you get one detonation. I use the word detonation because that expresses the idea; whether it carries along the scientific factors of detonation we do not know, because it is purely a question of degree. You might get one detonation, in 15 seconds another, and in a very short period of time your motor will be detonating completely, and you will have to come down. Once you get one detonation in the cylinder you immediately throw a large quantity of the heat of the explosion, by radiation of energy, into the cylinder walls and heat them. With the next compression it gets hotter, and you get more heat into your cooling waters; it gradually rises in temperature and you pass from a normal to an abnormal operation on an apparently slight change in the thermal condition of the motor.

We then made a search of various other chemical compounds, and found aniline had a similar effect. We did a great deal of work on

aniline and its kindred compounds. It took about 2 per cent of aniline to obtain the same results that 3 per cent of iodine gave.

There were many objections to aniline; the principal one was that it can not be obtained in quantities. We had been investigating a great many compounds and making a study of the physical chemistry of these problems, so that we might know what the factors were that we were dealing with. We tried one of the selenium metallo-organic compounds. We found that was an antiknock. We tried various other selenium compounds and tellurium compounds, and we finally took the atomic weights of the elements and went over the thing systematically. We found that while there are compounds which you can add to gasoline to stop its detonation, there are other compounds you can add that make it worse. If some surface above the top of this table be represented as zero, and if you put a pin to represent each element showing its value as an antiknock, the heads of the pins will lie on a warped surface, representing the antiknock potentialities of each element in its various valences.

These results tended to show that elements of high atomic weight were most effective as antiknocks, and almost as a last resort we started to study the properties of lead.

We tried for a long time to produce various organic lead compounds which would be soluble in gasoline. We did that without very much success, and finally, after a long period of time, we are able to get the tetraethyl lead compounds which are soluble in gasoline. When we tried those out we naturally had the factor of around 2 or 3 per cent in our minds, so when we got a small quantity of these we put it in a gasoline in the same proportion we had been dealing with. There was no indication of a knock. We kept diluting it and found that we were dealing with a material requiring only about one-thirteenth of 1 per cent. In other words, it was about forty or fifty times more effective than anything we had ever dealt with.

We then started a long series of road tests, after we had learned to mix small quantities of this material, and converted a few motors into the type of motor that could be operated with this fuel. We had a great many practical dufficulties, due to the fact that the lead burns to lead oxide, and that, deposited on the spark plug, fuses, lead oxide being a good flux for the porcelain and electrodes of the spark plug, which are of nickel. We tried various ingredients with the lead compound and finally used the bromine compounds, ethyl dibromide. The lead burns to lead bromine, and it does not stick on the valve but passes out of the motor.

That is really the high-spot history of this study. Up to this time we have not done anything on the motor for the reason that we were repeating tests to determine whether we could take out of

the fuel the characteristics which prevented us from decreasing the space above the piston. We have gone back and checked and rechecked many times the mechanics of this thing.

Briefly stated, here is where the economic phase of the thing comes in. As you increase the compression you get a higher gain in efficiency at the partial loads or driving speeds of the motor, and it is possible for us to-day to build motors that will give us at least 50 per cent increase in efficiency, and I do not think it is at all out of the range of good engineering to double the economy of gasoline.

That is the problem which we are working at entirely from the economics of the situation, recognizing that to-day with the enormous increase in automobiles, we will use 12,000,000,000 gallons of gasoline this year and 15,000,000,000 next year, and at the increasing rate we have *got* to do one of two things: We must build motors which are more efficient—we must build motors of very much smaller size and sacrifice a great many factors which we now enjoy in the motor industry, or we must do something which will allow us to get more work out of the fuel unit. Now, in regard to the building of such motors, there is nothing of a patentable or unknown thing in the building of higher efficiency motors. Our neighbors on the other side a few years ago built high compression, relatively high efficiency motors, because we shipped to them a better grade of gasoline than we use in this country. They did not have tank wagons and, therefore, we shipped the gasoline over there in tins, and, with the increased cost, it made very little difference whether they bought gasoline of 2 or 3 or 4 cents lower grade or higher. Consequently, they use a higher grade of gasoline in our export machines, and a great many times we have had letters saying, "Why don't you go to Europe and buy European machines and bring them over here and try them out?" We have done that very consistently, and have never been able to drive them under American conditions with American gasoline.

Looking at it entirely from the economy standpoint, so far as our research goes in 10 to 12 years, we know of no way of getting increased efficiency other than changing the compression or redesigning motors from many standpoints. The automotive art to-day knows enough to design motors to take a better fuel, but it is handicapped because it has not been able to do it.

In the introduction of so-called ethyl gasoline on the market we recognize that there were many factors in its marketing that we did not know. We recognized that we would have to get a distribution method for fuel before changes in motor design would be effective.

That briefly states the history and purely economic phases of the situation. We have been interested in it from the motor industry

standpoint very largely, because we recognized that with the enormous demand for internal combustion-engine power some day we would have to answer this question, and we started a good many years ago with the idea purely of an elementary scientific problem to direct the general laboratory research to the problem of what we could do to modify our engines.

We found out that we could do nothing to modify engines unless we could do something to remove from the fuel a very important property, and that is why our research organization undertook the study of fuel relationships, to find out what that had to be, first, recognizing that the changing of parts of the motor could easily be made after that problem was solved. I thank you very much.

The CHAIRMAN: I may relieve the minds of some of you by saying that we are having a verbatim report of the conference, which will be available as soon as practicable.

Before going into a general discussion I would like to ask if anyone else here has any facts to bring before the conference with reference to the manufacture of the tetraethyl lead compound. Mr. Edgar, are any of your people who are interested in the manufacture present? I have not picked out anyone in particular. We do not want general discussion just yet, but anything else you would like to explain with reference to it at this time.

MR. W. F. HARRINGTON

General manager, representing the E. I. du Pont de Nemours & Co.

Mr. Chairman, ladies, and gentlemen, I understand that what you want first is the question of information as to whether in our opinion tetraethyl lead can be manufactured safely.

The CHAIRMAN. We would like to have that.

Mr. HARRINGTON. I imagine this is the most important factor of discussion, and it is the manufacturing factor which I am prepared to discuss right now. The tetraethyl lead desired by the Ethyl Gasoline Corporation has been manufactured by the du Pont Co. We were called upon to manufacture, and we proceeded with the effort to determine a method of manufacture because at the time that this work was started no method of manufacture was well-known; the product was almost a laboratory curiosity. The research work had to be conducted in the laboratory and carried into the semiworks for further experience, and finally manufacture was started in the newly constructed plant. I am prepared to say now, after the experience that we have had in the last two years in the manufacture of tetraethyl lead by the ethyl chloride and the ethyl bromide processes, that tetraethyl lead can be safely and properly manufactured. I believe that I can also give sufficient evidence to

prove the correctness of such an assertion. We started out originally to manufacture tetraethyl lead by the ethyl-bromide process. We got into trouble. We did not have a background necessary to prevent some of the difficulties which are always incumbent upon manufacturing operations when going from the laboratory scale into plant scale of manufacture. We had fatalities. The last we had in the manufacture of tetraethyl lead by the ethyl-bromide process was in July, 1924.

Up to that time we had manufactured approximately 400,000 pounds of tetraethyl lead. Since that time in the plant we have manufactured something like one and three quarters million pounds of tetraethyl lead without any serious mishaps. The fact is that in this plant we have not even had any man very seriously sick, and yet we have had, as is always to be expected, certain mechanical mishaps, so-called messes, which are the result of mechanical failures and which have had to be house-cleaned. About a year ago it was realized that bromine had to be used with tetraethyl lead in making ethyl gas. There was not a sufficient supply of bromine in sight at that time to treat the ethyl gas. At about this time a process for the manufacture of tetraethyl lead via the ethyl chloride route was developed. This process seemed to be simpler than the ethyl-bromide process and attended with no more hazards of manufacture. Here again a long laboratory experimentation was carried out followed by long experimentation in the semiworks. A plant was then designed and constructed according to the most modern ideas as to industrial safety and ventilation. No expense was spared to insure safety of operations. However, we did err in our calculations in the design of this plant, with the result that difficulties were encountered when the plant was started and fatalities occurred. The plant was closed down, the difficulties in ventilation and operation were corrected and manufacture was resumed on March 25 of this year. Until the closing down on the first part of this month, when at the request of the Ethyl Gasoline Corporation the manufacture was discontinued, we have manufactured successfully some 50,000 pounds. No men at all in this plant, since we rectified errors and resumed operation in March, have shown any physiological symptoms of poison, so that I can say, and I think I can say with correctness and conviction, that tetraethyl lead can be safely manufactured. I say that for the du Pont Co., and I think that the du Pont Co. has a right to a conviction as to what can be done in the way of manufacture of dangerous chemicals. That has been the experience of the du Pont Co. almost through its whole period of existence—first, the manufacture of black powder, then the manufacture of dynamite, smokeless powders, detonators—all these products have been manufactured successfully. If

there is any question of doubt I refer you to the statistics. More recently we have manufactured organic chemicals also of a dangerous nature. Truly we have had a background in the manufacture of various chemicals which has been of inestimable assistance in assuring safe performance. We have, moreover, manufactured successfully such products as aniline, nitrobenzol, dinitrobenzol, nitrochlorbenzol, etc.

One seldom nowadays hears of an aniline poisoning case coming from a plant where aniline is manufactured. Nitrobenzol falls in the same class as a poisonous article. Dinitrobenzol is even worse, and nitrochlorobenzols, in my opinion, are still worse. We are successful manufacturers of every one of these products. We have no doubt at all from a manufacturing point of view that tetraethyl lead in proper hands, in the proper plant design, and under a proper discipline can be manufactured successfully.

The CHAIRMAN. Are there any further remarks on the manufacture of the compound? Before starting the discussion of any phase, I think it is better to develop the facts which we know. We have not a cut and dried program, but wish suggestions from anybody here who has any facts to present first to the conference as to the industrial hazard in the manufacture of the compound. If anybody has any suggestions as to change of program, we shall be glad to hear them.

The next thing logically is about the facts as to the mixing, distribution, and transportation of the substance from the wholesaler to the distributer of the compound. Has anybody anything to give to the conference with reference to that?

MR. THOMAS MIDGLEY, JR.

Vice President, Ethyl Gasoline Corporation

In this connection, for your information, it might be well to outline the passage of the tetraethyl lead from the manufacturing plant to where it is finally sold to the public.

It is shipped to our plant at Dayton, Ohio, in steel drums (being a liquid), taken from the drums and put into storage tanks; mixed with ethylene dibromide—producing the final product—and returned to the drums. These drums are then shipped out to our customers at various so-called "bulk stations" in 27 States. (Bulk stations are where the gasoline is put into the tank wagon, not where it is sold to the public.) It is mixed at the bulk station with the gasoline in the tank of the tank wagon, which then takes it in this diluted form to the service station, where it is put into underground tanks and then sold to the public through the customary pump.

Shipping in the drums from the du Pont Co. to us has never shown any effects whatever of hazard to the people handling it. Other toxic things are handled in the same way. In handling tetraethyl lead in our plant we had trouble in the early days from lack of background. It was natural to expect the symptoms of tetraethyl poisoning to be the symptoms of ordinary lead poisoning, which were carefully watched for. This was quite deceptive, as was only determined after sad experience, ordinary chronic lead symptoms not showing until serious poisoning had already resulted. That was in the early days of handling the material—not more than 1 or 2 per cent of what has been handled since. After such a background had developed we found the essential thing necessary to safely handle it was careful discipline of our men. Tetraethyl lead is not so much a dangerous poison as it is a treacherous one. It becomes dangerous due to carelessness of the men in handling it, but by enforcing proper discipline, with mechanical devices to perform certain operations so that the men did not have any excuse for contact with the material, the record has become quite good.

Mixing the gasoline is carried on by using a special device. The operator at the bulk station is a trained operator, and as many as 2,000 such stations have been in operation. The men operating them have been observed for evidence of any abnormal hazard, and no evidence has developed.

With regard to our own plant, where we have quite accurate data, I would like to ask Doctor Kehoe, who was in charge of the work, to give a brief summary of what has taken place.

DR. ROBERT A. KEHOE

Department of Physiology, College of Medicine, Cincinnati, Ohio

Early in June of last year, as a result of some difficulties which had occurred at the plant of the General Motors Chemical Co., at Dayton, Ohio, I was asked to take under observation the men at the plant to make studies of the hazards which were existing at that plant, and also at the same time to undertake to obtain some experimental data as to the means of combating and eliminating the hazards that existed.

It seemed perfectly plain at the outset that there was only one manner in which to deal with this problem, and that was not the treating of men who were sick, but the prevention of sickness among them. The men in this plant were exposed to several possible hazards. First of all there was the inhalation of tetraethyl lead, which was demonstrated to occur. Second, there was absorption through the skin of tetraethyl lead, which we also demonstrated to be possible, this being largely explainable on the basis of the fat-

soluble character of tetraethyl lead. In addition, there was still another hazard, the inhalation of dust decomposition products of tetraethyl lead, which might be found in containers of tetraethyl lead. Those who were responsible for the general care of the plant made possible the elimination of practically all these factors, by the installation of suitable automatic machinery, so that the actual exposure of the men was reduced to a minimum, and so that also the number of men employed in the plant was reduced to a minimum. It was also possible, since it was found experimentally feasible, to use gas masks at points at which there might be moderate concentration of the tetraethyl lead vapors; and the use of these masks at this time, plus also extremely high rates of ventilation, (of necessity down ventilation because of the specific gravity of the vapor), made possible almost complete elimination. The matter of dust was taken care of largely by changing the methods of distribution of the material in such a way that it became quite unnecessary to handle small containers, so that from the time the distribution was made in large drums, it was possible to handle that hazard completely.

Early in the course of the work of the plant there had been a considerable number of poisonings and two fatalities. This was before the time I undertook the work at the General Motors plant and this was the unusual circumstance which brought about my appearance at the plant. Since that time there have been no fatalities. There have been some cases of varying degrees of poisoning. The cases, taken all in all, in the entire history of the Dayton plant, including chemists in the laboratory and all others who were affected with symptoms of any type, number about 60 men.

Since the installation of proper equipment, the initiation of careful medical examination, and careful selection of men there have been, all told, since August 1, 18 cases. In these 18 cases are included all men who have shown the slightest symptoms of any degree of intoxication.

I might say by way of explanation that the recognition of the symptoms of tetraethyl lead poisoning are by no means as easy as would appear. They are easy only after experience because there is nothing in the early symptomatology of tetraethyl poisoning which resembles ordinary lead poisoning, as we see it in the industries. It became necessary, therefore, to observe carefully and to make detailed and frequent observations of men. In the course of these observations an occasional man has been found who showed very early symptoms suggestive of tetraethyl lead intoxication.

The 18 men whom I mentioned as having been affected to some extent since August 1 include all men who have been known to have any toxic symptoms whatever. Those men were immediately put off

the work and have since been able to take up other occupations in other places.

In the interest of completeness I might say that one case occurred in the plant, approximately two months ago, of rather unusual type. This man, who had shown no signs or indication of poisoning whatsoever, developed a type of infection resembling epidemic influenza, which was at that time in the community in which he lived. He was sent home and was apparently convalescent when he developed what was either an acute tetraethyl lead intoxication or an influenza encephalitis. The diagnosis in this man's case is a matter of doubt, and it is quite impossible for me to say whether the condition is lead poisoning or infectious encephalitis. At any rate, the man recovered from the maniacal condition. When last seen he was in a good physical state, but had some mental abnormalities. Since that time there has been no evidence of poisoning in any of these men. The number of men who have been employed over this period of time is in the neighborhood of 100. So altogether, of the men employed in the plant since August 1, there have been 18 cases. This indicates the possibility of a reduction of hazard in the blending of ethyl fluid to the point of almost complete disappearance, and there is every reason to think that by further close observation, by the closest attention to details of discipline and careful warning of these men, that the hazard at this point may be reduced to a point of complete disappearance.

The CHAIRMAN. I would like to hear from anyone else interested who has facts to present. There must be somebody else who has had experience along these lines.

Doctor AUB. Have any determinations been made in regard to the excretion of lead?

Doctor KEHOE. I will answer that question at once or await further questions.

The CHAIRMAN. I think it would be better to follow the facts down and then open up discussion. Otherwise we would not get all the facts, if that is agreeable to Doctor Aub.

Doctor AUB. And has anyone had under observation men engaged in handling and selling to the distributer and the effect of the compound upon them?

MR. FRANK HOWARD

Standard Oil Co. of New Jersey

I can not give you any medical data on that. I think the conference would be interested in knowing of the handling of this material by the Standard Oil Co. of New Jersey, beginning June, 1922. At that time the General Motors laboratory, with whom I had been working on this problem, as Mr. Kettering described to you

this morning, first placed in our hands tetraethyl lead for pursuing the experimental work that they had been carrying out on its uses with gasoline.

We have had tetraethyl lead continuously in use in our engine laboratories and garages since that time, June, 1922. It has been handled without any precautions at all, that is, without anything more than the most obvious precautions, until the unfortunate accident which happened in our pilot manufacturing plant last November. That was a manufacturing hazard and is not a point of discussion here.

With regard to the use of this material, it has been freely handled in the engine laboratory as received in a pure state from the manufacturer (Doctor Kraus produced our first supply at Clark University), by simply pouring it from an open vessel into the gasoline in the proper quantity, this being done by regular mechanicians and attendants in the laboratory. The supplies handled in this way for the garage at our refinery were sufficient for 80 trucks, and at Newark 15 trucks, and we handled the product in the same way, pouring it out of the bottle into the gasoline in which it was used.

As further evidence of the use which we have put the material to in the past three years—it will be three years this June—we have worked with it in experimental carbureters of the wick-feed type. That is, we have had a wick an inch in diameter immersed in the tetraethyl lead which fed the material, and from the surface of which it was evaporated by the passing air current. These wicks stop up with a deposit from the tetraethyl lead and the regular practice for a few months was to take them out and wring them out with our hands. I had such a carbureter on my own car for six months. If there has been any symptom of lead poisoning during that entire experience of three years in the handling of the product in the central laboratories and garages of the Standard Oil Co. of New Jersey, not only in the regular manner of use and as sold to the public, but in the experimental methods I have described to you, the symptoms have not been such as could be detected. I may say we have had at least a yearly medical inspection of all men engaged in the handling of this material. I think this is important, because I believe our work of three years has demonstrated that there are no poisoning difficulties in long-continued experimental and commercial work. In connection with the experimental work referred to, perhaps Doctor Kehoe can give you medical data.

Dr. Robert A. Kehoe. We were asked in the first place to find out whether there would be a hazard in the handling of this gasoline and investigate it from an experimental point of view. It seemed to us, even months ago, that the application of animal experimenta-

tion to this particular phase of the matter would serve to give qualitative evidence only, not quantitative.

Therefore, it seemed important at the outset to make observations in the actual field where hazards existed, because there we had proper experimental conditions to handle. It so happened that at a number of places in Dayton ethyl gasoline has been used over a considerable period of time. At the time these observations were made, the data that I will present to you show that a considerable number of men had been exposed to actual hazard over a period of two years. The observation of these men, therefore, was thought to present a good situation for the determination as to whether or not these hazards really existed. In the first place it might be worth while to consider just what those hazards are. The hazard from the use and distribution of ethyl gasoline, omitting for the time being the matter of exhaust gases, may be subdivided into two parts:

First, the possibility, theoretically at any rate, of absorbing tetraethyl lead out of gasoline by reason of the skin contact; second, the possibility of obtaining tetraethyl lead out of gasoline by inhalation.

There is a third, the rather remote possibility of absorbing by inhalation the dust of decomposition of any tetraethyl lead which might be dropped on the floor as the result of spillage of gasoline. That might be a remote possibility but should be considered for completeness.

We began the observation of these men and made arrangements with an oil company of Dayton that had been handling material longer than any other company, that if symptoms of any type developed in their own men when they were being examined by company physicians, they would be sent to us for observation.

The men in the research garage of the General Motors plant had been handling the material and had also been handling machines that had been using it. (I should like permission to discuss at this time, the subject matter of a title which comes under a later subheading, that of garage employees and the general public, because the garage mechanicians are subject to hazards from handling carburetors and tearing down the motors, etc.) We observed a number of these men, and now, if I may, I will read from an article which I have written on the subject, as follows:

THE HAZARD OF LEAD POISONING FROM THE HANDLING AND USING OF ETHYL GASOLINE

The interpretation of animal experiments in terms of human beings is, at best, a questionable procedure. When one is determining the toxic properties of a general protoplasmic poison, a reasonable assurance exists as to the qualitative importance of the experiments. The quantitative value of such experi-

ments is always a matter of doubt because of certain variations in the physiological mechanisms of different organisms, and because of unavoidable variation in the manner and rate of introduction of the material in question into the tissues of various animals.

The interpretation of the hazard existing from the handling and use of "ethyl gasoline," in terms of animal experimentation is doubly questionable, because it is impossible to duplicate the actual conditions under which such handling occurs. An attempt was made to err on the side of an increased exposure of animals over that likely to occur. Whether or not that was accomplished is a matter of judgment.

In this situation the advisability of making observations in the actual field of operations suggested itself months ago.

Accordingly arrangements were made for the careful taking of histories of exposure, the making of careful physical examinations, and the analyses of specimens of urine and feces of a considerable number of men who had been exposed to actual conditions over a considerable period of time. The opportunity to do this was present in that employees of the General Motors research garage and of the Dayton Power & Light Co. and of the Refiners Oil Co. of Dayton had been exposed to all the conditions which could possibly bring danger of lead poisoning from the distribution and use of ethyl gasoline and from the use and mechanical care of cars using ethyl gasoline, and over a considerable period of time. (It must not be supposed that these men had been carelessly allowed to assume these dangers without any knowledge of them, or without medical observation at regular intervals. The fact remains, however, that the early methods of use and distribution of ethyl gasoline were of such a sort as to present hazards of such a magnitude as will never exist under the present methods of use and distribution.)

Full data are available as to the histories of exposure, the physical findings, and the clinical symptoms of these men. Analytical data will be presented on as many of them as are now available.

The following table presents in brief the items of importance found in the analysis of these data:

Persons examined

General Motors research garage:	
Mechanics	1
Handlers of ethyl gasoline	1
Drivers	3
Total	5
Refiners Oil Co. at Dayton:	
Handlers of ethyl gasoline	2
Dayton Power & Light Co.:	
Mechanics	5
Handlers of ethyl gasoline	2
Drivers	16
Total	23

History as to exposure

Not less than 2 years	26
Not less than 1 year	3
Less than 1 year	1
Total number exposed	30

Symptoms appearing in 30 men exposed to ethyl gasoline and exhaust gas

Headache	1
Loss of weight	[1] 1
Insomnia	None
Disturbing dreams	[2] 2
Polyuria	None
Gastric cramps	None
Digestive disturbances	[3] 1
Weakness	None

Physical signs appearing in 30 men exposed to ethyl gasoline and exhaust gas

Pallor	2
Subnormal temperature (3 (97.6), 1 (97.2))	4
Bradycordia	None
Subnormal blood pressure ((1) 114–72, (1) 112–70, (1) 110–74, (1) 106–66)	4
Lead line	None
Stippling	None
Low haemoglobin	2

NOTE.—Of the two showing pallor, one has a chronic cholecystitis and the other has a history of tuberculosis of long standing.

The other findings are of no more frequent occurrence than may be seen in any group of men taken at random, and they are explainable on the basis of other physical findings, such as very bad dental condition, existence of common colds, etc.

At the same time, 64 men, at no time exposed to ethyl gasoline, have been questioned as to the details of their employment for the past several years, and have been carefully examined. Specimens of urine and feces have been obtained for analysis so as to furnish a comparison with the previously examined exposed men.

A detailed analysis of the data obtained from unexposed men as to their histories and the results of physical examinations would require too much space for the present needs. However, the data now available as to the results of the chemical examination of specimens of urine and feces are appended hereto.

CONCLUSIONS

A careful consideration of the results of the examination of 30 men who have been exposed over a period of about two years, to one or more of the hazards arising from the general distribution and use of ethyl gasoline, fails to show any evidence of the appearance of either symptoms or signs of lead poisoning.

Appended hereto are data as to the analyses of urines and feces. They are as yet incomplete, and are submitted for what they are worth.

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[1] This man lost weight following an attack of cholecystitis.

[2] Both of these men gave a history of dreaming for years and admitted the condition only after leading questions.

[3] This man gave a history of diarrhea and fever, followed by constipation.

Analytical data from 10 men exposed to ethyl gasoline

(Nos. 13, 14, 15, and 17 were also exposed to undiluted fluid containing tetraethyl lead and ethylene dibromide for a considerable period of time. See history)

Average sample urine ..... 0.182 mg. / 1,525 c. c. urine.
Average sample feces ..... 0.519 / 33.05 gm. dried feces.
Urine ..... 0.12 mg. per liter.
Dried feces ..... 1.57 mg. per 100 gm.

Sample	Weight of dried feces in—		Volume of urine in—	
	Grams	Milligrams	Cubic centimeters	Milligram
1	27.4	0.50	700	0.14
3	21.1	.32	1,200	.17
4	11.1	.11	3,000	.22
6	4.5	.14	470	.12
8	40.2	.65	1,200	.17
11	29.8	.32	1,500	.08
13	7.8	.30	1,400	.10
14	117.3	1.91	2,900	.14
15	33.0	.29	1,350	.56
17	38.3	.65	1,530	.12

Analytical data from 10 control (unexposed) workmen

Average sample urine ..... 0.091 mg. / 1,473 c. c. urine.
Average sample feces ..... 0.38 mg. / 27.32 gm. dried feces.
Urine ..... 0.06 mg. per liter.
Dried feces ..... 1.36 mg. per 100 gm.

Sample	Weight of dried feces in—		Volume of urine in—	
	Grams	Milligram	Cubic centimeters	Milligram
29	22.7	0.74	2,200	0.14
68	35.6	.32	1,650	.11
74	45.4	.24	1,300	.15
77	50.0	.22	1,170	.7
78	11.8	.16	1,850	.15
80	18.3	.22	1,320	.10
81	28.4	.14	1,400	.7
82	7.8	.18	1,950	.5
83	32.8	.58	710	.7
84	23.4	.54	1,170	Nil.

I might say that to my surprise all of the specimens obtained from exposed and nonexposed men showed a certain quantity of lead. The analysis of this data will in all probability be made at a later time.

I only wish to point out the magnitude of the quantity of lead in controls as compared to exposed men is of such a sort that no conclusions can be drawn as to the absorption of lead in those exposed men as the result of their exposure to ethyl gasoline.

The CHAIRMAN: Before we leave the question of the distributer, I think the Standard Oil Co. of Indiana, which is said to be the largest distributer, is represented here and we should like to hear from that company.

DR. FRANK MORTON

Medical Director, Standard Oil Co. of Indiana

I am here representing the company. Our company has not done any experimental work in handling tetraethyl lead. We have taken practically all instructions in regard to handling the tetraethyl lead in gasoline from the Ethyl Gasoline Corporation. It is probably true that we have distributed a great deal more of this ethyl lead than any other company in the country. We have developed a method of mixing the ethyl solution with gasoline so that the solution is not handled, and there is practically no danger of the men who mix the ethyl with gasoline inhaling any of the fumes or coming in contact with the solution on their clothing or body. We have made it a point to examine all men who are to handle ethyl solution. This examination consists of taking their weight, urine analysis, blood pressure, examination for nervousness and anemia, and questions as regards previous illnesses, particularly signs of nervousness. This examination is checked every three months. As regards cases of supposed ethyl gasoline or ethyl solution poisoning, we have had none, nor have we come in contact with any cases which looked like lead poisoning.

The particular cases which have come to my attention, about 40 in all, are mostly eye cases and skin irritations. The eye cases occur at the stations when the station men in filling up the gas tank at times swing the hose around, spilling the gasoline in their eyes or the customers' eyes.

If the ethyl gasoline gets in the eyes, from my experience, it only produces an irritation which lasts from 12 to 24 hours. It is not much different from spilling gasoline in the eyes, though the smarting is probably more severe. For treatment we have recommended washing the eye out with water or boric solution and then using drops of paraffine oil in the eye. One case who reported to an outside doctor had more trouble. The doctor used atropine so that the man's pupils were dilated, and the man complained for several days of irritation in his eyes.

As regards skin irritation, this irritation is no different from the type which occurs if gasoline, kerosene, or crude oil is spilled over the hands or body, particularly if evaporation is interfered with. Our own men are well instructed how to handle our products, and for that reason we have very few cases of skin irritation. The so-called ethyl solution skin irritations were of the same type. Dr. William Allen Pusey, president of the American Medical Association, and a prominent dermatologist, saw one of these cases. He called it an irritating dermatitis, such as could be caused by gasoline.

Last Saturday Dr. Alice Hamilton had an article in the American Medical Journal. As usual, after an article appears on so-called

dangers of ethyl solution, we had a number of cases reported. This time we had three or four cases. One case in particular claimed that the garage man in draining a crank case had the oil come in contact with his hands and produced a dermatitis with pustules. This was formerly quite a frequent condition, particularly when handling screw machines or thread machines, where the oil was used over and over again and became contaminated with bacteria and dirt, so that I do not feel that the lead had anything to do with this condition. Now, manufacturers who have to use oil over and over again use lysol, creosol, etc., to keep the oil from becoming contaminated.

Monday we received word from Indiana that one of our men at Delphi, Ind., who had never handled ethyl solution or ethyl gasoline (and the records show he had only used ethyl gasoline in his car for two weeks, that is as much as he handled it), had acute lead poisoning. We sent a man from La Fayette to see him. Our man thought it was meningitis. He ran a slight temperature, became irrational, delirious, so they had to put him in a strait-jacket and remove him to the hospital at La Fayette, Ind. Consultation, at which five doctors were present, was called. They all diagnosed it as acute lead poisoning, possibly due to ethyl fluid. I had Dr. L. J. Pollock, of Chicago, one of our leading neurologists, visit La Fayette and see the case with two of the men who had cared for him previously. Doctor Pollock reported back to me yesterday. He said it was a peculiar case. He made a lumbar puncture and found a marked increase in the cell contents, and made a diagnosis of meningitis. Since then further examination of the blood and spinal fluid showed that this man had a syphilitic meningitis.

This last case was the case which had the nearest appearance of acute lead poisoning, and there were about 40 cases in 11 States.

The CHAIRMAN. Thank you, Doctor. Has anyone else any facts to present with reference to further observations in the distribution to garage workers or the public?

DR. J. H. SHRADER

Representing the City Department of Health, Baltimore, Md.

When this matter first came out we looked into the distribution end and had some difficulty in securing any of the product. Ethyl fluid was put up in small steel bombs or cylinders which were attached to the delivery pipe of the service station gasoline tank and introduced the ethyl fluid into the gasoline as it flowed from the rubber hose into the consumer's machine. After much perseverence our men finally obtained some samples from the distributing company in Baltimore. We went around to the service stations to find out to what extent the operators came into personal contact with the ethyl fluid, and found

that the personal equation seemed to be the determining factor; that some operators were very careful, in fact the majority knew that they should not allow any ethyl fluid to be splashed on them, but if it did they were to remove it immediately by washing with gasoline and soap; but some became careless, and particularly as time went on and nothing deleterious happened, they became more careless. Some wiped off the splash with waste and others allowed it to evaporate. We found that the Standard Oil Co. had evidently taken some precautions to see that the operators were instructed how to take care of themselves, but we found that as time went on these instructions were more or less neglected, and so we took the matter up with their office in Baltimore, who assured us that the method of distribution was or would be changed and that the steel bombs were not to be used any longer. Distribution was to be effected by mixing the ethyl fluid into the gasoline at the factory and selling the mixed product in bulk. We checked up this practice about the city and found that such was the case. Therefore, as the matter stands to-day, the only persons that we have observed in contact with ethyl fluid in the past were the station operators, who are now removed from that hazard. We used as much ingenuity as we could to mask our identity to try to secure some ethyl fluid from the distributing station operators in order to see if we could still obtain some of the ethyl fluid as such, but we have not been able to obtain a bit of it.

The CHAIRMAN. Has anybody any further facts to present along this line?

MR. A. M. MAXWELL

Vice President and Sales Manager Ethyl Gasoline Corporation

I will show by steps the distribution growth of ethyl gasoline. It was marketed commercially first on February 1, 1923, at Dayton, Ohio, through the medium of the Refiners Oil Co. At that time it was distributed through the medium of small ethylizers which are simply hand pumps attached to the customer's gasoline pump.

From February 1 to August 1 there were about 30 of these small pumps operated by the Refiners Oil Co. From August to February, 1924, there were about 500, at which time, in addition to the Refiners Oil Co. of Ohio, there came into the picture the Standard Oil Co. of Indiana, and then the Spears & Riddle Co., of Wheeling, W. Va.

In May, 1924, approximately 12,000 of these so-called "ethylizers" were on the pumps of the customers of the Standard Oil Co. of Indiana, Standard Oil Co. of New Jersey, Gulf Refining Co., Standard Oil Co. of Louisiana, the Refiners Oil Co., and Spears & Riddle Co. Up until October, 1924, the number probably increased to 17,000. About this time, the accident happened at Bayway, N. J., and the Ethyl Gasoline Corporation issued orders to discontinue the distribu-

tion of ethyl fluid through the medium of the small ethylizer, which did away with these 17,000 small ethylizers. From that time on until May 1 of this year, there have been in operation about 3,500 installations selling ethyl gasoline throughout approximately 27 States, embodying the territories of the companies which I have mentioned.

The cut down from 17,000 small ethylizers to 3,500 service stations was due to the fact that the material was mixed in bulk through a bulk mixing device, the ethyl fluid being shipped in steel drums to the bulk stations and to the refiners; the gasoline being then treated by these bulk pumps and hauled by tank wagons to the service stations for commercial consumption.

About 300,000,000 gallons of ethyl gasoline have been sold from February 1, 1923, to date of suspension, May 5, 1925.

The CHAIRMAN. If there is not anything further along this line, I will ask Dr. Gilman Thompson to give us a bird's-eye view of the conditions under which the experiments are carried on.

DR. GILMAN THOMPSON

Chairman of Medical Investigation Committee representing the Standard Oil Co. of New Jersey, the General Motors Co., and the E. I. du Pont de Nemours Co.

It will be of interest to state briefly the results of the experiments. It was suggested on July 27, 1924, by the president of the General Motors Co., that it would be well to have a medical committee appointed consisting of representatives from the three companies interested in the manufacture, distribution, and sale of tetraethyl lead and ethyl gasoline. This committee was constituted with a membership of three, Dr. A. K. Smith, representing the E. I. du Pont de Nemours Co., of Wilmington, Del.; Robert A. Kehoe, representing the General Motors Co.; and myself representing the medical department of the Standard Oil Co. of New Jersey. The committee was given *carte blanche* to ascertain all facts obtainable at that time in regard to tetraethyl lead and ethyl gasoline. The first thing that the committee did was to visit the several plants that are interested in the manufacture and distribution and find out what already had ocurred in the way of fatalities and sickness among the employees at the plants, look over the general method of production of the material, and then after visiting those several plants the committee determined on a line of experimentation.

It occurred to the committee at once that the best thing to do to get the facts in the matter from the experimental side was to appoint two impartial bodies that could conduct the experimentation, and this committee could keep in touch with the work and coordinate it.

It seemed desirable to the committee to have one department of

the Government undertake this work and one department of a well-known university undertake it, and therefore we applied to the Bureau of Mines at their laboratories in Pittsburgh, and we commissioned Professor Flinn, who is a member of the industrial hygiene department of Columbia University, to undertake animal experimentation.

Moreover, the committee has made frequent visits since that time to the various plants and done all it could to coordinate the work of these different experiments and to aid in outlining it.

The object of the experiments was to determine the hazards to the public, if any, which might exist in the use of ethyl gasoline in 1 to 1,300 dilution of ethyl lead. Monkeys, goats, guinea pigs, pigeons, rabbits, and dogs were experimented upon. The committee at the end of July, 1924, ascertained that a great deal of experimental work had already been done. There was some experimental work done on animals at the Bayway plant of the Standard Oil Co. of New Jersey a year ago last May by using the strong tetraethyl lead.

The committee also found that much experimentation had already been done, as mentioned by Doctor Kehoe, at Dayton, Ohio. They further ascertained that the Bureau of Mines was already making experiments with exhaust gas from ethyl gasoline and its effects upon animals.

It was further suggested, therefore, that the future experiments should cover the additional hypothetical hazard until it was proved one way or the other of skin contact from the use of ethyl gasoline of 1 to 1,300 dilution, and also the possibility of any hazard from inhalation of the vapor.

The results of these experiments have been checked as rapidly as was consistent with scientific thoroughness and accuracy.

This whole matter, therefore, has been under the supervision of a committee appointed for the special purpose, and the results of the experiments will be presented here, in as much detail as may be called for, by those who have been conducting them.

The CHAIRMAN. I will ask the Chief of the Bureau of Mines or one of his representatives to tell us about the experiments.

DR. R. R. SAYERS

Representing the Bureau of Mines, Department of the Interior

THE TOXIC EFFECTS ON ANIMALS OF ETHYL GASOLINE AND ITS COMBUSTION PRODUCTS

The Department of the Interior, through its Bureau of Mines, is interested in the economic utilization of mineral and allied products of the United States. Further, it is interested in the preven-

tion of illness and the safe production of such substances. More than two years ago the attention of the Bureau of Mines was called to the potential economic importance of tetraethyl lead. At the same time the possible public and industrial hazards were considered. On account of lack of specific knowledge in regard to these hazards, the Bureau of Mines, in cooperation with the Ethyl Gasoline Corporation, made a number of studies on animals. While it was fully realized that the results of animal experimentation can not be translated directly to man, it was believed that the knowledge to be gained would be of value as a criterion.

Further, it was thought that some of the results from studies of lead poisoning might be applicable in the mining, smelting, and refining of lead.

The problem of the health hazard due to tetraethyl lead may be divided into three parts:

1. The hazard in manufacturing and handling the concentrated tetraethyl lead.

2. The possible hazard in handling ethyl gasoline (approximately 1 part of tetraethyl lead to 1,300 parts of gasoline).

3. The possible hazard due to exhaust gases from automobiles using ethyl gasoline.

The scope of the work undertaken by the Bureau of Mines included an investigation of all these possible hazards as outlined. The first, that of the danger in the manufacturing and handling of concentrated tetraethyl lead, has been studied only to a limited extent. The second, the possible hazard in handling ethyl gasoline as sold to automobile drivers, was divided for study according to the portals of entry into the body; i. e., inhalation, skin absorption, and ingestion. Tests were made to determine the effect of inhalation, of skin absorption, and of the sum of the three, inhalation skin absorption, and possible ingestion (by the animals licking themselves or other animals).

The inhalation studies are described in progress report No. 2, Part II.

The skin-absorption effects and summation effects are given in progress report No. 2, Part III.

The third of the above-outlined problems, the possible hazard due to exhaust gases from automobiles using ethyl gasoline as ordinarily sold, was carried on for about eight months, and the results are given in progress report No. 1. (Monthly Reports of Investigations, Serial No. 2661.)

A similar study was made, using gasoline containing five times the commercial amount of ethyl fluid, in an attempt to determine the necessary concentration of tetraethyl lead in gasoline to cause lead poisoning in animals exposed to engine exhaust. The results

of this study up to April 28, 1925, are given in progress report No. 2, Part I.

The studies have been summarized as follows:

EXHAUST GASES FROM AN ENGINE USING ETHYL GASOLINE (COMMERCIAL)

PROGRESS REPORT NO. 1.

1. The following species of animals, monkeys, dogs, rabbits, guinea pigs, and pigeons, were exposed 188 times to exhaust gas from an engine using ethyl gasoline (commercial) during a period of about eight months. These animals were exposed in two groups for 3-hour and 6-hour periods, respectively.

2. The quantity of lead found (average, 0.0045 milligrams per cubic foot) in suspension in the air was about 28 per cent of that theoretically possible. The remainder of the lead was retained in the engine head, exhaust pipe, or muffler, or it was discharged in pieces too large to remain in suspension.

3. The carbon monoxide in the chamber air was controlled between 0.01 and 0.02 per cent.

4. The growth of test animals was similar to that of controls.

5. The entire group of animals used in this study showed no lead line, loss of appetite, or other symptoms usually associated with lead poisoning.

6. Chemical analysis of animals that died or that were killed gave no evidence of lead storage.

EXHAUST GASES FROM AN ENGINE USING GASOLINE CONTAINING FIVE TIMES THE COMMERCIAL AMOUNT OF ETHYL FLUID

PROGRESS REPORT NO. 2, PART I.

1. The following species of animals, monkeys, dogs, rabbits, guinea pigs, and pigeons, were exposed for 206 times to exhaust gases from an engine using ethyl gasoline containing five times the commercial amount of ethyl fluid. Some of these animals were continued from the study on exhaust gases from an engine using commercial ethyl gasoline.

2. The quantity of lead found (average, 0.38 milligram per cubic foot) in the air was two and one-half times that which would be present, assuming all the lead from commercial ethyl gasoline was discharged from the engine and remained in suspension.

3. The dust from the floor of the test chamber contained 10.5 per cent of lead after six months without cleaning.

4. The carbon monoxide in the chamber air was controlled between 0.01 and 0.02 per cent.

5. Growth of test animals was similar to the controls.

6. The entire group of animals used in this experiment showed no lead line, loss of appetite, or other symptoms usually associated with lead poisoning.

7. Of the animals exposed, only guinea pigs and rabbits showed storage in the 3-hour group. Some of the animals in all species showed storage in the 6-hour group, which was more or less proportionate to the total time of exposure.

EFFECTS OF INHALATION OF VAPORS FROM ETHYL GASOLINE AND VARIOUS OTHER MOTOR FUMES

PROGRESS REPORT No. 2, PART II.

1. The following species of animals, monkeys, dogs, rabbits, and guinea pigs, were exposed to vapors of straight gasoline and ethyl gasoline in concentration of 0.3 per cent for two hours.

2. The guinea pigs were exposed to straight gasoline, commercial ethyl gasoline, gasoline containing two and one-half, three and three-fourths, and five times the commercial amount of ethyl fluid, benzol, and benzol gasoline blends in the following concentrations:

(*a*) 1.0 per cent vapor in air for one hour.
(*b*) 0.3 per cent vapor in air for two hours.
(*c*) 0.1 per cent vapor in air for three hours.

3. The experiments were conducted in such a manner that the vapor composition in all cases was the same as that of the material evaporated.

4. A large proportion of the tetraethyl lead of gasoline containing ethyl fluid was found to remain in the residue when the liquid was evaporated in open vessels and by bubbling air through it. The first 20 to 50 per cent of the liquid evaporated at room temperatures contained relatively small amounts of lead.

5. In the first stages of the evaporation of commercial ethyl gasoline, by bubbling air through it, there is imparted to the air a very low, roughly constant concentration of tetraethyl lead.

6. Guinea pigs subjected to 114 to 125 exposures of straight gasoline showed no symptoms in low concentrations. In high concentration (1 per cent for one hour) marked intoxication occurs temporarily.

7. On similar exposure to commercial ethyl gasoline guinea pigs show no effects in the lowest concentration. Animals analyzed show lead accumulation after a number of exposures to the higher concentration (0.3 per cent for two hours). In the highest concentration the 1 per cent for one hour animals became inactive, and loss of weight was noted.

8. The animals exposed to vapors of gasoline containing two and one-half, three and three-fourths, and five times the commercial amounts of ethyl fluid all showed symptoms of intoxication, and some

developed tremors and other symptoms usually associated with lead poisoning. An accumulation of lead was found in all animals analyzed.

9. The guinea pigs exposed to motor benzol and a benzol gasoline blend showed signs of marked intoxication and irritation of the eyes and respiratory passages, and a great proportion of those exposed to high concentrations died.

10. No dogs or monkeys exposed to 0.3 per cent gasoline and 0.3 per cent commercial ethyl gasoline have shown any ill effects.

11. The guinea pigs and rabbits which died after a number of exposures to commercial ethyl gasoline showed an accumulation of lead.

TOXIC EFFECTS OF ETHYL GASOLINE WHEN APPLIED TO THE SKIN OF ANIMALS

PROGRESS REPORT NO. 2, PART III.

1. Tetraethyl lead, ethylene dibromide, gasoline containing ten times the amount of ethyl fluid used in commercial ethyl gasoline, commercial ethyl gasoline, and gasoline were applied to the skin of monkeys, dogs, rabbits, guinea pigs, and rats in amounts from one-tenth cubic centimeter to 1 cubic centimeter.

2. The summation of skin absorption, inhalation, and possible ingestion of lead is shown by a group of test animals treated with tetraethyl lead and with gasoline containing tetraethyl lead and housed together. All animals in this group showed lead accumulation on analysis of those that died or were killed.

3. A group of animals treated so as to prevent inhalation with gasoline containing ethyl fluid in commercial concentration and ten times the commercial amounts showed lead accumulation.

4. A group of animals treated so as to prevent inhalation and ingestion (by washing and blanketing) with gasoline containing ten times the commercial concentration of ethyl fluid showed lead accumulation.

5. A group of animals are being treated as given in 4, but with commercial ethyl gasoline. This work has been in progress only a comparatively short time, and no symptoms have been noted to date.

6. Animals treated with ethylene dibromide (about 95 per cent pure) showed marked intoxication and died within 24 hours after one application of 0.25 cubic centimeter.

7. Animals treated in the same manner as given in 6, but with tetraethyl lead, showed marked intoxication and died within 36 hours.

All the studies described in progress report No. 2 are being continued, and a final report will be prepared when the work is completed.

The Public Health Service, as stated by the Surgeon General, did not feel it had the funds to carry on the investigation, and the Bureau of Mines undertook a certain portion of the investigation.

More than two years ago we first took up the study on the exhaust-gases phase of the subject described in progress report No. 1. As stated, the group of animals that we exposed was composed of monkeys, chicks, guinea pigs, rabbits, and pigeons. They were exposed to exhaust gases diluted to a concentration so that they would not be affected acutely, at least, by the carbon monoxide present. It was necessary to have careful carbureter adjustment and control or we would get acute carbon monoxide poisoning, as Doctor Henderson has suggested. The carbureter was adjusted so that the exhaust gas contained instead of an average of 7 per cent carbon monoxide approximately 2 per cent. The animals actually breathed air containing 0.01 per cent or 0.02 per cent of carbon monoxide, because the average in the exhaust gas was less than one-half that usually found. This allowed the lead content of the atmosphere to be that normally found when the air contained 0.04 per cent of carbon monoxide.

No storage of lead was found in any of the animals analyzed—that is, within the experimental error of the chemical methods used—and we believe them to be as good methods as can be obtained.

The findings on exposed animals were checked by controls. Lead was injected in some unexposed animals and these killed and analyzed to obtain the lead. A report was published in December, 1924. You are acquainted with the results of this report. This report was published due to a demand for information and due to an apparent feeling among groups of people that we were holding back information at that time. As a matter of fact, we had nothing that indicated that there was lead poisoning or a possibility of lead poisoning. However, we thought best to give the information to the public and to issue progress reports as phases of the studies made it possible. Many of the animals from this first study were continued on the following, which was made to try to determine the amount of tetraethyl lead required in gasoline to cause lead poisoning or lead storage in animals exposed to engine exhaust.

In the studies described in progress report No. 2, Part I, five times the usual amount of tetraethyl lead was put in the gasoline. The same species of animals were exposed for similar periods for 206 times as in the first study.

In progress report No. 2, Part II, a study was made to try to determine the possible hazard due to the inhalation of tetraethyl

lead and gasoline containing various amounts of tetraethyl lead. In addition to unexposed controls, other controls were exposed to various motor fuels, as straight gasoline and benzol gasoline.

Attention is called to the fact that the experiments were conducted in such a manner that the vapor composition was the same at all times as the liquid evaporated; that is, all the liquid was evaporated and mixed with the air to be breathed in every case. This was done because it was found that after evaporating 20 per cent or even 50 per cent of the gasoline from the ethyl gasoline the residue contained the greater portion of the tetraethyl lead or ethyl fluid. It was found that if air is bubbled through ethyl gasoline any part of the air so treated will contain about the same amount of tetraethyl lead as any other equal portion.

The CHAIRMAN. I think Colonel Vedder has done some work along this line.

LIEUT. COL. E. B. VEDDER, M. C.

Chief, Medical Research Division

About a year ago I was requested by the Chief of the Chemical Warfare Service to make some tests of tetraethyl lead, but the whole work that we did was done with the pure compound and has no direct bearing on this present discussion, except for the fact that it does show that tetraethyl lead is absorbed by inhalation, as well as through the skin, and that it is cumulative in its action; but it bears no relation to the toxicity of its dilution in gasoline. We worked with the pure product. The report is available and will be deposited with you so you can have it for reference and get all of that data from it.

A STUDY OF THE TOXICITY OF LEAD TETRAETHYL, OCTOBER 5, 1924

By W. A. ELDRIDGE

[Supervised by D. C. Walton, lieutenant commander M. C., U. S. N.; approved by Edward B. Vedder, lieutenant colonel, M. C., U. S. A.]

I. INTRODUCTION

The object of the following tests was to determine the toxicity of lead tetraethyl upon animals and to study the symptoms produced by this compound. Four different methods were used to administer the compound, and lethal points were established by each method. The methods employed were as follows: Local application, subcutaneous injection, intravenous injection, and inhalation.

II. SUMMARY

1. The lethal point by skin application was placed at 0.6 cubic centimeter, or 0.996 gram per kilo, for guinea pigs and at 0.3 cubic centimeter, or 0.496 gram per kilo, for dogs. One cubic centimeter of pure lead tetraethyl weighs 1.659 grams.

2. The lethal point for guinea pigs by subcutaneous injection is approximately 0.08 cubic centimeter, or 0.132 gram per kilo.

3. The lethal point for dogs by intravenous injection is placed at 0.011 cubic centimeter, or 0.018 gram per kilo.

4. The lethal concentration for mice by inhalation is placed at 5.11 milligrams per liter.

5. The evidence indicates that smaller doses are cumulative in action by whatever route administered.

6. When an animal receives a lethal dose by skin application its life may be saved by washing with kerosene, followed by tincture green soap and water, provided this treatment is carried out within 30 minutes after application.

III. HISTORICAL

Although chronic lead poisoning is the commonest of all forms of metallic poisoning, true acute lead poisoning that is the effect of a sudden absorption of lead in man has been hitherto unknown. When a large quantity of some soluble salt of lead is swallowed it gives rise to the ordinary symptoms of irritant poisoning, namely, nausea, vomiting, pain in the abdomen, violent purging, weakness, and collapse.

In animals also it has been difficult hitherto to produce acute lead poisoning, because when most forms of lead are injected the proteins of the blood are precipitated, and death so produced is purely mechanical; and only local symptoms were produced by administration by mouth. However, Harnack injected salts of lead triethyl. In the frog this produced general paralysis, apparently by the action of lead on the central nervous system. In the dog the symptoms following intravenous injection were weakness and paralysis, violent diarrhea and colic, chorealike movements, tremors, and convulsions. The diarrhea was found to be due to violent contractions of the intestinal walls, which maintained a degree of contraction even when no peristaltic wave was passing. (Cushny, Pharmacology and Therapeutics, p. 653.)

Lead tetraethyl was developed by the General Motors and Du Pont corporations as an addition to motor fuels. But soon after large-scale production was commenced a number of men handling this product became ill, and several of them died. The following description of the symptoms was included in a report to the Standard Oil Co. by Doctors Thompson and Schoenleber, rendered May 18, 1924:

"The first symptoms observed are a marked fall in blood pressure, sometimes as low as 60 points below normal. There is an accompanying fall in body temperature, which has been recorded as low as 94.6° Fahrenheit, or 4° below normal. The heart action is slowed, the pulse having dropped in one case as low as 48; that is, 12 or more counts below normal. There is at first some digestive disturbance, such as loss of appetite, vomiting, and a tendency to looseness of the bowels. Vertigo may be present. The red blood corpuscles show marked changes in size and shape. The blood in one of the fatal cases failed entirely to coagulate and at autopsy showed an unusual color such as is observed in carbon-monoxide poisoning. There is no cyanosis and no shortness of breath, nor is headache or other pain complained of. The urine remains normal usually, but in one case reported, treated by Doctor Aub, of Harvard, lead was present in it. Following these symptoms in severe cases other phenomena appear indicative of profound cerebral disturbance. The victim suffers from persistent insomnia and becomes delusional, extraordinarily restless, and talkative. His gait is staggering like that of a drunken man, but there is no paralysis, and convulsions do not appear. There is exaggerated movement of

all the muscles of the body, accompanied by perspiration, and the patient finally becomes violently maniacal, shouting loudly, leaping out of bed, attempting to smash furniture or windows, and behaving like a violent case of delirium tremens. Morphine only accentuates the symptoms. The victim may finally die in exhaustion. One man smashed a window and cut his hand badly. He had delusions of vision, seeing imaginary groups of persons, and accusing the doctor of trying to cut him up. Another man saw the wall paper converted into swarms of moving flies and thought pictures of his family on the walls were alive and moving about.

"Of the two fatal cases the body temperature in one patient rose to 110° just before death. Both these men had been at work only five weeks. The elder, 53 years of age, was not very vigorous, originally having a chronic fibroid condition of the lungs. The younger man was of fine physique. Doctor McCann, who has had a very extensive general practice, stated that he never in his life had seen anyone die in such agony as these two men—'they died yelling.' One man had to be strapped in bed by an expert accustomed to restraining the insane.

"As in nearly all poisonings of industrial origin, considerable personal idiosyncracy may exist as to bodily resistance. Many of the workmen showing only slight symptoms have continued at work. In other cases quite marked symptoms have developed within from three to six hours. In one case the blood pressure dropped in only three and a half hours after beginning work—from 190 to 112—a fall commensurate with that which occurs in excessive hemorrhage. Convalescence from the severe symptoms is quite protracted and may occupy from 6 to 10 weeks."

The following table, which was furnished us by the chief surgeon of the du Pont Co., records the symptoms observed in 28 such cases:

Symptoms recorded in 28 cases of tetraethyl-lead poisoning

[The figures refer to the number of cases in which each symptom was observed]

Insomnia	28
Anorexia	18
Nausea	18
Morning vomiting	10
Abdominal cramps	12
Unaccustomed and annoying dreams	11
Bodily weakness	16
Decided loss of weight	9
Markedly diminished blood pressure	20
Slowing of pulse rate	7
Photophobia	1
Metallic taste in the mouth	6
Lead line on the gums	4
Subnormal temperature	19
Hyperacidity of the urine	18
Albumin in the urine	2
Acetone in the urine	1
Skin test for lead	12
Tremors	6
Scotoma	3
Increased muscular reactions	7
Dilated pupils	1

Itching of the skin	4
Marked drowsiness in the daytime	1
Sluggish pupils	2
Headache	7
Vertigo	10
Irritation of mucous membranes of the nose and throat	1

The physicians employed by these companies were of the opinion that the toxicity of lead tetraethyl was caused partly by the compound as a whole and could not be ascribed entirely to lead poisoning, especially in view of such symptoms as insomnia and mental excitement. But in view of the fact that little has been known heretofore concerning acute lead poisoning, and since all the symptoms described have been previously described as occurring in cases of chronic lead poisoning, we are inclined to the opinion that the toxic effects of lead tetraethyl are simply a manifestation of acute lead poisoning. Thus Osler (Principles and Practice of Medicine, ninth edition, p. 394) says:

"*Symptoms—Acute form.*—We do not refer here to the accidental or suicidal cases, which present vomiting, pain in the abdomen, and collapse symptoms. In workers in lead there are several manifestations which follow a short time after exposure and set in acutely. There may be, in the first place, a rapidly developing anæmia. Acute neuritis has been described, and convulsions, epilepsy, and a delirium, which may be not unlike that produced by alcohol. There are cases in which the gastrointestinal symptoms are intense and rapidly prove fatal. These acute forms occur more frequently in persons recently exposed and more often in winter than in summer. Da Costa reported the onset of hemiplegia after three days' exposure to lead.

"Certain of the cases with colic may present the features of an acute intra-abdominal inflammatory condition. A case may be admitted to the surgical wards with a diagnosis of appendicitis or simulate intestinal obstruction. Localized pain, slight fever, and moderate leucocytosis may be present. The history, the presence of a blue line on the gums, and the blood changes are of importance in differential diagnosis.

"The cerebral symptoms are numerous. Seven of our cases showed marked cerebral involvement. One had delusions and maniacal excitement and had to be removed to an asylum. In other cases there occurred transient delirium, attacks of unconsciousness, and in one case convulsions. Optic neuritis or neuretinitis may occur. Hysterical symptoms occasionally occur in girls. Convulsions are not uncommon, and in an adult the possibility of lead poisoning should always be considered. True epilepsy may follow the convulsions. An acute delirium may occur, with hallucinations. The patients may have trance-like attacks, which follow or alternate with convulsions. A few cases of lead encephalopathy finally drift into lunatic asylums. Tremor is one of the commonest manifestations of lead poisoning."

IV. EXPERIMENTAL

(A) *Material.*—The sample of lead tetraethyl, $Pb(C_2H_5)_4$, used was furnished by the du Pont Co. It was a transparent, pale-amber colored, volatile liquid, purity 95 per cent. The impurities were olefines. It decomposes at 120° C. and is soluble in alcohol, ether, ethyl bromide, and gasoline. It is stable toward water but decomposes in direct sunlight, and was stored in a dark bottle in a closet.

(B) *Methods and results—Local application—Guinea pig.*—This test, whereby a definite amount of the compound is applied directly to the skin of the animal, depends upon absorption by the skin for its toxic effects. The

guinea pig's chest and abdomen were shaved and cleansed 24 hours before applying the compound. The pig was strapped to an operating board and the compound was gradually applied to the skin from a pipette. The animal was allowed to remain on the board until all trace of the compound was absorbed. The time required for absorption was 20 minutes. The animal was then removed and placed in the hospital, where symptoms were noted. The results follow:

Amount applied	Weight of pig	Result	Amount applied	Weight of pig	Result
Cubic centimeter	*Grams*		*Cubic centimeter*	*Grams*	
1	578	Died in 12 hours.	0.3	502	Died in 60 hours.
1	600	Died in 82 hours.	.3	400	Died in 24 hours.
1	625	Died in 26 hours.	.3	420	Died in 18 hours.
0.75	585	Died in 60 hours.	.2	500	Lived.
.5	520	Lived.	.2	405	Do.
.5	490	Died in 36 hours.			

The average weight of three pigs receiving 0.3 cubic centimeter was 440 grams. The lethal point by local application for guinea pigs is therefore placed at 0.6 cubic centimeter per kilo.

Symptoms: The first few hours after the application was made the pigs appeared normal. With the superlethal application (1 cubic centimeter) two hours after exposure, marked depression was noted. This was quickly followed by body tremors. In four hours' time the animal was helpless, the body and extremities trembling violently. Death followed in six hours. At the lethal point (0.3 cubic centimeter) the symptoms were the same as described, except the onset of the symptoms and death were delayed a little longer. These guinea pigs exhibited signs of pain and tenderness on pressure over the abdomen. After death the area of application appeared normal. There were no signs of excitement noted.

Local application—Dogs: Local applications were made upon six dogs, the lead tetraethyl being applied to the previously shaved thorax and abdomen. The results follow:

Amount applied per kilo body weight:	Results
0.6 cubic centimeter	Died 24 hours.
0.5 cubic centimeter	Died 30 hours.
0.5 cubic centimeter	Died 73 hours.
0.3 cubic centimeter	Died 180 hours.
0.25 cubic centimeter	Recovered.
0.2 cubic centimeter	Recovered.

The lethal point by local application for dogs was placed at 0.3 cubic centimeter per kilo body weight.

Symptoms: The symptoms following skin application to dogs were similar to those described for guinea pigs. When the animal received a lethal dose it required about half an hour for complete absorption. The dog was then released from the board and placed in a large cage, where he could be observed. The dogs gave prompt evidence of distress and abdominal pain, circling about the cage, sitting down and at once getting up, as though it was impossible to reach a comfortable position. In several instances this period of uneasiness was followed by a profuse bowel discharge, the feces being followed by watery fluid. After this the dog appeared easier and would lie down. Later the animals were depressed and comatose, but the belly was hard and

rigid and pressure caused intense pain. On the second day the condition was much the same, except that the animal could only get on its legs with difficulty. The entire belly wall was tense and rigid and the abdomen was very tender to pressure. Later trembling of the limbs occurred, followed by convulsions, collapse, and death. In the case of sublethal doses the symptoms were all milder and gradually disappeared as the animal returned to normal.

Pathology: Autopsies were performed on four dogs dying after having skin applications of lead tetraethyl.

The external appearance and body cavities were normal, except in one case. In this case necropsy was performed immediately after death, which occurred 73 hours after the application. Gas escaped as soon as the abdominal wall was opened, and the small and large intestines were acutely inflamed, probably as the result of perforation of one of the numerous ulcers. In all four cases the heart, lungs, spleen, and liver showed no change, but there was a mild congestion in all zones of the kidney. One case had a normal intestinal tract. In three cases there were ulcers throughout the intestines. These were in the region of Payers' patches, which were swollen and prominent. The ulcers were 1 or 1.5 centimeters in diameter, punched out in appearance with clean-cut edges and a smooth base with very little necrotic tissue in connection. The ulcer extended to the muscle layer undermining the mucosa slightly at that point. There was a large amount of blood in the lumen of the intestines in the three cases. One case had a small ulcer near the pyloric end of the stomach, resembling the intestinal ulcers but much smaller in diameter. In the other cases the mucosa of the stomach was normal.

From both the symptoms observed when living and the pathological findings it is evident that when lead tetraethyl is applied locally near or over the abdomen the lead acts directly on the intestines, producing acute lead colic followed by ulceration, which may lead to peritonitis. This confirms the observations of Osler concerning cases of colic in ordinary lead poisoning which present the features of an acute intra-abdominal inflammatory condition.

Local application—Cumulative effects.—A test was made upon a dog weighing 4.08 kilos, applying 0.1 cubic centimeter every 24 hours to a shaved area upon the chest, to ascertain the cumulative effects of the compound. The first ten 0.1 cubic centimeter applications did not affect the dog appreciably. After the twelfth application the dog began to show depression and occasionally some nervousness. After the eighteenth application the dog was markedly depressed, also very unsteady upon its feet, and trembling of the body showed marked increase. The trembling gradually increased until the twenty-first application had been made, the dog dying 40 minutes after. No excitement was noted.

Subcutaneous injection—Guinea pigs.—Two tests were made by subcutaneous injection. The pure compound was drawn into a hypodermic syringe and injected under the skin of the animals. The results follow:

Amount injected	Weight of animal	Results
	Grams	
0.25 cubic centimeter	510	Died in 164 hours.
0.1 cubic centimeter	580	Died in 96 hours.

Symptoms: The symptoms were similar to those noted under local application. The area of injection after death appeared normal.

Subcutaneus injection—Cumulative effects—Guinea pigs.—0.1 cubic centimeter in pure olive oil injected every 24 hours. Three guinea pigs were

selected for this test. Care was used to select pigs of the same weight. The results follow:

Amount injected	Average weight of pig	Results	Amount injected	Average weight of pig	Results
cc.	*Grams*			*Grams*	
0.01	640	0/3	0.01	640	1/3
.01	640	0/3	.01	640	2/3
.01	640	0/3	.01	640	2/3
.01	640	0/3	.01	640	3/3

Symptoms: The first three injections did not appreciably affect the animals. Six hours after the fourth injection one pig showed marked body tremors, while the other two pigs were markedly depressed. One pig died 16 hours after the fourth injection. Six hours after the fifth injection the second pig was seized with body tremors and died after 20 hours. One pig survived for the eighth injection, dying 22 hours after. There was no marked excitement noted.

Intravenous injection—Dogs.—Five dogs were used in this test. Pure olive oil was used as diluent for the compound. The results follow:

Amount injected per kilo body weight:

Cubic centimeters	Results
0.078	Died 14 hours.
.039	Died 14 hours.
.011	Died 25 hours.
.0083	Died 336 hours (delayed).
.0055	Lived.

The lethal point for intravenous injection for dogs is placed at 0.011 cubic centimeter per kilo body weight.

Symptoms: Dogs injected intravenously showed almost immediate and marked symptoms from the compound. Five minutes after being injected there were marked twitching of the face and eyes, lachrymation of the eyes and nose, and rapid breathing, followed by marked excitement lasting for one hour to two hours. During the first hour after the injection animals vomited blood-stained mucus and diarrhea was also produced. The ejection from the bowels, however, did not appear blood stained. The excitement may have been caused partly by colic. The stage of excitement was followed by collapse, the dog becoming helpless, with marked trembling of the body and extremities until death.

Inhalation—Mice.—A number of tests were run on mice by the continuous-flow method to determine the toxicity of the compound by inhalation. Ten-minute exposures to a gas-air mixture of the compound were made, five mice being used for each concentration. The average weight of the mice was 20 grams. The construction of the mouse chamber will be found in report E. A. M. R. D. No. 11. The results follow:

Concentration	Acute death	Delayed death	Concentration	Acute death	Delayed death
5.598	4/5	0/5	3.617	0/5	0/5
5.11	5/5	0/5	3.425	0/5	0/5
4.958	0/5	0/5	2.812	0/5	0/5
4.166	0/5	0/5	1.615	0/5	0/5
3.679	0/5	0/5	.71	0/5	2/5

The lethal concentration for mice by inhalation is placed at 5.11 milligrams per liter.

Symptoms: The mice showed activity while being exposed to the gas-air mixture of the compound. Upon removal from the gas chamber the mice were markedly excited. In the case of lethal doses the excitement gave way to marked depression followed by collapse, trembling, and death.

Inhalation—Cumulative effects—Mice.—Mice showed the cumulative effects of the compound. Ten mice were subjected to concentrations of 0.5 milligram per liter for 10 minutes once every 24 hours, the sample being changed for each run. After the fourteenth run there was one death resulting from the compound. The fifteenth run produced two deaths, the nineteenth run one death, and the twentieth run one death. The total number of experiments made was 32, resulting in five deaths from 10 mice used. The results follow:

Date	Number of mice	Concentration	Results	Date	Number of mice	Concentration	Results
May 27, 1924	10	0.49	0/10	June 18, 1924	7	.604	0/7
May 28, 1924	10	.49	0/10	June 19, 1924	7	.564	1/7
May 29, 1924	10	.438	0/10	June 20, 1924	6	.648	1/6
June 2, 1924	10	.392	0/10	June 21, 1924	5	.534	0/5
June 3, 1924	10	.497	0/10	June 23, 1924	5	.543	0/5
June 4, 1924	10	.473	0/10	June 24, 1924	5	.479	0/5
June 5, 1924	10	.458	0/10	June 25, 1924	5	.419	0/5
June 7, 1924	10	.462	0/10	June 28, 1924	5	.5	0/5
June 9, 1924	10	.481	0/10	June 30, 1924	5	.486	0/5
June 10, 1924	10	.505	0/10	July 1, 1924	5	.437	0/5
June 11, 1924	10	.428	0/10	July 2, 1924	5	.494	0/5
June 12, 1924	10	.5	0/10	July 3, 1924	5	.563	0/5
June 13, 1924	10	.552	1/10	July 7, 1924	5	.563	0/5
June 14, 1924	9	.47	2/9	July 8, 1924	5	.521	0/5
June 16, 1924	7	.626	0/7	July 9, 1924	5	.598	0/5
June 17, 1924	7	.648	0/7	July 10, 1924	5	.584	0/5

Total number of runs made were 32. The average concentration was 0.5 milligram per liter. The total deaths were 5 out of 10 mice used.

Symptoms: The symptoms produced are the same as those recorded above for mice subjected to continuous inhalation.

Metabolism: If we assume, as is indicated by the symptoms, that the toxicity of lead tetraethyl is due to the lead atom rather than the entire molecule, a study of the metabolism is of especial interest as showing a new form of acute lead poisoning. For we are dealing with a highly liquid soluble lead compound which is capable of skin penetration and which, furthermore, is comparatively stable. It is probably the only compound where acute lead poisoning follows absorption through the skin.

In chronic lead poisoning the skeleton of the body has been shown to be the storehouse for the comparatively large amount of lead accumulated. In acute lead poisoning distribution is throughout the body, with the urine and feces as the sources of elimination. Elimination through the feces takes place even when absorption is through the respiratory tract, probably by excretion from the liver along with the bile.

A number of analyses were made on organs from both dogs and guinea pigs, of which the best example is the systematic study of dog 1682 as given below:

Dog 1682: Weight 17.7 kilograms. Given a skin application of 0.25 cubic centimeter lead tetraethyl per kilo body weight, equivalent to 4.42 cubic centimeters or 7.07 grams, on August 12, 1924.

Days after application	Urine volume	Lead content	Feces weight	Lead content	Days after application	Urine volume	Lead content	Feces weight	Lead content
	Cubic centimeters	*Milligrams*	*Grams*	*Milligrams*		*Cubic centimeters*	*Milligrams*	*Grams*	*Milligrams*
1	600	2.04	----------	----------	5	135	.6	----------	----------
2	330	1.32	35	15.5	6	165	.5	----------	----------
3	340	1.09	5	3.0	7	None.	----------	----------	----------
4	150	.8	----------	----------	8	280	.6	----------	----------

The dog was killed and autopsied on the eighth day.

	Milligrams lead per 50-gram sample	Weight of organ in grams (approximate)	Total lead in milligrams (approximate)
Brain	1.8	75	2.7
Bone	5.0	2,000	200
Intestines, small	4.8	1,000	96
Intestines, large	5.3	20	2.1
Kidney	5.8	50	5.8
Liver	7.6	500	76
Lung	4.2	200	16.8
Skin, area of application	25.2	1,000	504
Spleen	3.4	50	3.4
Total	----------	----------	906

It is seen that approximately one-fifth of all the lead applied was found in organs and tissue representing one-quarter the total weight of the dog. The amount excreted was very small, amounting to only about 1 per cent of the total applied.

In a number of other animals that had received small doses some time before being killed, in the analysis of their organs, no trace of lead was found. This would indicate that the lead was removed from the body tissues and deposited probably in the skeleton.

Since the amount of lead excreted in the feces and urine is very small, it is easy to understand how small amounts of lead tetraethyl may have a cumulative action. The differences in individual susceptibility to this cumulative action are probably to be explained, at least partially, by the different rates of excretion of lead by different individuals. It is evident from the very small lethal dose by intravenous injection (0.011 cubic centimeter) that very small amounts of lead in the circulating blood are productive of a serious disturbance of the nervous system, and also have a direct effect upon the intestines producing lead colic or even ulceration. These results of the acute action of lead are precisely similar to the symptoms of chronic intoxication, except that they are much more violent.

Prophylaxis—Counteracting the effects produced by skin application.—Chemical agents were used to counteract the effects produced by applying lead tetraethyl to the skin. In these tests a lethal dose was applied and the chemical agents applied immediately afterwards. Hydrochloric acid in strengths of 10, 25, and 50 per cent, and C. P. were used and found to be valueless. Calcium hypochlorite was used, both in the form of a dry powder and paste, and was found to have no value.

The value of solvents in removing lead tetraethyl.—A number of solvents were used to remove the lead tetraethyl before a sufficient quantity to produce

death was absorbed by the skin. In the following experiments the animals used were guinea pigs. The amount of lead tetraethyl applied was a superlethal dose (1 cubic centimeter). The results follow:

EXPERIMENT No. 1—*Olive oil.*—Two pigs were cleansed with olive oil one minute after application of lead tetraethyl. Both pigs died.

EXPERIMENT No. 2—*Ordinary soap and water.*—Two pigs were cleansed with ordinary soap and water one minute after the application of lead tetraethyl. Both pigs died.

EXPERIMENT No. 3—*Tincture green soap.*—Two pigs were cleansed with tincture green soap and water one minute after application of lead tetraethyl. Both pigs lived.

EXPERIMENT No. 4—*Tincture green soap.*—Two pigs were cleansed with tincture green soap and water two minutes after application of lead tetraethyl. Both pigs lived.

EXPERIMENT No. 5—*Tincture green soap.*—Two pigs were cleansed with tincture green soap and water five minutes after application of lead tetraethyl. Both pigs died.

EXPERIMENT No. 6—*Kerosene.*—Two pigs were cleansed with kerosene one minute after application of lead tetraethyl. Both pigs lived.

EXPERIMENT No. 7—*Kerosene.*—Two pigs were cleansed with kerosene five minutes after application of lead tetraethyl. Both pigs lived.

EXPERIMENT No. 8—*Kerosene followed by tincture green soap and water.*—Two pigs were cleansed with kerosene, which was followed by tincture green soap and water 10 minutes after application of lead tetraethyl. Both pigs lived.

EXPERIMENT No. 9—*Kerosene followed by tincture green soap and water.*—Two pigs were cleansed with kerosene, followed by tincture green soap and water, 15 minutes after lead tetraethyl application. Both pigs lived.

EXPERIMENT No. 10—*Kerosene followed by tincture green soap and water.*—Two pigs were cleansed with kerosene followed by tincture green soap and water 20 minutes after application of lead tetraethyl. Both pigs lived.

EXPERIMENT No. 11—*Kerosene followed by tincture green soap and water*—Two pigs were cleansed with kerosene followed by tincture green soap and water 25 minutes after application of lead tetraethyl. Both pigs lived.

EXPERIMENT No. 12—*Kerosene followed by tincture green soap and water.*—Two pigs were cleansed with kerosene followed by tincture green soap and water 30 minutes after application of lead tetraethyl. One pig lived. One pig died.

EXPERIMENT No. 13—*Kerosene followed by tincture green soap and water.*—Four pigs were cleansed with kerosene followed by tincture green soap and water. Two pigs were cleansed 35 minutes after exposure. Two pigs were cleansed 40 minutes after exposure. All four pigs died.

Conclusion: Both olive oil and common soap and water proved valueless as agents to remove the lead tetraethyl from the skin. Tincture green soap was effective if used within two minutes after the application of the lead compound. Kerosene proved to be the best agent tried; all pigs lived that were kerosene treated up to 30 minutes. It was observed that the skin of the pigs that were treated with kerosene alone became tense, interfering with the movements of the animals. The skin would also crack and tear, causing great discomfort. It was found that following the application of the kerosene by tincture green soap and water removed the kerosene, leaving the skin soft and pliable.

V. DISCUSSION

It is quite evident from these observations that the manufacture, handling, and distribution of lead tetraethyl involves considerable danger to operatives of acute lead poisoning in those instances where considerable material is splashed upon the skin and of chronic lead poisoning from the absorption of small amounts by inhalation, by the skin or by mouth. Tests by the Bureau of Mines appear to show that lead tetraethyl in exhaust gases of automobiles is not toxic to animals, having been changed to insoluble forms of lead.

It is not believed that this compound is of any great value as a warfare agent, because of its low toxicity as a vapor and the fact that it decomposes at 120° C. Although splashes of this liquid on the skin will produce death, if toxicity for man is similar to toxicity for dogs, it would require 21 cubic centimeters to cause the death of a man. Thus it could hardly be used as a spray for lethal effect, although possibly a certain number of casualties could be so produced.

MEMBER. May I ask Doctor Sayers just one question? That is, How long he feels he will require to go on before he can contemplate final publication of his material?

Doctor SAYERS. Do you want me to answer that now or go on with it later?

The CHAIRMAN. Whichever you prefer. I thought we would have a general discussion a little later on.

Doctor SAYERS. It might come in better a little later.

The CHAIRMAN. Would that be agreeable to you, Doctor?

MEMBER. I do not care to go into the specific point that Doctor Sayers brought up, but it seemed to me that in going into the details of this matter we should have some notion as to how long the reasonable experimentation that is now projected will continue. It would be really fundamental in considering the technique of the situation. I would be glad if Doctor Sayers can enlighten us.

Doctor SAYERS. Of course, it is very difficult to give a definite estimate or anything like a definite estimate. However, I would say it ought not to take too long, because, as I have stated in this paper here, we fully realize that animal experimentation can not be readily translated to man. We talked it over with Doctor McCoy over three years ago, and that is the opinion we came to at that time. I do not know just how much longer it will take.

MEMBER. Do you think by the first of the year?

Doctor SAYERS. I will say yes.

Doctor CLARK. I should like to correct a misapprehension. Doctor Sayers spoke of the statements by my colleagues and myself in regard to the ventilation of New York tunnel, 4 parts in 10,000 carbon monoxide. That was on the standard we worked out as something which would be entirely safe for people using the tunnel, which can not be used, as it has to some extent been used, as the

standard representing actual conditions. The concentrations of gas, therefore the concentration of other substances in exhaust gases in garages and in repair shops, run three to four times as high as that standard, so that it does not afford the background which it has seemed to give.

The CHAIRMAN. I was going to ask Prof. Frederick B. Flinn, professor of physiology at Columbia University, if he would be good enough to tell us about their work.

DR. FREDERICK B. FLINN

Professor of physiology, Columbia University, New York City

When we first started our study of the possible public-health hazard from the commercial use of tetraethyl lead at Columbia University the medical committee of the allied companies suggested that inasmuch as the Bureau of Mines had been investigating the exhaust gases from engines using ethyl gasoline for some months, we confine our attention to the other hazards. Therefore we concentrated our attention on the possible health hazards that might arise from contact with the concentrated tetraethyl lead, to the possible hazard of skin absorption through contact with the dilute ethyl gasoline, the 1,000 to 1 mixture, and to the possible hazard from breathing in the fumes of the gasoline evaporating around garages and filling stations. We were unable at the beginning of our work to collect any data as to the concentration of the gasoline fumes around garages or filling stations, although we made inquiries at the laboratories of the New York State Section of Industrial Hygiene and of the Bureau of Mines. We were therefore compelled to go ahead with that part of the study rather blindly. Before our work with the concentrated tetraethyl lead had really gotten under way the unfortunate poisoning of the men at the Bayway plant occurred. The company decided that they would not distribute the concentrated lead product to the filling stations in the future. On account of this decision, it was again suggested that we discontinue our study of this part of the problem.

We gave considerable time to a study of the men sent to the Reconstruction Hospital, with the idea in mind of gaining some knowledge of the symptoms we might expect to find in our animals. It is not necessary for me to go into that part of our study, as Dr. Gilman Thompson and others will touch on the symptoms found.

On account of the above-mentioned facts, we confined our experiments to the possible hazards that might arise from any contact with ethyl gasoline, whether by skin contact or through breathing the fumes of the evaporating gasoline. In beginning our experiments as to skin absorption we were fully aware of the habit of the garage

man of cleaning the grease off of his hands by washing them in gasoline. In order to determine how much gasoline would remain on his hands if he neglected to wipe them off on a towel or waste, a few experiments were carried on, and we came to the conclusion that it amounted to approximately 10 cubic centimeters. We therefore used this as a basis for determining the amount to be applied to our animals. Rabbits, guinea pigs, rats, pigeons, and goats were used in our experimental work. When we first started our work we were rather skeptical as to whether any skin absorption of the lead actually did take place and expressed this doubt to several persons. We felt that the lead got into the system through ingestion or inhalation of the fumes. It is very hard to keep a rabbit or guinea pig from licking its fur—something we should have taken into consideration at the beginning of our work—and we felt that possibly the gasoline evaporated and left the concentrated tetraethyl lead on the skin and that the animal in cleaning its fur ingested it. We tried to rule this error out by placing jackets on the animals, but these jackets got torn, and normal animals treated in the same way died as quickly as the dosed animals. One was led to the opinion that it interfered with the physiological activity of the animal—possibly the heat-regulating mechanism.

To determine for our own satisfaction whether absorption really did take place through the skin and not by ingestion or inhalation we anesthetized three cats at different times with ether. Tracheotomy was performed and a cannula placed in the carotid so as to observe the blood pressure and respiration. The tube from the trachea was led away from the body in such a way that there was no chance for the animal to inhale any of the fumes. To further safeguard against accidental breathing in of any tetraethyl lead fumes an exhaust fan was placed near the body to draw off any fumes from the head. As a further precaution an electric fan was placed near the head. Six cubic centimeters of concentrated tetraethyl lead were allowed to flow from a pipette onto the clipped abdomen. After the animal died the skin was quickly removed and the abdomen opened up. Blisters were observed in each case all through the abdominal region, and the intestines had a peculiar bluish hue. The average lead content of the three cats outside of the skin was found to be 0.65 gram of lead. This experiment would seem to indicate that there is no doubt that this lead compound is quickly absorbed through the skin.

Our rabbits received 0.30 cubic centimeter of ethyl gasoline daily on the skin over the various periods of time. During the passing weeks some of the guinea pigs and rabbits died, but it is not our opinion that they died of lead poisoning. In some of the animals which received

the application daily for 189 to 190 days definite signs of lead intoxication were present. One of our rabbits became absolutely paralyzed in the hind quarters. On analysis this animal was found to contain 4.9 milligrams of lead per kilo. Many of the animals showed stippled cells in the blood. All of the animals that died were examined for lead, which was found to be present in every case in varying quantities.

When we observed the tendency of the smaller animals to lick themselves we decided to use the goat in part of our work. The goat has many advantages, being a hardy animal and not so susceptible to respiratory diseases as the rabbit. The goats received 2 cubic centimeters of ethyl gasoline on the neck and other parts of the body daily, and up to date the number of exposures vary from 79 to 107. One of the goats that has received 107 applications shows a very marked muscular weakness in the hind quarters. We have another goat that is beginning to develop the same weakness. At first we were not sure of our observations on this second goat, but Dr. Gilman Thompson confirmed it during one of his recent visits. Four of our goats have aborted, and an analysis of the fetuses shows that they contained on the average 3.45 milligrams of lead. Stippled cells were not found in any of our goats for the first two months, but the number of these cells has increased with the continued exposure.

We examined the blood of the first 12 men sent to the Reconstruction Hospital and found stippled cells in 9 cases. I believe that later examination indicated that the proportion of men showing stippled cells was not so great, only 50 per cent of the 46 men examined showing this condition. The same ratio held true for our rabbits, 52 per cent of them having stippled cells. These rabbits at the beginning of the work did not show any stippled cells.

Each month the feces of our animals were collected and examined for lead. The animals were not exposed to ethyl gasoline during this period of collection. The rate of excretion for the rabbit is about 0.04 milligram of lead per 24 hours. Because of this small quantity of lead, it was found necessary to collect the feces for several days.

For the purpose of comparing the effects of the ethyl gasoline with those of the concentrated tetraethyl lead, as well as to study the distribution of the lead in the body, we dosed two goats daily with 1 cubic centimeter of tetraethyl lead. These animals have received 60 applications. As the number of applications increased the animals showed a tendency to stand in a hunched position and refuse to eat. By letting them rest a few days the animals apparently recovered and would begin to eat again. The same thing has been noticed in man when he has been removed from his industrial hazard. About two weeks ago one of these goats became suddenly paralyzed

in its hind quarters, cried all day long, and died during the night. We examined this goat and found lead in all of its organs. The brain, weighing 60 grams, contained 3.36 milligrams of lead. The bones contained about 90 per cent of the lead present, thus confirming the work done at Harvard. We also found that the muscle contained 0.67 milligram of lead per 100 grams. These findings show that the lead is distributed all over the body. I think it is commonly agreed that it is the lead distributed in the various organs and carried in the blood stream that causes lead intoxication and not that stored in the bones. We have stopped dosing the second goat with tetraethyl lead for the purpose of seeing if it would recover from the lead intoxication. It shows marked improvement at this time. The goats receiving the concentrated lead excreted approximately 0.56 milligram of lead each 24 hours. The goats receiving the dilute material give a lower rate of excretion, or about 0.10 milligram per 24 hours.

Going on to our fume experiments, we can only say that we were at a loss to determine the exposure that we should give our animals. We made various evaporation tests. We poured gasoline on to nonabsorbent material in order to duplicate, if possible, the conditions around filling stations and garages. We found, of course, that the rate of evaporation varied according to the temperature, air movement, and the area over which the gasoline spreads itself. However, we did find that we could evaporate on the average about 400 cubic centimeters of gasoline in four hours. We decided from this that we would aim to duplicate this evaporation in our gas chamber. This gas chamber contains approximately 180 cubic feet of air and is so ventilated that the air is changed six times per hour. During our tests the gasoline was evaporated by bubbling air through a bottle containing it in the same manner as has already been described by Doctor Sayers. Before starting the exposure of our animals to leaded gasoline we exposed them for 17 to 20 hours a day over a period of a week in the gas chamber to the determined concentration of gasoline fumes. The animals were in as good a condition at the end of the week as at the beginning. This made us feel that we could expose them to the leaded fumes for a period of four hours a day without any ill effects from the gasoline fumes. As far as we could determine from analyzing the air and the residue left in the bottle, there was, on the average, 0.03 milligram of lead in each cubic foot of air in the chamber during the exposure to ethyl gasoline. Rabbits, rats, monkeys, guinea pigs, and goats were used in this part of our work. To our surprise we found that the rat was rather susceptible to lead exposure. I do not quite understand it. Every one of our 24 rats that were exposed died. Their exposure varied anywhere from 56 to over 220 hours. We found lead

in the body of every animal that died. I might say at this point that we did not have the experience that Doctor Sayers and Doctor Kehoe had—that of finding lead in the body of our normal animals.

We kept our control animals upstairs in another room where there was no chance for them to come in contact with the lead compound. I would also like to say that the normal man does not contain lead in his body as commonly as some people think. I examined the stools of many of the men exposed at the Bayway plant and was able to find lead in the stools of only 18 or 19 cases out of the 28 examined. Also in the past year we have had in our hands records of the urine and blood findings of, I should think, 500 men. Over 300 of these men were employed by the National Lead Co., and concerns in similar lines of business and the records show that lead was found in the urine of only 20 per cent of the men. Of course the exposure of these varied. The stippled cell findings in these cases was rather rare also, but this is in agreement with the literature. We ourselves have examined the urines of several hundred men during the past year and found lead only in about 30 per cent.

For fear that we might have some mistake in our lead chamber and because the question arose as to whether lead, or rather the tetraethyl lead, evaporated with the gasoline we decided on further experiments. We took a galvanized iron pan 30 inches in diameter, having a depth of 20 inches, and placed a movable false bottom of ½-inch mesh screen 11 inches from the bottom. Each morning we poured a liter and a half of ethyl gasoline on the bottom of the pan after it had been thoroughly cleaned and dried. The movable false bottom was then placed in position and on it were placed 10 rats. The top of the pan was left open to the natural air movement, except for a ½-inch mesh screen placed over the top to keep the rats from jumping out. The rats were exposed to the fumes resulting from the natural evaporation of the gasoline for 22 hours daily for 7 days.

For two hours each day the rats were removed to give them a chance to eat and drink and to permit us to clean out the pan. It was observed that approximately 200 cubic centimeters of gasoline were left unevaporated at the end of the 22 hours. At the end of the seven days the rats were killed and examined. An average lead content of 4 milligrams per rat weighing 150 grams was found. There was no way that the rats could have come in contact with any lead except through the fumes formed by the natural evaporation of the ethyl gasoline. There was no dust as the bottom was still moist. We feel after this experiment that there can be no doubt in our minds that the lead concentration in the ethyl-gasoline fumes is of sufficient degree to cause lead storage in the body in appreciable quantity. Of course, we are not claiming that man has the same exposure that these animals have had. No one expects a man to be

standing over a pool of gasoline for 20 hours a day. It has been stated that a man retains 80 per cent of the gasoline that he breathes into his lungs. If this is so there can be no doubt that he runs a chance over a long period of time of accumulating an appreciable quantity of lead. The thing to remember is that lead is an accumulative poison, while such poisons as carbon monoxide or benzol are washed out of the system when the exposure is over.

There is one interesting fact, which has had some newspaper notoriety, I believe, in some parts of the country. Two persons working with all the care they could in making this investigation have shown lead absorption. These persons were not exposed to any straight tetraethyl lead except to very small amounts and then for only a couple of minutes a day. I do not believe they had what we would call lead-intoxication symptoms—I would hesitate to say that. They showed wakefulness at night and irrational dreams, etc., but the fact that they accumulated lead under those conditions shows that lead could be absorbed under ordinary conditions around garages. Our windows were kept wide open and the ventilation in our experimental room was as good as one would find in such places.

Our experience leads us to believe that if man is given the same exposure that our animals have had that he can not help but absorb lead, whether it be through the skin or by means of the lungs. Whether the symptoms are well enough known for the average practicing physician to recognize is a question. Even an autopsy fails to give conclusive indications. We have sent animals to the Presbyterian and Bellevue Hospitals and have asked them to make an examination for us. Each time we have got back a report that there is nothing significant. One animal, on which the Presbyterian Hospital made a special examination of the nervous system, was reported on the other day, and lesions of the brain were noted, but the report closed with the remarks: "These lesions are no more than we find in 50 per cent of our animals." We find that an autopsy of the men who died at the Reconstruction Hospital revealed practically nothing that would indicate lead poisoning, except from the chemical findings and the fact that it was known where the men worked. We have had the same experience with our animals. Our leaded animals showed nothing that was not observed in a certain percentage of normal animals. All we have to go on, except for the rare animal, was the fact that we found lead in the excretion, lead in body after death, and stippled cells in about 50 per cent of the animals. Thus our animal work checks the findings on man.

The CHAIRMAN. Has anybody else anything to add? Doctor Thompson, you probably know of some one who has something to say along this line.

Doctor THOMPSON. I suggest Doctor Kehoe.

DR. ROBERT A. KEHOE
College of Medicine, University of Cincinnati, Cincinnati, Ohio

Mr. Chairman and gentlemen, I have here quite a mass of data which I will not inflict on you at this time. There are a number of items here of experimental work that we have carried out during the course of the past year. The first of these refers to the actual toxicity of tetraethyl lead. Since this is not germane to the subject under discussion, I should like to omit reading it, except to point out one thing. We carried out this study, not only with the tetraethyl lead, but with certain other compounds of lead as well, the chloride and nitrate, and compared their toxicity. It is worth while to say at this time that, considering those manners of absorption which are common to both, the toxicity of tetraethyl lead is of the same order and magnitude as that of ordinary lead compounds. The only difference in the toxicity of the two lies in the fact that the one, tetraethyl lead, is capable of being absorbed through the skin. I should like to bring that out, in order to show that their toxicity is practically identical. The data are presented in this paper covering the actual toxicity of tetraethyl lead with regard to rabbits only.

The toxicity of tetraethyl lead for rabbits has been determined for the various methods of administration, and it has been compared with the toxicity of certain inorganic salts of lead. In the case of both tetraethyl lead and the inorganic salts of lead a sufficient number of animals have been studied to make possible a proper allowance for individual variation. If only the lethal amount for a single administration be considered, little individual variation is seen. However, if the toxicity be considered on the basis of numerous repeated administrations, a considerable variation is found.

The fatal dosages of tetraethyl lead administered in one dose to rabbits by various means are substantially as follows: Intravenously, 0.014 cubic centimeter per kilo body weight, approximately 0.014 gram lead per kilo; cutaneously, 0.7 cubic centimeter per kilo body weight, or about 0.7 gram lead per kilo; by oral administration, 0.11 cubic centimeter per kilo body weight, or about 0.11 gram lead per kilo; the quantity taken into the body of the animal by inhalation is difficult to calculate for a variety of reasons, but the concentration of tetraethyl lead in terms of lead in the air breathed by the animal which will kill in about three days of six-hour daily exposure is approximately 0.182 milligram per liter of air.

In all of these methods death of the animal takes place in from 6 to 72 hours.

The fatal dosages of salts of lead, such as the chloride and nitrate, are not widely variant from the above figures.

When lead chloride is administered intravenously a variety of things may occur, dependent upon the salt employed, the speed of administration, and the concentration of the solution. The animal may die at once, may develop a thrombosis at the site of the injection, or may develop a general systemic poisoning. The lethal dosage is calculated, on the basis of the last situation, to be about 0.015 gram of lead per kilo.

When administered orally approximately 0.037 gram of lead per kilo is required to produce death from one dose.

In the case of lead nitrate approximately 0.011 gram of lead per kilo injected intravenously brings about death within 24 hours.

The cutaneous application of inorganic salts of lead results neither in death nor illness of the animals.

Comparison of the toxicity of tetraethyl lead with that of the inorganic salts of lead shows that in general these are of the same order of magnitude. An exception of sufficient magnitude to be well outside the limit of chance variation is seen, however, when one compares the poisonous character of lead salts taken by mouth with that of tetraethyl lead taken in the same way. In this case the salts of lead are seen to be about three times as toxic as tetraethyl lead. This is probably due to the greater ease of absorption of lead salts in the alimentary tract. On the other hand, lead salts are not absorbed in lethal doses from skin, whereas death may readily be produced by the application of tetraethyl lead to the skin.

The general conclusion which seems to be obvious from the data given above is that tetraethyl lead owes its toxicity to the lead and not to any other part of the compound. Furthermore, it is plain that the compound, tetraethyl lead, is not peculiarly toxic as compared with other heavy metal compounds, but that its principal danger resides in the fact that it is readily absorbed through the skin, as well as being capable of inhalation because of its volatility.

When tetraethyl lead is administered in smaller repeated doses, the outcome is dependent upon the size of the dose and the time interval between doses. In a series of rabbits treated with 0.1 cubic centimeter at intervals of three days, symptoms began to appear in most cases after 6 or 8 treatments. (The only symptom was a slight loss of weight.) The total quantity applied before the death of these animals averaged about twice the amount of a single lethal dose. It will be seen from the consideration of later experiments that the lethal amount is dependent not so much on the total quantity of lead which the animal is led to absorb, but rather upon the concentration actively mobilized (in the blood stream probably) at a particular time.

The accumulation of lead in exposed animals treated with sublethal doses was also made an object of study. This is only of importance in pointing out that in sublethal dose lead is cumulative.

There are one or two items of value in this which it is worth while to point out. A considerable interval of time elapses between the period of the last dose applied to the animal and the period of analysis; the quantity of lead found in the animal is surprisingly low compared with the animals analyzed immediately following the last dose. In order to make that point clear, I should like to present a little of our data.

In the table given may be seen observations and analytical data collected on a series of nine rabbits treated at intervals of three days with 0.1 cubic centimeter of pure tetraethyl lead, applied to the skin of the abdomen.

These rabbits varied in weight slightly, running from 2½ kilos to a little less; in other words, they were approximately the same size. The number of their treatments varied as follows: 16 treatments, 13 treatments, 15, 17, 7, 14, 14, 11, and 10. That is to say, one of these animals received 16 treatments of 0.1 cubic centimeter of tetraethyl lead applied to the belly. Of these animals 3 have survived, and, so far as could be seen, developed no symptoms. The others died at variable periods of time. One of them died 23 days after his last treatment and contained 15.3 milligrams of lead. Another died the day after his fifteenth treatment, and this one had 96 milligrams. Several other animals are presented in the same way, and they show the same thing. That is, if the animal happens to be analyzed immediately after he dies, he has lead in him as a result of that treatment anywhere from 50 to 96 milligrams; if the animal be analyzed two or three weeks after the last treatment, as some of these animals were, the quantity of lead which is found in them varies from 7 to 15 milligrams.

Rabbit	Weight	Number of treatments	Time of appearance of loss of weight	Result	Lead determination in milligrams
	Pounds				
No. 31	5⅜	16	Seventh treatment.	Died 23 days after last treatment	15.3
No. 34	6⅛	13	No loss of weight	Same	9.78
No. 35	6	15	Eighth treatment.	Died day after fifteenth treatment	96.0
No. 36	5¾	17	Fourteenth treatment.	Survived	
No. 37	6¾	7		Died after seventh treatment	90
No. 39	4⅞	14	Seventh treatment.	Died 29 days after last treatment	7.10
No. 40	4½	14	do	Survived	
No. 42	4⅝	11	Ninth treatment	Died after eleventh treatment	51.25
No. 60	3½	10	Seventh treatment.	Survived	

This factor of variation puzzled us somewhat, because these animals were of the same general condition of health, approximately the same size and age, and it would seem they should have absorbed somewhat more nearly the same quantity, although there would, of course, be some allowance for individual variations. It appeared, however, that this variation is probably due to the rate of secretion. Lead from these animals and the rate of secretion in these animals was of such an order of magnitude as to lead one to question the toxicity of a compound of lead different from that ordinarily occurring in lead poisoning, and this question is presented the more strongly when the rate of excretion of lead in men poisoned by tetraethyl lead is studied.

The excretion of some of these animals was observed. They were put in an ordinary cage and their urine and feces were collected over periods of seven days in order to give a considerable amount of material, so as to avoid an experimental error, and careful analyses were made. The quantity of lead secreted by these animals, and these represent animals of this same group of which I spoke, was as follows:

Rabbit	Period of collection	Quantity of lead, in milligrams
	Days	
2 controls	7	Nil.
No. 31 [1]	7	5.89
No. 36	7	4.00
No. 39	7	2.08

[1] This animal died Dec. 21. His entire body contained 15.3 milligrams of lead. Some idea can be obtained of the quantity of lead in the body of this animal at a time when he was excreting almost 1 milligram per day.

This gives an idea of the quantity of lead which in the body of an animal gives rise to an excretion of about a milligram per day.

This fairly rapid rate of excretion raises the question as to whether in the decomposition of the tetraethyl lead molecule a compound of lead may not be formed which is more readily excreted than the ordinary compounds of lead. This question is presented the more strongly when the rate of excretion of lead in men poisoned by tetraethyl lead is studied.

The distribution of lead in poisoned animals.—A number of animals known to contain considerable quantities of lead at the time of death were analyzed after the separation of their tissues. The data below indicate the manner of poisoning of the animal, together with the lead content of various tissues.

Rabbit No. 32.—Exposed for 72 days to vapor of Pb $(Et)_4$ in air at the rate of 100 cubic centimeters PB $(Et)_4$ vapor to 5 liters of air.

Tissue	Weight	Lead in milligrams
	Grams	
Bones	225	9.15
Skin	300	3.18
Liver and kidneys	56	3.70
Central nervous system	13	Nil.

This animal had two young in the uterus at the time of her death, or several—I do not remember how many there were, but their entire weight was 126 grams, and they contained 0.28 milligram of lead. The other tissues weighed 2,045 grams and contained 8.75 milligrams of lead.

Note: One liter of saturated vapor of Pb $(Et)_4$ at 25° C. contains 0.00456 gram Pb.

In these cases, and after this long period of exposure, we find that considerably more than half of the lead in the animal was distributed in parts other than the bones.

Rabbit No. 31.—Treated every three days with 0.1 cubic centimeter Pb $(Et)_4$, 16 treatments. Died 23 days after last treatment.

Tissue	Weight	Lead, in milligrams
Bones	325 grams	8.04
Skin	260 grams	4.49
Liver and kidneys	105 grams	1.15
Central nervous system	13.5 grams	(1)
Other tissues	1,590 grams	2.02
Urine in bladder	50 cubic centimeters	0.14

[1] Lost in analysis.

We were at that time working on some theoretical notions of our own with regard to the materials which bring about increases in rate of secretion from poisoned animals, and this animal at this time had this quantity of lead in its urine, which I have no doubt is a very unusual quantity.

Rabbit No. 16.—Exposed for 98 days to vapor of Pb $(Et)_4$ in air at rate of 5 cubic centimeters of Pb $(Et)_4$ vapor to 5 liters of air, and then for 3 days to 200 cubic centimeters vapor in 5 liters of air. Died.

The bones of this animal contained 2.22 milligrams of lead, the liver weighed 82 grams and contained 3.75 milligrams, the central nervous system weighed 18 grams and contained 0.13 milligrams of lead, while the remainder, without the skin, weighed 2,160 grams and contained 26 milligrams of lead.

These data simply show that in these animals the distribution of lead is such as to show that not all the lead is stored in the bones. One wonders—and we are attempting to determine the point—whether the distribution of lead in experimental animals poisoned by tetraethyl lead is the same as that of animals which have been poisoned by ordinary lead compounds. That, of course, brings up the point, which can be seen at once, that when an organic compound such as tetraethyl lead is taken into the body its fate in the tissues can hardly be determined with ease, and one wonders what is the

exact nature of the decomposition. One thing is certain, the lead which appears in the urine and feces is in an inorganic form, but in exactly what state I am not able to say.

The pathology which has been observed in animals actually poisoned with tetraethyl lead may be a matter of some interest.

When toxic amounts of tetraethyl lead are administered to rabbits, the first symptoms seen are lack of appetite and loss of weight. A sluggishness and lassitude are apparent, and the animal sits with drooped ears and arched back. As the symptoms increase in severity, he becomes nervous, moving about in the cage from place to place, stopping from time to time to sink into a drowsy state. The temperature does not ordinarily vary more than is normal in these animals, but respiration quickens at first and then, with increasing severity of symptoms, decreases. If sufficient time intervenes before death, a watery diarrhoea develops. Convulsions usually occur as a terminal sign, and the animal dies, with bulging, congested eyes and paralyzed respiration, with the heart continuing for some time afterward. When illness results from inhalation there is an irritation, with some weeping of the mucous membranes. The upper respiratory tract may become red and in very severe cases even hemorrhagic. When the application is made on the abdominal wall there is an almost immediate increase in the peristaltic activity of the intestines. Rapid peristalsis may be easily observed under the abdominal wall. During the course of their illness, whether acute or prolonged, no characteristic objective signs develop. There is no typical alteration of the blood picture. (Stippling and polychromatophilia are found frequently in normal rabbits, so that no minute changes would be demonstrable.) Only a slight anemia has appeared in any experimental animal thus far.

We found, as a matter of fact, in the cases a considerable number of normal rabbits which we had at our disposal at the University of Cincinnati, where there was no possible exposure to lead, that a very large number showed stippling and polychromatophilia. We therefore came to the conclusion that a change of this sort in the blood is very likely to be of questionable importance.

Post-mortem examination of poisoned animals discloses certain characteristic, though not definitely differentiating, changes. These are confined almost wholly to the alimentary tract and the central nervous system. There is a considerable amount of capillary dilatation of the viscera generally, and the heart is usually dilated and flabby, but the pronounced findings are seen in an acute intestinal irritation and desquamation and an acute edema of the brain. The intestinal change is confined almost wholly to the small intestine and is most pronounced in the duodenum. Here the intestine is

filled with a sticky mucoid fluid which may be, but usually is not, blood tinged. It is characteristically yellowish and glairy, and often coagulates spontaneously on standing for a time. The mucosa in this region is thin and almost fluid in character. No actual ulceration is found, and there are seldom any definite hemorrhagic areas. The brain is either dry and swollen and very friable, or else it is very wet with a large amount of free fluid under the dura, especially at the base.

Microscopic findings are very meager. No characteristic change has been found. The study of microscopic pathology has not been completed.

Among the effects on experimental animals, which should be noted in passing, is the influence of lead poisoning on pregnancy and the procreative functions in general. A number of pregnant female rabbits have given birth to premature litters. In several cases abortion or miscarriage has resulted shortly after the administration of the poison. However, the loss of ability to reproduce has not occurred in the case of either male or female rabbits. Animals which have been severely poisoned have been both fertilized and become impregnated, and have brought forth normal young after only brief periods of recovery.

So far my entire discussion has referred to pure tetraethyl lead and has had nothing to do with the matter of gasoline. My next paper refers to the absorption of tetraethyl lead through the skin, and I am going to give you just a brief summary of it:

In the former experiments, in which the toxicity of tetraethyl lead as absorbed through the skin was determined, there was in almost every case a possibility that the animal had obtained a portion of the lead by inhalation and ingestion. It was determined, therefore, to carry out some experiments to control this factor and to establish, beyond any doubt, the facts in the matter.

For this reason animals of about the same size were selected, and several of them were exposed to a definite concentration of tetraethyl lead in gasoline in the following manner:

The animal had the hair clipped off of the fore foot, as well as could be done without any injury to the skin at all, then this fore foot was dipped up to the elbow joint in this solution of tetraethyl lead in gasoline, and was held there for the period of an hour in such a way as not to interfere with the circulation. During this period of time, in which we were working with concentrated solutions, a high rate of ventilation was maintained so the animal would have no opportunity of inhaling appreciable quantities of tetraethyl lead vapor. Briefly, the result of these experiments was as follows:

1. Three rabbits of approximately the same weight (about 2 kilos) were exposed for half an hour each on three consecutive days to a 1 to 10 dilution of tetraethyl lead in gasoline. Each animal was carefully tied down on a comfortable board, as much as possible of the hair was clipped from a foreleg without any abrasion, and the leg was gently but firmly held in a test tube of the solution, down to the elbow joint. Care was taken not to interfere with the circulation. The quantity of solution to which the leg was exposed was approximately 35 cubic centimeters. The exposure was carried out in a hood where the air was being changed rapidly. At the end of the exposure the leg was bathed in kerosene repeatedly, wiped dry, and then treated with cold cream, for the purpose of counteracting the harmful effect of the gasoline on the skin.

At the end of three such treatments the animals developed paralysis of the hind legs, and on the next day they died. Control animals, two in number, of the same weight, treated in exactly the same manner except that the gasoline contained no tetraethyl lead, showed no indication of injury beyond some degree of irritation of the skin.

One of the animals was ashed and an analysis for lead was made. The entire carcass contained 36.46 milligrams of lead. It is well to point out that this animal had been exposed for one and one-half hours to 105 cubic centimeters of a solution containing approximately 10 grams of lead. Approximately 0.35 of 1 per cent was absorbed.

2. Ten rabbits were selected and were treated in the same manner, three being used as controls and seven being exposed for half an hour at a time to a dilution of 1 part of tetraethyl lead in 100 parts of gasoline. For the first seven days the treatment was carried out daily. After this the exposures were made twice weekly. This was done because of the skin irritation which resulted from the daily treatment. It was found that the skin could be kept intact by increasing the interval between exposures, provided the skin be treated with cold cream in the interval.

The following table shows the results of such treatment:

Number of animals	Number of treatments	Weight		Result
		Before	After	
89 (control)	28	3¾	5⅛	Survived.
93 (control)	27	4¼	5⅛	Do.
98 (control)	27	3¼	3¾	Do.
90 (1:100)	7	4¼	4⅝	Killed for analysis.[1]
91 (1:100)	29	3¾	4¾	Survived.
92 (1:100)	29	4¾	5⅛	Do.
94 (1:100)	16	4¼	4½	Died suddenly without previous illness.[2]
95 (1:100)	27	4¼	3½	Ill after tenth treatment. Recovered.
96 (1:100)	25	5¼	6½	Survived.
97 (1:100)	22	4	4½	Paralysis and death.[3]

[1] Lead content of carcass of 90, 3.81 milligrams.
[2] Lead content of carcass of 94, 7.50 milligrams.
[3] No analysis was made of carcass of 97.

One of the animals received seven treatments and was killed for analysis at this time in order to get data as quickly as possible. As will be noted, of the remaining 6 animals 4 survived, 2 died; one of them died suddenly, without any evidence of illness, from a cause which could not be ascertained; another developed a paralysis which may have been due to the manner of handling on the board and which may have been due to the lead.

For our purposes it may be safe to assume both those animals died of lead poisoning. Of course the manner of taking a rabbit and tying him down to an animal board and keeping him there quietly for half an hour presents certain experimental difficulties of its own.

The above data show that there is an accumulation of lead in rabbits treated with gasoline containing a sufficient quantity of tetraethyl lead and that the animals may be poisoned by a concentration of 1 part tetraethyl lead to 100 parts of gasoline. It is of some importance to see that animals treated with a concentration of 1 part of tetraethyl lead to 100 parts of gasoline absorbed approximately one-thirtieth as much as animals exposed under identical conditions to ten times that concentration, i. e., 1 to 10.

The question, then, of the toxicity of ethyl gasoline arises. On one aspect of this matter Doctor Edgar has some experimental data which are worth while presenting to you, of the same general type as Doctor Sayers, showing the volatization of ethyl lead and gasoline. Leaving that out of the question for the moment, I should like to present some experiments we have done on the ethyl-gasoline work:

The question of the hazard existing in the handling of ethyl gasoline hinges upon two considerations: (*a*) whether the quantity of tetraethyl lead volatilizing out of gasoline at the existing concentration (1:1,300 approximately) is sufficient to cause appreciable absorption of lead; (*b*) whether skin absorption of tetraethyl lead in gasoline can occur to an extent sufficient to cause poisoning.

I should like to ask your permission to read this entire thing, because there are several details of it which I think are of rather vital importance.

Both of these problems were investigated by exposing animals to conditions as nearly like the normal conditions of human exposure as could be devised. For this purpose guinea pigs and monkeys were selected; guinea pigs, because of their susceptibility to lead poisoning, and monkeys because of their similarity to the human being.

The guinea pigs were divided into four groups, kept separate, but fed and cared for in exactly the same manner. Eleven pigs, four females and the remainder males, were treated on the skin surface of the belly, after clipping off the hair, with 1 cubic centimeter of ethylized gasoline. Eleven, all females, were set aside as untreated controls. Eleven, five of which were females, were treated with 0.2 cubic centimeter of ethylized gasoline. Three, one male and two females, were treated with 1 cubic centimeter of ordinary gasoline.

I might say that we took no precaution at this point, so far as the inhalation of the gasoline containing tetraethyl lead was concerned, nor did we attempt to take any precaution against the animals licking themselves, or others of their group. This we felt was, so far as the inhalation was concerned, only an addition to the excellence of the experiment and presented two hazards instead of one.

The gasoline used was a good grade of high-test commercial gasoline. The ethylized gasoline was prepared by first making a mixture of pure tetraethyl lead and ethylene dibromide in the proportion of three parts of lead to two parts of dibromide. This mixture was kept in a tightly sealed brown bottle to prevent decomposition, and was mixed in gasoline in quantities of 0.25 cubic centimeter to 200 cubic centimeters of gasoline, as needed. This corresponds to the most concentrated mixture of tetraethyl lead in gasoline, known as a 3 E mix representing approximately 1 part by volume of tetraethyl lead per 1,300 parts of gasoline.

The monkeys, four in number, of the Rhesus type, were all cared for in the same manner. Two were used for controls, and two were treated daily with 2 cubic centimeters of ethyl gasoline, prepared in the above manner. The hair was clipped from an area on the back, as large as the palm of the hand and the gasoline mixture was dropped on out of a pipette. One of the monkeys to be used as a control died within a few days after his arrival, having contracted pneumonia in transit. The other control escaped from his cage and died of exposure before he could be captured. The two being treated as above were continued without any controls for comparison.

The following paragraphs indicate the course of the experiments carried out upon these animals.

GUINEA PIGS

Pen No. 1.—Four females, seven males. Treatments twice weekly. Treated with 1 cubic centimeter ethyl gasoline. Number of treatments, 40.

In the period from November 25 to the present there had been no natural deaths among these animals. Three were killed for analysis on March 3, and one was killed for analysis on March 31. The females have given birth to six young, which have survived, two of which were born May 14. There have been two litters of young born dead. These occurred in January and February, during periods of inclement weather, in which all of the animals suffered somewhat.

Two pigs were selected, because of distinctive markings, for observation of blood conditions. The initial observations on the two were as follows:

(*a*) Hb. (Dare method) 90, red count, 6,160,000.

(*b*) Hb. 110, red count, 5,200,000.

Observations made on May 17 were as follows:

(*a*) Hb. 90, red count, 5,754,000.

(*b*) Hb. 105, red count, 5,230,000.

The variations in these, as can be seen, are well within the limits of experimental error.

Blood smears show no appreciable change now as compared with the original observations. Guinea-pig blood under normal conditions shows a variable amount of polychromatophilia, and an occasional stippled cell may be found in the blood of a normal animal. In the two pigs above no stippling has ever been seen. Bluish or basophilic staining erythrocytes may be seen in almost every field. There has been no noticeable increase in the number of these.

Of the seven pigs remaining in this group two males do not appear to be in good condition at present. They have been fighting almost constantly lately and have inflicted many deep wounds upon each other, some of which are infected and suppurating. It has been thought advisable to segregate these animals and continue the experiment to see if healing of wounds will bring about recovery. The two females remaining look healthy and sleek, except for the irritation of the skin of the belly.

Pen No. 2.—Eleven females. Not treated. Male from pen No. 4 introduced.

There have been no natural deaths among these animals. Three were killed for analysis March 3 and one was killed for analysis March 31. Forty young have been born alive, of which three have died within a few days of the day of their birth. Three females have given birth prematurely to young, one of these on May 13.

Two pigs were selected for their distinctive markings, and blood examinations were made as in the case of group No. 1. No variation was seen in the blood picture, and no variation as compared with those in pen No. 1 was seen, except that in one pig an occasional stippled erythrocyte was found.

These animals are in good condition and present no demonstrable deviation from the normal.

Pen No. 3.—Six females, five males. Treatments twice weekly. Treated with 0.2 cubic centimeter ethyl gasoline. Number of treatments, 40.

Since November 25, the beginning of the experiment, there have been no deaths among these animals as a result of illness. Three were killed for analysis on March 3. Twenty-four young ones have been born, of which 19 are now alive. The others died within a day or two of their birth. There have been three litters born dead. None of these occurred since April 1.

The blood findings in these animals are no more significant than those in the other groups of pigs. No variation from the normal has been found in spite of repeated examinations.

The animals are all healthy.

Pen No. 4.—One male, two females. Treatments twice weekly. Treated with 1 cubic centimeter gasoline. Number of treatments, 40.

There have been no deaths in this group. Two litters of young have been born, six young in all, of which one was dead at birth.

No blood examinations have been made on the pigs in this pen since the first examination. They were used largely as controls on the influence of the gasoline alone on the skin. No variation is seen either in the condition of their skin or their general appearance as compared to treated animals.

An unfortunate and unforeseen variable was found in the conduct of these experiments when a group of treated and control animals were killed for analysis on March 3. The table below shows the lead content of the carcasses of these animals. It will be seen that the quantity of lead is practically the same in all animals, treated and control alike. This was not due to any mistakes in handling or treating the animals, nor was there the remotest chance of incorrect selection of animals for analysis. The explanation can be found only in a detailed consideration of all the environmental factors. The first three groups of these animals were quartered in a single large pen, divided into three parts by wooden partitions of tongued and grooved siding. The top and front side were made of inch mesh wire netting. There was no chance, therefore, for the excreta of one group of animals contaminating the food of the others; nor could dust from one cage enter the other in considerable quantity.

I enumerate these things because in the handling of this type of volatile decomposing substances these matters are of the utmost importance in determining whether or not in a given animal you get a quantity of lead or none at all. Any variation in the manner of handling the animals from one of complete segregation leads to the accumulation of lead in control animals from unforeseen sources.

When the animals were received they were kept on the animal board until the treated surface was dry before being returned to the cages. No special ventilation was employed, since there was no objection in this case to inhalation of gasoline and tetraethyl lead vapor. (In the case of human exposure both of these possibilities are presented.) Under these conditions the opportunity for inhalation of vapor from treated animals was not presented to control animals.

The cause for the experimental result can be found only in a condition to which all of the animals were equally exposed.

These animals were moved in rather hurriedly when the weather became bad, and I suppose the rather hurried manner in which they were moved led us into error in the selection of a place for them.

One end of the large room, which was being used for housing the animals during the cold weather, was used from time to time as a place of storage for returned packing cases filled with empty and full cans used for the early distribution of tetraethyl lead.

It is apparent, and should have been foreseen, that a quantity of the dust resultant from the decomposition of such a portion of tetraethyl lead as was left in these cans accumulated on the floor of the room and was carried by currents of air, and the feet of attendants, to that portion of the room used by the animals. It is almost certain that the food of the animals was contaminated as well. In this manner the animals ingested and inhaled such quantities of lead as to completely spoil the experiment.

Analytical results, March 3

Three guinea pigs, pen No. 1, 2.10–2.10–2.55.

Three guinea pigs, pen No. 2, 2.00–2.00–2.10.

Three guinea pigs, pen No. 3, 1.60–2.00. Beaker broken, analysis spoiled.

Analysis repeated March 31 as check

One guinea pig, pen No. 1, white buck, weight 1⅛ pounds, 2.55.

One guinea pig, pen No. 2, white and black female, weight 1⅛ pounds, 2.10.

This analysis was repeated a little later, as we wanted to be absolutely certain of our experimental data and also wished to be certain of our analytical method. I might say at this time that I think there can be no question about the analytical method inasmuch as it was worked over by our staff under the direction of Doctor Edgar, and the method, we think, is as good as can possibly be devised for the determination of lead.

As a result of the error in the manner of conducting this experiment, no conclusions may be drawn as to the quantity of lead which may have been absorbed from the leaded gasoline. It may be of some significance, however, that the quantity of lead absorbed from the gasoline, if any, made no appreciable difference in the total lead obtained from all sources. Such variation as occurs in the entire group of animals may be explainable on the basis of variations in weight. It is certainly significant that even under these adverse conditions there was no demonstrable evidence of the poisoning of any one of these animals, unless the miscarriages be considered. This is of extremely doubtful significance, since such occurrences are not infrequent in a group of this number of animals in any environment.

MONKEYS

Monkey No. 1.—Rhesus male. Weight 5⅛ pounds, January 19. Treated with 2 cubic centimeters ethyl gasoline daily. Number of treatments, 88.

This monkey is now lively, apparently perfectly well, is tame, playful, and in good condition in every way, except for some degree of irritation of the skin of his back.

The second monkey was treated in exactly the same manner and showed substantially the same thing, so there is no need to repeat his story.

In April the animals concerned in the above experiments were moved into different quarters, which allow of no opportunity of exposure to lead in any way other than under controlled experimental conditions. Treatments are being continued to determine if symptoms and signs of poisoning can be produced by the experimental methods previously outlined.

The CHAIRMAN. I believe, if I can read your faces aright, this is the time to adjourn for lunch. We will meet again at 2 o'clock and complete the discussion.

(Thereupon, at 1 o'clock p. m., a recess was taken until 2 o'clock p. m.)

Afternoon Session

The CHAIRMAN. In accordance with the program, I suggest that we now take up the discussion of the experimental data which were reported this morning, and I am going to ask Doctor Henderson, of Yale, if he will open the discussion.

DR. YANDELL HENDERSON

Professor of Applied Physiology, Yale University

Mr. Chairman and gentlemen, I have no general paper to present, such as we have listened to this morning. There are, however, one or two quite general points that have occurred to me as this conference has gone on that I would like with your permission to mention before I touch on more specific matters. One point is that which Secretary Work spoke of, that we might be here for a number of days. I think I ought to say, on behalf of myself and my colleagues, that we can scarcely stay beyond to-day. We are down here on our own expense, neglecting work which we ought to do, and I hope this conference will finish this evening if possible. I think we ought to do so, and to set an example I am going to be very brief and merely try, as the chairman has suggested, to open this discussion.

There is one other point of a general character that I want to call to your attention. The Surgeon General, in opening this meeting, spoke of the lack of laws applying to such a matter as this, and, to my mind, there he touched on a matter which is more important by far than the specific question before us. As I understand it, the Surgeon General has neither authority to say that ethyl gas may be made or may not be made, or even to direct an investigation involving the expenditure of Government money without special act of Congress. I should like to point out that if gasoline were a food this situation would not exist. We have full legal protection and legal definition of foods and of their qualities, and it seems to me that this is one thing that we all can agree on. Perhaps the two sides here present will not be able to agree with regard to the par-

ticular question of whether ethyl gasoline shall be used or not, but it seems to me that we can all agree that such a situation as has arisen regarding leaded gasoline should not arise again; that there should be legislation to give the necessary power to the Health Service. Then, when other questions of this sort come up, as they certainly will, the Surgeon General would have full authority, just as the Bureau of Chemistry in the Department of Agriculture now has full authority over foods. The Surgeon General should have full authority to investigate and supervise and to advise the public, the State boards of health, and city boards of health in all such matters. I have handed to the Surgeon General a resolution covering this idea. I do not think we are at a point in the discussion as yet where we can present specific resolutions, but I hope before this meeting adjourns that we can all agree that it would be advisable, highly advisable, that Congress should be asked to vest in some branch of the Government the authority to investigate and to advise, at least, regarding substances other than foods entering into interstate commerce. I think we ought to be able to agree on that.

I have been assigned to open the discussion, and, as I said, I am going to be brief. In fact, I do not catch points presented verbally very readily; but there were three which I caught this morning which stick in my mind. They stand out like mountain peaks. One of them was reported by Doctor Sayers. He reported that there was 10 per cent of lead in the dust of his experimental chamber. Exhaust gases had been going through there for some months. Exhaust gases go through garages for a very much longer time than that. We may therefore take that observation as an indication of what the dust in a garage is going to consist of, namely, 10 per cent of lead.

Another point which struck me profoundly was that presented by Doctor Kehoe, that his controls were poisoned. I should not have said poisoned, I should say his controls became leaded, and I think he implied that this was due to the lead from the lead ethyl which he had around there being in some manner released, getting loose, going into dust, or vapor, or in some way getting into his control animals. That, I think, is a very fair illustration of what the sanitary experts expect with regard to conditions where you have a material of the high toxicity of tetraethyl lead, or of lead in any form lying about.

Then a third point, which I shall want to come back to, was made by Doctor Flinn, that tetraethyl lead, used even in small amounts, is absorbed through the skin, so that if you get it on your hands, it gets into the body in some way, either through the skin or through the respiratory tract. It is certainly a very striking fact that even the experimenters, even the investigators, who cer-

tainly would handle the product carefully, who are exposed very, very little, show that they have absorbed an appreciable amount of lead.

We have in this room, I find, two diametrically opposed conceptions. The men engaged in industry, chemists, and engineers, take it as a matter of course that a little thing like industrial poisoning should not be allowed to stand in the way of a great industrial advance. On the other hand, the sanitary experts take it as a matter of course that the first consideration is the health of the people. Now lead—as many sanitary experts here can tell you vastly better than I can—lead is the commonest industrial poison, or was until the production of the automobile. Recently carbon monoxide has displaced it. But it seems probable on the basis of the evidence that we have heard this morning that lead will soon recover its leadership, and that if leaded gasoline comes into use, lead will again take not only first place, but by far the first place as the greatest industrial problem.

I have talked with many chemists and engineers, and I do not think they have any appreciation of the place that lead occupies. Lead poisoning to-day is, in the eyes of industrial physicians, comparable to typhoid fever. It is almost comparable to tuberculosis in its character as a disease. It is a form of poisoning of a peculiar type. It is cumulative. It is already fairly common. We do not know what percentage of the population, how many tens of thousands of people in America, are carrying a greater or less quantity of lead in their bodies now. We have every reason to believe that it is a very considerable number. I can well understand that the Ethyl Gasoline Corporation may say, "We are not responsible for the lead in the bodies of typesetters, printers, and house painters," but the sanitarian has to look at the matter from another side. He knows that if a painter or a typesetter has in him already such a quantity of lead that he can just keep it down—he can just keep it in his bones or just keep it excreted at the rate he takes it in—then the addition of a little more is going to increase enormously the number of cases of lead poisoning in the community. We have to look at the thing from that side. So while we want to be as considerate as we can in regard to the industrial standpoint, we must also ask that our standpoint should be understood and considered.

There is a matter upon which I touch with hesitation, because I am afraid that I may cause offense, and yet I have to. This is not the first poisonous substance that has been developed. In modern industry more and more frequently we have poisonous chemicals of one sort or another developed. This was particularly the case during the war. There I can speak from personal experience. When the war started I was assigned to the physiological or medical side of

the development of war gases. I got a very capable man and put him in charge of the sanitary supervision of production. Very considerable amounts of phosgene and mustard gas were produced in America during the war; and we did not poison the people who made it. Such substances can be handled so that you do not kill people. On the other side we have a list, according to different counts, of between 11 and 15 men killed by tetraethyl lead. They died in a terrible form of insanity. Furthermore, somewhere between 50 and 100 other men have been poisoned more or less severely. It is probable that not all the cases have been reported. I was surprised this morning not to hear the Whiting plant in Indiana mentioned, because I have a letter here from a man whose son was severely poisoned in the laboratory at Whiting, Ind. This indicates that we have not heard of all the cases. Chemists and engineers surely have no desire to kill people; and if that is the case, then there is something about the manufacture of tetraethyl lead, something about its lack of odor, something about its other qualities, which renders it peculiarly liable to result in severe poisoning. That is a very important point. Chlorine, although a very irritating substance, seldom causes death. Hydrogen sulphide, although as toxic as cyanide, seldom kills a laboratory worker. The reason is that chlorine is so irritating and hydrogen sulphide smells so bad that a man gets out of the way.

I am going to read one or two communications showing how people are poisoned by tetraethyl lead. Before I do so I want to say that I am not combating what was said this morning about the special merits of lead for automobiles. I am simply trying to show that there is another side. I have asked some of the chemists, my colleagues in Yale University, and I have found that lead is not by any means the only substance which, on theoretical grounds, or even on the basis of experiments, can be used as an antiknock medium. I find from the engineers in the mechanical engineering laboratory of Yale University, where they work quite largely on automobiles, that they have a feeling that even with the present fuel it will be possible to develop engines that will make use of the rapid form of explosion, which is called detonating. I do not offer an opinion on that matter. I simply quote it as showing that men who are competent to have an opinion believe that there are other chemical and engineering possibilities.

The subject of masks was mentioned. I had a good deal to do with the developing of the gas mask during the war. It has now been developed into the Burrell mask, now used in industry. I think it is very doubtful whether you can permanently protect men by means of masks under industrial conditions. A man will put on a mask and go into ammonia, but you can not depend on masks

to protect men under constant working conditions. It is not known, I believe, whether the masks will stop tetraethyl lead.

I had occasion this morning to mention in connection with Doctor Sayers's remarks that his use of the standard of four parts of carbon monoxide is not well founded. In the streets of New York it is true that the concentration of carbon monoxide runs from 1 to a little more than 1 part of that gas in 10,000 parts of air; but in garages the concentration of carbon monoxide runs up to 10 or 12 or more parts of carbon monoxide. So we would have to multiply Doctor Sayers's figures by 3 or 4 in order to estimate what the effects will be in garages.

I have already talked longer than I meant to, but I want to mention one or two cases I have collected to show how careless people become, and also to show the really terrible responsibility—I am sorry to have to say this—which rests upon the gentlemen who have developed this substance in not having warned more effectively the people who have used it. I received this letter only a day or two ago, dated May 8, from West Virginia.

> In the early stages of the sale of ethyl fluid they were not able to furnish ethylizers and we filled thousands of 1-ounce bottles with the fluid. In serving the customer we would pour the contents of the bottle in his tank and run the gasoline in on top of it. In filling these bottles the writer took an active part, and I have had my hands and arms up to my elbows covered with the fluid. This not only happened once, but a number of times before we knew there was any danger.

At least we should have some guaranty that in future people will be adequately warned.

I have here also a quotation from a report of Doctor Shrader, in Baltimore, describing the mixing of the ethyl fluid to make ethyl gasoline. I believe this mixing is now done at the works, so I will leave out the first part of the report in which the men he interviewed mention having had the liquid often splashed over their faces and arms. This passage, however, applies. He says:

> One service man reports that he gets it all over his hands and coat sleeves, and that the company issues instructions that in all such cases I was to wash it off with gasoline and tincture of green soap; but we do not bother with that any more, we just wipe it off.

This service operator had it splashed upon his face and reported that "it smarted some," and another that it splashed up his nostrils and that "he nearly sneezed his head off."

In this connection I should like to mention one other point. I have spent my summers for some years motor boating, and I find it the regular practice of the men on motor boats when the gasoline pipe plugs up to first blow into it to blow it clear; and if they can not blow it clear, to suck until they suck it clear. I have seen

men time after time squirt mouthfuls of gasoline overboard. We have to keep such conditions in mind. I think it is sufficiently well known to everybody that gasoline is spilled around garages, and I would merely instance one or two collateral points. Methyl alcohol is much less poisonous than tetraethyl lead, yet cases have been reported of men poisoned by inhaling the fumes from the radiators of cars using alcohol in winter. This shows that considerable amounts of fumes are inhaled by men, particularly those driving trucks, and that men have been seriously affected, even by the present fumes. There are also cases on record where the atmosphere in a closed car has become so charged with carbon monoxide as to cause death. I quote this fact to illustrate the point that exhaust gas is sometimes discharged inside of cars.

The main calculation which I want to contribute to this discussion is this: Doctor Haggard, my associate here, and I have published extensive work on automobile gases in the streets. We know the amounts of carbon monoxide in garages; we know that the figures run to 1 or 2 parts in the streets and 8 to 10 or 12 parts in garages, and more than that in repair shops. Now, taking the data obtained by Mr. A. C. Fieldner, of the Bureau of Mines, and combining them with other data we have, it appears that in an automobile every kilo of gasoline burned involves 12 kilos of air. In the exhaust gas there would then be about 1 milligram of lead for each 0.8 liter of carbon monoxide produced, or 1.4 milligrams of lead per liter of carbon monoxide. From this we can calculate the amount of lead in a 1 to 10,000 mixture of carbon monoxide, or the amount of lead in a 10 to 10,000 mixture. If, then, a man breathes four to five thousand liters of air in 10 hours, and the air contains 1 part of carbon monoxide in 10,000, as in the streets, he would inhale in the course of 10 hours one-half milligram of lead. That, of course, sounds to a chemist like an exceedingly small figure. To the man interested in industrial diseases the daily inhalation of half a milligram of lead is a serious matter. In a garage, where often there are 10 parts of carbon monoxide, the worker would inhale daily 2½ milligrams of lead. Of course, this would be reduced in proportion as the lead sticks in the muffler. We come up to the high figure in proportion as all of the lead is discharged. As processes improve, more will probably be discharged. It seems to me that the Surgeon General, or some officer of the Government, should have general supervision, so that in future the regulations can be adjusted to actual conditions. Even now we often have 200 cars per block in Fifth Avenue, and if they each burn 2 gallons of gasoline per hour it runs up to about 200 pounds of lead in Fifth Avenue between Twenty-third Street and Central Park. Even one-fifth of that amount as volatilized lead is a very large amount. These figures are based on

the carbon monoxide content as we have found it in streets and garages. Carbon monoxide is a true gas; it diffuses rapidly. Lead does not act as gas; it hangs in the air so that one would expect a very considerable concentration of lead dust as compared with the rapid escape of the carbon monoxide. Thus it seems to me, on the basis of all the data that we have at the present time, that the ordinary conditions in thoroughfares in heavy traffic would afford about one-half of a milligram of lead a day for a man to absorb. Kobert estimates that the amount of lead, day in and day out, which would almost certainly result in distinct lead poisoning is 1 milligram. Garage workers and repairers would absorb very much more.

Now, I put it to the gentlemen on the industrial side of this conference that they, no more than any sanitarian, would approve of having a milligram of lead in every gallon of the city's water supply. Yet if the city's water supply contained 1 milligram per gallon we would take daily from it just about the amount of lead which, as nearly as we can figure it on the basis of such facts as we now have, the people of New York, especially in the denser parts, would be expected to inhale.

I have here somewhere—I will not read it now—a paper by Dr. Alice Hamilton in the last Journal of the American Medical Association. She is here and will speak for herself. In that article Doctor Hamilton expresses the matter as fully and as clearly as anyone possibly can. In the last sentence of her paper she sets up this very simple proposition that this substance, this new industrial hazard, should not be put into general use, or its use should not be extended until we have adequate and full information assuring us that we are not introducing another health hazard into our daily lives.

The CHAIRMAN. I am going to ask Doctor Thompson if he will follow.

Doctor THOMPSON. There are others here very much more competent to discuss this subject than I, and I should like to yield my place to Doctor Edgar. Will you call on him?

The CHAIRMAN. Doctor Edgar.

Doctor EDGAR. With Doctor Thompson's permission, I also, not being a physiological chemist or even a physician, would like to have Doctor Kehoe answer the questions, not myself.

The CHAIRMAN. Doctor Kehoe.

DR. ROBERT A. KEHOE
College of Medicine, Cincinnati, Ohio

Mr. Chairman and gentlemen, there are one or two items of Doctor Henderson's talk that I should like to speak of first, beginning particularly with that one which refers to the experiments which were conducted by myself, in that the controls in our animal experimentation showed that they had absorbed lead. I should like to point out the manner in which those animals were exposed to lead. The condition was such as does not and could not conceivably occur in the industrial handling of gasoline. Now, to make that point clear I should like to recite the exact conditions to which these animals were exposed. At the time when it was decided, on the initiative of the Ethyl Gasoline Corporation, to remove completely from the industry that hazard which was regarded by the medical committee as a most important one, namely, the handling by garage men and filling station employes of concentrated fluid, all of the material which was then out on the market was returned to the Ethyl Gasoline Corporation. This came in in varying quantities and at different times over a period of a number of weeks, and it came in in such quantities that the immediate disposal of it was a matter of some difficulty. Various storage rooms in and about the buildings used for the blending and distribution of this material were filled for a time with the cases containing these small cans that had been returned, and it was only in that situation that the overflow took place into the room in which we were experimenting. Under these conditions an exposure on the part of these animals was had, not to the dust of dilute gasoline, which appears on the public market, but to the dust which arose from the decomposition of concentrated tetraethyl lead, a situation which presented opportunity for absorption of an enormously greater quantity than could occur under other conditions. It was under these conditions that our animals absorbed lead—conditions which, let me emphasize, have no relationship to the hazards existing from the handling and distribution of diluted tetraethyl lead in gasoline.

There is one other point that I should like to make with regard to the poisoning of certain persons who were experimenting with tetraethyl lead, whose specimens of feces and stools, or feces and urine, later showed lead. Anyone who experiments in any way at all with concentrated tetraethyl lead is bound to absorb a certain amount of vapor of tetraethyl lead into his body. I see no possible escape from that condition. One may work with a very good hood, but in the very business of treating the animal with concentrated tetraethyl lead and staying in the same room with it there would be a certain absorption of lead. It seems to me that the absorption

of lead which will occur under those conditions is also not a matter relating to the absorption through the skin or inhalation of such lead as occurs in the dilute form of 1 part of lead to 1,300 parts of gasoline. In addition to that, I should like to point out the quantity of lead found in these specimens is no greater than the quantity found in the specimens of control persons whom we have examined, whose excreta we also examined, whose history, so far as we are able to find out, presented no exposure to the industrial hazards which bring about lead poisoning. The quantities, therefore, in these excreta are, to my way of thinking, of no particular importance to the matter in question.

As to the question whether or not all the poisonings which have occurred from tetraethyl lead have been reported, if there have been any poisonings which occurred other than those which have been reported, they have not come to my knowledge. As a matter of fact, there is no manufacturing or blending plant at Whiting, Ind., and I do not know how anybody could have been actually poisoned at that place. I might say this, however, that due to the hysteria which arose from certain items which appeared in the newspapers there was a considerable number of men scattered over the country, some of whom may have happened to be in Whiting, who conceived the notion they had been violently poisoned by tetraethyl, and I have had occasion to examine a number of these persons. Such persons will be found in almost any community, and up to the present I have not been able to find evidence of any foundation in the claims made by them. For example, a man reported to me, who thought that perhaps he was suffering from tetraethyl poison. He had gone to the dentist, and had a condition of his teeth, which, over a period of some weeks, the dentist was unable to treat with good results, so the dentist suggested, I imagine, as the easiest way out (knowing that this man had worked in a filling station where ethyl gasoline had been sold), that this was probably the reason for his teeth not clearing up. It so happened that this man had an ordinary, typical case of trench mouth, which on proper treatment cleared up in the course of a few days. Situations of that sort have arisen in view of the little knowledge existing as to the actual magnitude of the hazard, particularly so since there has been this newspaper commotion about "looney" gas, and all that sort of thing, and there are those individuals who think they have been poisoned but who have some perfectly definite lesion, recognizable by a good physician, not due in any way to lead.

As to the matter as to whether masks may be used where there is tetraethyl lead, or rather whether they can be used with success, I might say that experiments have been conducted at the research laboratory of the Ethyl Gasoline Corporation which I think are quite

adequate to answer that question. The experiments in question were carried out by Doctor Edgar and it would more properly be answered by him. I may say though, as a matter of practical experience, I have had under observation a considerable number of men who have been exposed to these hazards, and we found that with the introduction of the gas masks we got a very satisfactory diminution in illness among the men, so the question of whether or not the gas masks are of any value may be considered answered on the basis not of theory but of actual experience.

As to the proper warning to the users of gasoline, various cards describing tetraethyl lead, describing ethyl fluid, describing the gasoline, have been sent out with every container which has gone out of the blending plant. The character of the poison and the dangers attendant upon its misuse have been made perfectly plain to all users. Of much more importance, however, since one can not depend on either the intelligence or persistence of persons who would have to handle this sort of material, a thing of utmost importance was done when the concentrated fluid, as originally put out, was taken off of the market. This was done as the result of the advice of the medical committee. Considering this was a hazard, which in the hands of careless persons would not be taken care of, it was felt that the ethyl fluid, in concentrated form, should be immediately taken off of the market and should be handled only in such places as would properly regulate and control the manner of its mixing. The hazards, therefore, from the small containers and from the lack of information on the part of the public have been done away with by one stroke by that simple measure of taking the concentrated stuff off the market. There may be found, as a matter of fact, one or two places yet where some of these small cans can be gotten. If that is true, and I am not in position to say it is not true, it is only because they have not been returned; none has been shipped out and none will be shipped out.

One other point which was brought out and which is of general importance I should like to cover, that is the matter of two attitudes which are said to exist, one on the part of the industrial group and one on the part of the medical group, with regard to hazards which may be said to exist. In the past several months—as a matter of fact, for some time—these hazards attendant upon the distribution, manufacture, and production of tetraethyl lead have been not in the hands of the industries; they have been in the hands of medical men, who have had the interests of the public at heart. I am convinced from the association I have had with the company that has had charge of the distribution of this commodity that their attitude is one of complete regard for facts. They have expressed

themselves repeatedly not so much as being interested in opinions as being interested in facts, and if it can be shown—if it is shown as the result of this discussion—that an actual hazard exists in the handling of ethyl gasoline, that an actual hazard exists from exhaust gases from motors, that an actual danger to the public is had as a result of the treatment of the gasoline with lead, the distribution of gasoline with lead in it will be discontinued from that moment. Of that there is no question.

I make no plea for industrial progress, because in my own opinion industrial progress is not synonymous with human progress at all; but I must say, from the standpoint of industry, that when a material is found to be of this importance for the conservation of fuel and for increasing the efficiency of the automobile it is not a thing which may be thrown into the discard on the basis of opinions. It is a thing which should be treated solely on the basis of facts. That has been our attitude from the beginning, and that will continue to be our attitude.

The CHAIRMAN. We have this discussion divided somewhat arbitrarily, I fear; but are there any remarks by anyone on the experimental phase of this?

Doctor MORTON. I would like to answer Doctor Henderson about the letter he has in regard to a case of lead poisoning. This young man he refers to is the son of the dean of the law department of the University of Kentucky. He was working in the experimental laboratories at Whiting, Ind. A few days after the papers were full of the New Jersey accident, where a number of men died as a result of lead poisoning, this young man took sick. He is a graduate of the University of Chicago, and he was treated by one of the medical staff of the University of Chicago, who did not make a diagnosis of lead poisoning but said that his trouble was nervousness. I saw him, examined him, and had Dr. Ralph Webster, head of the Chicago laboratory, examine the urine for lead. I also had the blood examined. Everything was negative, so that my diagnosis was neurasthenia or nervousness. He went home to Kentucky. His father had three men at Louisville, I believe, take care of him for two or three weeks. We afterwards received a letter from one of the men at Louisville which said that no signs of lead poisoning had been found and that the diagnosis was nervousness, or a neurotic case.

Doctor HENDERSON. This letter states he had been assigned for several months to investigations on the method of developing tetraethyl lead. The doctor denied that.

Doctor MORTON. He was experimenting. He was using tetraethyl. He was not making it.

Doctor HENDERSON. Had he not been working with ethyl gasoline?

Doctor MORTON. No.

Doctor FLINN. I object to the insinuation just expressed by Doctor Kehoe that quantites of 0.7 and 0.8 milligram of lead are common findings in the normal stool. In an examination of 28 stools of men supposedly poisoned at the Standard Oil plant in Bayway we were able to detect lead in only 18 or 19 cases, and the stools of these men were examined more than once in most instances. Doctor Touart can correct me if my statement is incorrect. As I said this morning, the records of over 500 men showed that lead was present in the urine only in 20 per cent. These men were exposed to lead in their work. I think most medical men will agree that lead is not a common finding in the feces and urine of the normal man.

Doctor AUB. I should like to say a few words about the experimental side. Two or three things struck me this morning quite clearly, which I think men who have not been working in the investigative side would hardly appreciate. First of all, the different types of animals vary tremendously in susceptibility to lead intoxication. Guinea pigs, pigeons, rabbits, and cats are fairly susceptible. Some animals I have not worked with, so I can not say definitely whether goats or monkeys are susceptible or not, but dogs, chickens, pigeons, and rats are only fairly so.

The same thing is true of the blood picture. Some of the blood pictures given this morning might tend to give a false impression, because many animals will not show blood changes, as, for instance, anemia during lead poisoning, and when it is slight stippling does not appear in many animals, such as cats, hens, and pigeons. As one looks over the experimental data one has to be careful to realize that different types of animals give you different results.

Secondly, about the discussion of lead analyses. Lead analyses are particularly difficult when analyzing the bones. When one reports a tremendous variation, as, for instance, a high content of lead in acutely poisoned animals, and then a low content weeks later when there was found to be only an elimination at most of 10 milligrams in the feces and urine, the question arises whether perhaps the discrepancy lies in the difficult analyses. It took us several months to learn how to recover all of the lead present in bone, for it is a very difficult analysis.

The analyses which have been reported as found in normals I can not corroborate. We have done many determinations in normal individuals in the last three years, and so far as can be made out normal individuals do not have lead in their stools and urine. Nor-

mal lead was reported many years ago by several investigators. Their methods were not very accurate. With modern methods, even as recently as five years ago, manganese has been mixed in lead determinations and has given the picture of positive lead determinations. With the present methods—we use Fairbell's method—the stools from normal individuals contain no lead and the average individual in New England does not have normal lead in his body. We analyzed the bones of 26 individuals, who for one reason or another had to have an amputation. Of these 26 cases, 19 of them had no lead in their bones, and practically all the lead which is stored in the body is to be found in the bones. Seven of them did have some lead storage, and most of these were later found to have had an exposure to lead of some sort previously in their life.

There are one or two other things to speak about. We studied one man who had some symptoms from tetraethyl lead exposure. His excreta showed lead in the urine and feces just as it appears in the usual chronic cases, and it responded fairly well to medication, which suggests that the chronic effect of tetraethyl lead will be similar to that from the absorption of nonorganic lead.

Another point, and that is, in practically all the observations reported on exposure to tetraethyl, although many of them showed no symptoms, practically all showed absorption of lead, and to my mind that is very important because lead is an accumulative poison, and whether they showed signs of poisoning or not is not important in acute experiments, but it is important that these individuals have absorbed lead and retained it. That means in more chronic exposure the amount present will become increased. Besides, the amounts which were found in the experiments reported to-day are not small as one looks at the figures, at least compared to the animals which we have studied; the amounts found in organs are relatively large quantites.

There is one more thing. I do not think, as the problem occurs to me, that the question of the toxicity of tetraethyl lead itself or even the distribution of the product is the problem involved. By far the greater problem is the question of whether distributing lead over communities from the exhaust gas will cause any toxic symptoms in individuals who can not protect themselves. I am not perfectly certain in my calculations, but from what Mr. Kettering said, 15,000,000,000 gallons of gasoline will be used, and if we used tetraethyl lead in all of this it would mean 50,000 tons of lead distributed over the United States in a year. If that is correct, and I think it is, I am not certain that this would cause poisoning, but whether it would cause poisoning is a very serious question. One must give that considerable thought, and it seems to me that it must

first be proved that it is not poisonous, because of the tremendously diffuse results that this amount of lead scattered in fine powder over a long period might cause. It seems to me that this should be very thoroughly investigated before tetraethyl lead is again put on the market.

Doctor EDGAR. With reference to the question of the analysis of lead, as the doctor pointed out, as to small quantities of lead in animal tissue, it is difficult to get strictly accurate data. I do not know what method has been used by the Bureau of Mines. Our own method has been ashing animal tissue at low temperature, 500–600° C., the lead being precipitated by hydrogen sulphide, reprecipitated and dissolved and reprecipitated the third time as sulphide to get rid of various impurities that accumulate, and finally reprecipitated as chromate, and estimated colorimetrically by treatment of chromate with diphenyl-carbozide.

The details of our own method were worked out in the period of a month or so and have been conducted with extreme care. With the addition of known quantities of lead and materials giving blank quantities of lead we have obtained very satisfactory results, and I think we have reasonable certainty of accuracy in our own method—we have worked that over quite thoroughly, because it is an extremely difficult problem. The average person with inexperience in lead analysis can not get accurate data with small quantities of lead without considerable care.

Doctor KEHOE. Whether or not lead is found in normal stools brings up the question of the manner in which these controls we used were obtained. We looked about for controls who could not in any conceivable way have been exposed to ethyl gasoline.

A community in which ethyl gasoline has never been sold or distributed was selected—Columbus, Ohio. We went to Columbus, Ohio, and originally had the idea of going to a commercial garage of some sort which employed men and subjected them to physical examination and collecting specimens for analysis. This did not appear to be feasible, so that the procedure which was adopted is as follows: We went to an employment agency, and the men were sent to us from the employment agency just as they came in. Careful histories were taken—I have these histories with me—to obtain information as to whether or not these men had ever had any exposure to lead of which they knew. In order to obtain that information leading questions were asked as to their occupations over a period of years.

Specific questions were asked as to whether or not they had worked in an automobile factory, a tire factory, whether there was known exposure to lead, whether they had worked in battery factories or

for battery works of any kind, and so on through the industries which we know presented lead hazard. Histories were taken by one man and physical examination was done by another without any knowledge of the history, and specimens were turned over to the laboratory without either history or physical examination, simply with the names and numbers, and those specimens, both of urine and feces, were examined. The amount of lead which was found uniformly in these specimens was as much a surprise to me as to anybody in this room. This report was presented to me yesterday. I have no reason to doubt its accuracy, and there it is. Take it for what it is. The result is not complete, because we have only data on 10 men out of 30 who had exposure and 10 men out of 64 who had no exposure.

The data on this particular matter will be completed and published later, but it just happens that 10 men on whose specimens I have reports were taken at random by the laboratory group, they having no knowledge of the number of controls or the number of exposed men, and it simply turned out the way I presented it.

Doctor HAGGARD. Doctor Kehoe's report certainly shows a serious hazard. People do not have lead in their excreta unless there has been an exposure to lead. In the past lead has been found only in the excreta of typesetters, painters, and the like. But now Doctor Kehoe finds lead in the excreta of all persons tested. It would appear that such a general exposure could only come from one source, and that is the leaded gasoline which was widely used in the city when he made his study. Doctor Kehoe's work offers an experimental demonstration of what sanatarians had assumed on theoretical grounds.

The CHAIRMAN. Is there any further discussion of the experimental results? If not, I will ask Doctor Edsall, of Harvard, to open the discussion on this subject from the clinical standpoint.

DR. DAVID EDSALL

Dean School of Public Health, Harvard University

I suppose I am asked to speak about the clinical side because I have had some experience in the general question of lead poisoning. I would say that I have not had clinical experience with tetraethyl lead poisoning. I have not seen cases. I have seen the conditions under which it is produced and handled, but my knowledge in the matter is really confined chiefly to the general question of lead poisoning and experience in that for a good many years.

The CHAIRMAN. We want to bring out everything we can.

Doctor EDSALL. I speak then from the standpoint of a clinician somewhat experienced in lead poisoning and in industrial conditions.

In the first place, as regards the manufacture of tetraethyl lead, I am personally prepared to believe that while it is an extremely hazardous thing, it can be made reasonably safe as compared with the manufacture of other very dangerous substances. I would deplore some of the things that were said this morning as regards careless handling of it for a long time without any dangerous symptoms, because the impression might readily get about that that is a safe thing to do. I think the escape from dangerous symptoms in these circumstances was unquestionably a pure piece of luck. There can be no doubt that in the handling and in the manufacture, in the first place, all the mechanical precautions that can be taken should be taken, and in addition to that there should be extremely careful observation of the plant all the time.

I have also very little doubt that the transportation and gross distribution of it can be reasonably safely handled if done very carefully. I was impressed, however, by the numbers that Doctor Kehoe mentioned this morning as showing symptoms. Out of 100 men since last August, 18 had showed symptoms that could be interpreted as being some degree of mild poisoning. That means, it seems to me, that the methods of handling were as yet far from perfect. It is a high incidence of lead poisoning in any kind of occupation where there is exposure to lead to have in that time 18 per cent of workers show symptoms of lead poisoning.

Nevertheless, I think the manufacture and gross handling of it could be made reasonably safe as compared with many other things that are done and must be done. But that means that everything must be done with constant care and watchfulness, because disturbances may occur at any time which might lead to serious results; and under the best circumstances I feel sure there would be occasionally serious cases of poisoning. That, however, is unfortunately necessarily true in the handling of all dangerous chemicals, and it is generally recognized that that does not make the manufacture of them a thing to be necessarily limited or forbidden.

On the other hand, I have been in much doubt about the question of the use of the product in garages and sales stations and in regard to the question of the effect of the exhaust. I have been very much impressed by an examination of the results reported here to-day. The only evidence that I have heard that would indicate that it may be safe is the evidence that Doctor Kehoe mentioned in the group he studied of people exposed to it about garages where it was used. In spite of what Doctor Kehoe has just said, I think that his work will have to be neglected for the reason that the finding of lead in such a large proportion of control people means that however carefully these observations were made there was something wrong technically. Very careful and prolonged work by our group and

other groups has shown that lead in the excretions of apparently normal persons is very unusual and can be traced generally to some previous exposure. Therefore one must feel that with the people that were taken as controls something has been overlooked or there were technical errors, and therefore the results can not be accepted.

On the other hand, I am impressed by Doctor Sayers's report of a large amount of lead in the dust of the chamber in which animals were exposed and in which an extremely high degree of ventilation was being carried out. Of course larger amounts of tetraethyl fluid were used than are used commercially, but, on the other hand, Doctor Henderson is technically correct in saying that the standard dilution of carbon monoxide in the experiments to 1 in 10,000 is not correct, for the conditions in garages often provide a higher proportion of carbon monoxide.

Those two things will probably balance each other, so I think we can take Doctor Sayers's results as indicative of what may occur in garages, not necessarily as what will occur but as the only evidence we have as to what may occur.

We are dealing here not with tetraethyl lead but with lead, so that the observations in regard to lead that have been made for many years are observations that can be directly transferred to this question. For 100 years and more observations have been made as to the effect of having a noteworthy amount of lead dust around in any occupation. We know what happens to some of the people exposed to it. It is not a question, then, whether there is or is not a hazard. There is a hazard, if these observations of Doctor Sayers and the observations of Professor Flinn are correct. The question is, how great is the hazard? Judging from other conditions in industries in which lead dust occurs, I am disposed to believe that the hazard is a noteworthy one. How severe I am not prepared to say. The only way in which one can determine how serious it is would be through a very large number of extremely carefully carried out observations as to what the effects are upon a large number of human beings with ethyl gasoline in general use in the neighborhood in which these people live.

It has to be remembered, and this can be repeated in occupation after occupation, that even where there is a noteworthy hazard only a limited number of people show clinical symptoms of lead poisoning that are clearly recognizable. A very much larger number, if you examine carefully, will show signs of ill health of an indefinite character, and these are the things that are very likely to be overlooked. They show chronic disease, as of the gastrointestinal tract, anemia, and vague chronic disorders of health much more frequently than they show the commonly recognized effects, namely, lead colic or paralysis or mental symptoms of lead poisoning. I accept with

the greatest skepticism general statements as to lead hazards, such as reports that "nobody has been sick" or "nobody has shown any symptoms of lead poisoning."

That kind of testimony is negligible. The only kind of testimony that would show whether there was lead poisoning or not would be based on extremely careful and highly experienced observation, including carefully carried out examinations of the excreta and including also the recent methods that Doctor Aub's group have been carrying out of producing artificial acidosis and determining whether this leads to lead excretion in exposed people who have been carrying lead quietly in their systems without having symptoms and without excreting any of it under ordinary conditions.

That is one of the most striking things in regard to this whole question, that persons may be absorbing lead and keeping in their systems a large portion, and yet have no obvious symptoms. Then these persons may develop symptoms or show excretion, owing simply to alterations in their diet, or to other simple circumstances. Under ordinary conditions you may say that besides those people who show definite lead poisoning in consequence of exposure to lead there are a much larger number that are carrying lead and are therefore potentially liable to symptoms of poisoning.

The only conclusion that I can draw from the data presented here to-day is that in the question of the exhaust and to a certain extent in the question of the effects of the ethyl gasoline mixture, we are dealing with a matter that has to be judged by the accumulated experience of many years now as to lead poisoning in whatever circumstances or occupation it occurs. And I can not escape feeling that a hazard is perfectly clearly shown thus far by what has been reported here to-day, that it appears to be a hazard of considerable moment, and that the only way that it could be said that it is a safe thing to continue with that hazard would be after very careful and prolonged and devoted study as to how great the hazard is.

In occupations in which there are lead hazards it has been the increasing viewpoint not only of public health men but of industries themselves and of governments, for many years now, that a hazard having been discovered must be relentlessly struggled against and essentially eliminated before the conditions are passed as being approved. When we are dealing with industry, with a manufacturing process, that is nearly always a feasible thing, and it has been done in some of the lead processes that at first looked as though they were perfectly impossible to control. But there you have a group of workers entirely controllable as a group. Regulations which can be put upon them can be carried out with care and the whole matter is within the control of the individuals who are responsible for it.

We have one occupation, however, that is an outstanding exception and that is comparable to this situation, namely, the occupation of painting. There are some others that are comparable also, but that is the outstanding one.

There you have this situation: The individuals carrying out instructions are individual human beings working separately, they are subject to no control, and you have all the errors of the human individual to deal with, as contrasted with a group that work under control and under conditions that can be made very definite.

Painting has been widely studied by students of hygiene, by the employers themselves and increasingly by governments. In that occupation regulation and instruction are really very disappointing and oftentimes entirely fruitless. Hence governments are increasingly acting toward the elimination of lead from paints to a more or less considerable degree, because they know no other method of controlling the situation.

In the use of tetraethyl lead by the public we have to take into consideration the fact that we are in a position where we must depend upon the individual in garages, both public and private, and in other uses as to the care with which the substance is employed, or special precautions used. That makes a very difficult situation, it seems to me. You may make all the regulations you wish and you may give all the warnings that you will, but we know from experience in other conditions that are quite comparable that those warnings will very commonly be neglected and that most individuals will be utterly careless in the way that they use the dangerous substance. Furthermore, I find it very difficult to conceive how a garage, for example, could be kept hygienically safe if there were amounts of dust in it comparable even to those that Doctor Sayers found in his room. It is very difficult to see how they could be made safe, with the floor, the rafters, and everything covered with fine dust such as this. Conditions in a garage are not such that it can be kept clean, as most factories can be kept clean. I should suppose that there would be necessarily always a considerable amount of lead-containing dust if this substance were used in garages. Granting that, I think we can scarcely deny that there is a definite hazard.

I repeat, the only way that I can conceive of that we could determine how serious, how extensive that hazard is, would be by making very extensive and very elaborate and very careful studies over a long time.

The CHAIRMAN. Doctor Touart, have you something to say in regard to hospital education?

DR. M. DE M. TOUART

Medical Director, Reconstruction Hospital, New York City

Mr. Chairman, ladies, and gentlemen, I doubt if I have anything to say that would be of very great help to this conference, but I speak from the observation and treatment of 49 individuals who were suspected of being poisoned by tetraethyl lead. Thirty-nine of these patients presented clinical evidence that might be charged to the poisoning. The other 10 we may disregard.

I am impressed by the fact that this substance, in concentrated form, produces a train of symptoms that in some cases results in a severe and fatal illness. Among the cases that did not die, several were ill, with great suffering, for a long period of time.

I can not help but feel, under these circumstances, that if the hazard is going to be extended to the general population the matter should be carefully considered before doing so.

I might say that of these 39 patients, 28 had stool examinations for lead, and, as Professor Flinn said, 18 of these showed positive lead findings. The other 10 did not show positive lead findings in the stool. At the same time, however, there was definite clinical evidence of tetraethyl lead poisoning, and I feel we have had sufficient experience with the condition to be able to recognize it clinically where well developed.

I would also say, however, that some of these individuals gave no physical evidence and no symptoms or any evidence that could be found by a physical examination that would indicate they were ill, but at the same time showed lead in the stools. This suggested to me that perhaps a man may be poisoned from the tetraethyl lead without showing clinical evidence, and that therefore there may be a considerable number of individuals so poisoned who have not come under observation.

It would not be of any interest to this meeting to hear anything about the clinical signs that are found in this condition. It has been said to-day that industry was willing or is willing, if it is shown conclusively that the use of leaded gasoline is a hazard to the general population, to cease the distribution of the same. It seems to me that perhaps the attitude should be taken that this ethyl gasoline is under suspicion and therefore should be withheld from public consumption until it is conclusively shown that it is not poisonous.

The CHAIRMAN. Any discussion of this clinical question?

Dr. JOSEPH C. AUB. Mr. Chairman, may I just say a word in regard to this question?

The CHAIRMAN. Yes.

DR. JOSEPH C. AUB
Medical School, Harvard University

I would like to say that I think that some who have to diagnose industrial hazards feel that the finding of lead in the stools constitutes lead poisoning, but anybody who is exposed to lead may have lead in the stools. That may mean only absorption, and it may mean poisoning; but it does not necessarily mean that lead found in the stools had been absorbed or that one can base a diagnosis of lead intoxication upon this finding alone. If that were so, everybody exposed to lead dusts would have lead poisoning, and many of them show no signs whatever of it.

The CHAIRMAN. Is there any further discussion on this aspect?

DR. ROBERT A. KEHOE
College of Medicine, Cincinnati, Ohio

Mr. Chairman, I have just one more word to say and then I have finished. I beg your indulgence in that matter.

One thing that has been seen in tetraethyl lead poisoning—and we have had occasion to observe it in every form in which it has occurred—is that in those cases in which absorption is present over a long period of time the symptoms do not differ strikingly from the symptoms in chronic lead poisoning except that up to the present the paralytic conditions have not been seen in any considerable number. However, it must be said that the lead line, stippling of the blood, that sort of effect, which is considered very good evidence of chronic lead poisoning in the human beings, appears in the tetraethyl lead poisoning. Such evidence has been found in the blood also in cases of more rapid poisoning, but in the case of slow poisoning—for example, in cases in which we have had any reason whatsoever to suspect that lead poisoning was occurring, or in which there have been any suggestive symptoms, or in the case of exposure over a considerable portion of time to minute quantities of lead—in all these cases we have been able to find stippling and in some few of them we have been able to find the lead line.

It would appear that the presence of a lead line in teeth is conditioned by a certain amount of inflammatory reaction in the gum margin. In a person of perfectly normal dental condition the lead line in the gums is not likely to appear, but stippling of the blood is much more likely to be present. In the case of the men examined we have made very careful blood examinations. The blood examinations have been made by myself, personally, and I can therefore say from my own observation that in the cases which have been examined which have had exposure to ethylized gasoline no

evidence even of this type has been found of poisoning in these cases.

The examinations made of men who have been exposed to any of these possible hazards must be made not on a basis of symptoms of tetraethyl lead poisoning but must be made on the basis of those symptoms, any one or all of which have ever been seen, which have been considered indicative of lead poisoning. Only by such a method of examination which we have made, or attempted to make, is it possible to determine whether any symptoms or any clinical signs have arisen.

May I say just one other word? I do not regard the data which we have presented on men examined up to the present as conclusive in any way. I should not like to be understood to say the examinations which have been made up to the present—the analytic work which has been done up to the present—are adequate. It only presents suggestive evidence which, in my opinion, should be carried further to a conclusive result.

The CHAIRMAN. Is there any further discussion of the clinical symptoms?

MR. FRANK A. HOWARD

Standard Oil Co. of New Jersey

If I may comment just a moment on Doctor Sayers's report here on page 6, section 9—"The guinea pigs exposed to motor benzol and a motor-gasoline blend died."

My reason for commenting on that is that in the oil industry we know only of one situation, one commercial situation, that has any parallel to the one we are now discussing; that, is, the use of benzol blends marketed as motor fuel.

In the city of Baltimore our own company's statistics show that in 1923, 70 per cent of the motor-gasoline consumption of that city was benzol blends. That was largely 40 to 50 per cent benzol blend, which is the type that Doctor Sayers was working with. Is that correct?

A VOICE. Fifty-fifty.

Mr. HOWARD. There was a statement also made in regard to benzol poisoning this morning that very much surprised me. Doctor Flinn, I thought, said that benzol vapor was poisonous but that the poisoning was not cumulative. I do not think he meant to say that. I think what he meant to say was that the benzol itself was not acumulated, because the poisoning certainly is cumulative. I think it produces a very dangerous condition of anemia. This has been recognized in the State of Massachusetts, and legislation has been enacted prohibiting its use in factories.

Now, we have just that one piece of evidence concerning the use of cumulative poisons in motor gasoline. We have a record of about 10 years of use, growing steadily up to proportions of 70 per cent in a city of the size of Baltimore, and to a lesser extent in other isolated spots throughout the country. On that point I think Doctor Shrader, who addressed the conference here, might tell us whether the condition in the use of benzol in Baltimore has shown any indication whatever of the development of a chronic condition of benzol poisoning.

The CHAIRMAN. Mr. Howard, may I ask, for my information, under what trade names is the benzol mostly sold?

Mr. HOWARD. It is mostly under the name of Lightning Motor Fuel, Betholene, Amoco Gas, and Standard Gasoline blended with benzol; I do not recall any others.

A VOICE. C–4 is another.

The CHAIRMAN. Thank you very much. Any further suggestions on this question? If not, we will hear from Doctor Shrader, of Baltimore, on the next subject.

Doctor SHRADER. We have not investigated it.

The CHAIRMAN. The public health aspect will be opened by Dr. Haven Emerson, professor of Columbia University.

DR. HAVEN EMERSON

Professor of Public Health, Columbia University, New York City

Mr. Chairman, members of the conference: It is, of course, recognized that until the laboratory and clinical findings have been reasonably conclusive and in agreement, administrative action is not justifiable. We must recognize that the object of public health administration is to get the maximum amount of protection with the minimum interference in private activities, but it would seem to me that in view of the public and private interests involved throughout the United States we might properly look to your office, to the United States Public Health Service, to prepare, after due consideration of all material facts, possibly presented to you by a committee appointed for this purpose, recommendations for administrative action by State and local health departments. A poor impression will be made upon the public and the industry if individual health officers throughout the United States rely upon their individual opinions or resort to political or publicity measures to get support for their administrative actions. It would be very conducive to effective and intelligent public health action in this matter if the health officers of the country were advised by you at some future time of a desirable policy. I feel that a policy of such importance can hardly be arrived at now or with the evidence pre-

sented to us to-day. At some future date we ought to expect the issuance of a statement from the United States Public Health Service not only with regard to possible Federal action but recommendations which should apply to those conditions appropriately dealt with under the police power of the respective States, either under their departments of industrial hygiene or under the departments of health.

I should think we must admit, after all that has been said, that we are in the face of a distinct industrial hazard, so far as production is concerned and, as others have indicated, one that is not at all beyond the scope of industrial ingenuity and technical skill to control. But I think it might be worth while to have it specifically admitted and included in the list of compensable diseases, in the laws of the different States, that poisoning by tetraethyl lead is a real hazard. The question has come up from time to time as to whether this is to be regarded as a lead hazard or as a new type of industrial poison. It seems to me that the producing companies concerned might with great advantage participate in advising the various industrial and health commissioners of the country to include this as a definitely proved industrial hazard so that workmen in the plants where this substance is made or used might get the benefit of the protection that is now given to those injured by certain other specified and listed lead products.

The proof of possible or demonstrable damage as offered by an animal experiment will never wholly satisfy health officers or physicians. But there remain to be carried out, as Doctor Edsall has suggested, and as have been attempted in a small way by Doctor Kehoe, very carefully controlled clinical tests of persons exposed to the ethyl-gasoline mixture as ordinarily used in garages or elsewhere.

It seems to me that the problem before us, the precise information on which a health officer would wish to predicate his individual action would be clinical observation of persons exposed to ethyl gasoline in the ordinary course of use. Since the use of ethyl gasoline has been discontinued for the time being it certainly ought to be possible to create practical experimental conditions which would indicate whether or not a substantial number of persons thus exposed developed evidence either of acute, temporary, or progressive chronic lead intoxication.

In connection with this I would like to comment upon the difficulty of clinically identifying the effects of ethyl lead poison. Health officers and physicians are faced everywhere with the great difficulty of getting the true etiological factor in the great variety of anemias and chronic diseases of the kidneys, damage to the brain, and interference with other functions possibly due to unrecognized chronic lead poisoning.

Our problem is not one of detecting acutely fatal conditions caused by exposure to the concentrated tetraethyl lead, but to distinguish between health and something a little less than good health. The notorious indifference of people to anything less than a striking disabling symptom is one of the problems of modern health administrators. People wait until they suffer an obvious illness or disability before they complain. It is the business of the health officer to see that people through medical observation become much more acutely sensitive to the slightest deteriorations in their health which are constantly being caused by a multitude of harmful conditions of environment among which lead in industry is a common cause of disability.

Up to the present time those who have reported upon the toxic results of tetraethyl lead have laid considerable emphasis on the occurrence of a number of deaths. I think health officers would agree, and certainly students of industrial hygiene would, that the number of deaths is not necessarily an index of the extent of the industrial hazard. We should like very much in this conference to know the number of days lost on account of disabilities which have been created among those who did not die. We should like to know whether those who have been subjected to acute poisoning by tetraethyl lead have ever resumed their former perfect physical fitness. In this our information is very incomplete. We have reason from other examples of lead poisoning to suspect that there is a considerable duration of deterioration in physique and in capacity for work and attention and self-control which follows any form of serious lead poisoning.

Unless we know the relation between the number of man-days of exposure and the duration of days of handicap from minor illnesses resulting from nonfatal poisoning, we shall not be in a position to measure the true importance of the hazard. Certainly the death rate is a very poor and incomplete indication, although a serious one, of the degree of any industrial hazard.

I presume that it is the inclination of every health officer to urge a continuance of the cessation of the use or sale of the ethyl gasoline which has been voluntarily determined upon by the company.

I should like to suggest and request—and this I say with due respect for the undoubted determination of the industries here represented to act as humane and considerate men—that in the future animal experimentation will precede and not follow human experimentation.

Up to the present time we have almost invariably got our first inkling of a new industrial chemical hazard by some human catastrophe. The technique of approaching any problem of possible toxic effect of a new substance is so well known to medical schools,

experimental laboratories, and government laboratories of various departments that it seems rather pitiable in a country of such wealth in means and knowledge that we had to wait for a series of human catastrophes to develop the demand for a series of animal experiments. Certainly in the future we could properly expect, either by common consent or by some form of governmental suggestion or direction, that no possibly dangerous new chemical substance should be put into retail use until proof of its harmlessness had been shown beyond doubt.

Such suggested control need not imply governmental interference with the liberty of process and discovery of chemical materials, but it seems inevitable that in some way or other there should be a clearing house for hazards, preferably at the expense of the Government, but if not at the expense of the Government, certainly by mutual agreement among the chemical industries generally, before retail distribution of a new product is carried out.

I believe that the Surgeon General would find it greatly to the advantage of his colleagues in State and municipal health work throughout the country to have as a result of such a conference as this the basis for recommendations following such a series of clinical studies as has already been suggested.

The CHAIRMAN. Dr. Henry Vaughan.

DR. HENRY F. VAUGHAN

President of the American Public Health Association

Mr. Chairman, as a health officer and as one of the few health administrators whom I see here in attendance to-day, I have been trying to assimilate and trying to arrive at some decision as to how a health commissioner might logically proceed in drawing some conclusions from the discussions which have taken place to-day, and my feeling is that the whole thing is more or less in a state of flux. I find myself wobbling in one direction at one time and in another direction the next moment.

As health administrators it is our prime function and duty to try to keep our respective communities as healthy as possible. In the city of Detroit, where I happen to be engaged as a health administrator, I am sorry to say that we have on an average one death each day from automobile accidents, approximately 300 to 350 each year, and yet there has been no legislation so far to do away with the automobiles.

Furthermore, we annually have a few people who close themselves up in the winter months in their garages, and in spite of the publicity which we have given to this subject insist upon choking themselves to death with carbon monoxide, and still we have not legislated

against the construction of garages; nor have we said that such people can not drive automobiles. It seems to be almost impossible to safeguard against all foolhardy accidents.

There are other things which have contributed to the lead hazard in large cities. With us we have had quite a hazard in the painting of automobile bodies which fortunately has been eliminated, and there has been a marked decrease in the incidence of lead poisoning in our city. I judge that this is true also in other automobile centers.

This question of whether there should be a prolonged discontinuation of the use of ethyl gasoline is not a matter that can be settled in any degree by the administrative health officer and one for which he would not assume prime responsibility at this time. It is rather a function of the physiologist and the physiological chemist to tell us from this mass of information which has been brought together to-day whether we may expect an accumulative health hazard. Certainly in a study of the statistics in our large cities there is nothing which would warrant a health commissioner in saying that you could not sell ethyl gasoline.

Now, you take our own city, for example: We have made a little survey there on ethyl gasoline. Ethyl gasoline has been sold in Detroit for approximately a year and a half, and the amount which has been consumed has averaged from 60,000 to 1,250,000 gallons a month. It was first used in October, 1923, and discontinued in May, 1925, and we have personally interviewed 170 individuals who have handled ethyl fluid and ethyl gasoline both, and who have averaged over 11 months of service in the handling of this fluid; men at the filling stations who have not only handled the complete mixture, the ethyl gasoline, but also the ethyl fluid.

In 139 instances the men handled the fluid and in 169 instances the ethyl gasoline. You can see, therefore, that most of the men had had experience with each type.

During the period of 11 months there were 9 out of the 170 who were sick at some time, and only 1 individual claimed as the cause of sickness the ethyl gasoline, and in further questioning concerning any ill effects from ethyl gasoline his reply was in the negative. So apparently his sickness was not connected at all with the use of ethyl gasoline.

Now, of these 170 individuals 137 had spilled ethyl fluid or ethyl gasoline on their clothing or on their bodies, or had had some of the material squirted into their faces or into their eyes. They had had the warning, they had been told that they must remove the ethyl fluid with gasoline and use a soap, but this warning had not been followed, and in practically all instances the material had simply been wiped off the clothing or off the skin. Out of the 137 claiming to have been exposed in this fashion only 16 felt any slight ill

effects at all—temporary burning and skin blotches, but nothing more serious.

Now, that is the situation as we found it in interviewing those who had handled ethyl fluid and also ethyl gasoline, and the results are entirely negative. As health administrators, you will readily see that in a report like that you would not be justified in stating that it is logical to discontinue the use of ethyl gasoline on those results alone. We must be guided entirely by the findings and the result and the dictum of those who can foresee whether there is toxic material or lead poisoning which may make itself felt in the future; but so far as the present situation is concerned, as a health administrator I feel that it is entirely negative.

I would certainly urge, as Doctor Emerson has, the continuation of these experiments, and I would also like to urge that the Surgeon General ultimately arrive at some decision which may act as a guide to the health commissioners and health officers throughout the country.

Now, Mr. Chairman, the American Public Health Association has seen fit to appoint a committee to represent the association at this conference, and Doctor Hayhurst, of Columbus, who is an active member of our section on industrial hygiene, is here, and I hope that you will permit Doctor Hayhurst to continue this discussion on behalf of the health administrators.

The CHAIRMAN. Doctor Hayhurst.

DR. E. R. HAYHURST

College of Medicine, Ohio State University, Columbus, Ohio

I have also been delegated by the State Department of Ohio to state our experiences with ethyl gasoline. The substance of the whole situation is summed up very much in this, that we have been undecided what to do because of the animal experimentations on the one side, in this place and that, and in the result of the reports of our health officers. We have had to get out, as the late President Burton, of Michigan, said in a story and root for ourselves. President Burton said that a man who decided to raise pigs scientifically put one in a pen on a balanced diet and it gained a hundred pounds in six months. Another one he put in a pen on a balanced diet and all the alfalfa it could eat and it gained 200 pounds in six months. Another he put in a similar pen, but he left a hole in the end of the pen. It got out in the yard and rooted for itself and gained 300 pounds in six months.

I am only going to talk about the rooting part of the investigations.

Last August when we were called to Dayton, Ohio, we made reports on conditions which had been investigated by the State de-

partment of industrial relations and by the State department of health. The reports on those investigations are on file. The distinct paragraphs of them have already been addressed to you in response to a communication from the Surgeon General asking us to summarize the material which we could prepare for the conference.

I will read simply the end paragraphs in the two reports, first that from the department of industrial relations:

In view of the fact that the hazard of contact and of inhalation no longer exists since this new equipment has been installed, it is the opinion of the writer that the chances of a recurrence are very remote.

This refers to the manufacturing laboratories.

From the physician's report from the State department of health I will read the the conclusion in its entirety:

Since the installation of the new filling and "blending" arrangement with the downward exhaust, no symptoms have been experienced by the workmen, whereas previously complaint of sleeplessness, headache, loss of weight and appetite were quite common among those employed in this process.

It is the opinion of the writer that: (1) As at present handled the hazard of the compound to workmen at the plant of the Research Corporation is slight; (2) the great dilution of the compound in fuel gasoline makes the danger to garage workers and auto repairmen practically negligible, and (3) although proof is not yet established it is very probable that there will be no appreciable detriment to the health of the public and of garage men because of the infinitesimal amount of lead which may be present in automobile exhaust.

Those were the reports on August 1, 1924.

Official certificates of occupational diseases for tetraethyl lead poisoning of 24 employees have been filed by Dr. Robert A. Kehoe of the General Motors Research Corporation (now the Ethyl Gasoline Corporation). Eighteen of these are concerned with the events of the year 1924. During 1925 the following number of cases have been reported by months: January, 1; February, 1; March, 1 (?) reported as "influenzalike infection" occurring during the epidemic of same and with mania, also recovery; April, 2; May, 1, reported as complicated with "gingivitis with abscess."

These cases, totaling 24 all told, had acute symptoms only. The severe or fatal cases which occurred in Dayton and in Bayway, N. J., are exactly similar to the cases reported in "Dangerous Trades," published by Sir Thomas Oliver in 1902. If anyone can distinguish the symptomatology from that which Sir Thomas Oliver gave at that time for acute lead poisoning going to the brain (lead encephalopathy), I must be convinced.

For instance, he states, on page 307 of that book published in 1902, that young women are especially susceptible, become pale, lose appetite, have a severe headache in the morning, falling in convulsions, with unconsciousness, coma, and death within two days, and he recites several cases of three days' duration which were

preceded by premonitory toxic hyteria (which he marks in italics), followed with blindness, convulsions, coma, and death in three to four days. Acute mania is also emphasized, usually followed by death or incomplete recovery, and then (I quote) "the individual passes the remainder of his or her days in an asylum." In a total of 133 cases of lead insanity 33 cases of mania are recorded. (Dangerous Trades, p. 308.)

On page 45 of the Ohio "Survey of Industrial Health Hazards and Occupational Diseases," published in 1915, there is shown a case, recorded in 1914, with a full-page picture of a man suffering from acute lead encephalitis, with mania, who had to be strapped to his bed. This was in the Cincinnati General Hospital.

I want to emphasize the point, therefore, that in my opinion, the symptomatology of the recent cases associated with tetraethyl lead is nothing new. It is the usual, clear-cut set of symptoms of lead poisoning involving the brain.

It is also pointed out in the literature that this type of poisoning, lead encephalitis, is most apt to occur in cases using lead in the form of dust.

I would say, in reference to the point made by Doctor Emerson, that all of our cases of lead poisoning are compensated in Ohio, irrespective of the form of lead, provided it is industrial in origin. These cases of the Ethyl Gasoline Corporation have been compensated; i. e., all who have filed claims. There has been no question about them.

In regard to data relating to public health hazards in the use of tetraethyl lead compounds and gasoline, under date of May 9 and May 12, we sent out the following request to our health departments of the cities listed:

> In view of a possible alleged hazard to the public or to the filling station and garage employees from the use of ethyl gasoline, we desire to ask whether you have received any information, direct or hearsay, pointing to mishap or ill health among the citizens of your community.

I have arranged the following list of cities in alphabetical order. The health commissioners of these cities (most of them full-time men) have been known to us in health work and associations for many years: Akron, Cincinnati, Cleveland, Dayton, Hamilton, Middletown, Sydney, Piqua, Springfield, St. Marys, Toledo, Youngstown, and Zanesville. Up to date all but two had been heard from (Middletown and St. Marys). The cities heard from represent over 2,000,000 of the 6,000,000 population of the State of Ohio and represent, of course, the most densely concentrated aggregations of population as well as the filling stations and sales places of ethyl gasoline in those cities.

I have these replies all here, but allow me to summarize in a single statement:

"All of these replies (that is, 11 out of the 13 received) are unanimous in stating that no mishaps or ill health resulting from the use of ethyl gasoline have occurred. Three commissioners—those of Cincinnati, Dr. William H. Peters; of Dayton, Dr. A. O. Peters; and of Cleveland, Dr. R. L. Rockwood—state that they have made special investigations and given the subject considerable attention and have come to the conclusion that there are no facts concerning the handling of this product or its distribution that would justify prohibiting the sale of the product in their cities" (or words to this effect, since I am quoting the composite statements of these three men).

I shall be pleased to read these replies. I have them here.

It should be added that the State department of health gave considerable publicity to this question, beginning November 1, 1924, following the report of mishaps at the Standard Oil Co. at Bayway, N. J., last October, and proclaimed that no steps would be taken to prevent the sale of ethyl gas in Ohio, as no evidence had been received that it was dangerous to the public or to garage men and others except those concerned in its manufacture, where apparently successful methods of control have been worked out.

Since that date we have asked a number of health commissioners and others to watch the situation continually and inform us of any evidence of danger. It was a subject of limited discussion at the annual conference of health commissioners of Ohio held in Columbus in November, 1924. The public has also been kept informed of the possible hazard through the press, including copies of press statements from New York and elsewhere.

To date no unfavorable reports, official, unofficial or hearsay, have been received at the State department of health.

To verify certain points concerning the time and circumstance of placing a possibly dangerous substance upon the market for sale in Ohio to the public without proper admonitions, we sent a questionnaire to the Ethyl Gasoline Corporation on November 21, 1924, and received reply November 25, 1924, from Mr. Thomas Midgley, jr., vice president and general manager of the corporation, stating that the sale and distribution of tetraethyl gasoline was first begun on February 1, 1923. That was at a filling station in Dayton, which was the first city in the United States where it was publicly sold. This was after the research staff of the General Motors Research Corporation had recognized and investigated its acute and chronic toxic nature for a considerable period prior to February 1, 1923; that the corporation also devised a proper set of instructions

for the safe handling of ethyl fluid and ethyl gasoline at filling stations, which instructions were first worked out by one of their own men at the filling station where it was first dispensed. Furthermore, after they had satisfied themselves of the absence of apparent danger to the public, these acute cases appeared. They were especially concerned in their preliminary investigations with the chronic and cumulative forms of lead poisoning which apparently failed to occur. It was then that this matter was taken up with the Government for investigation and our health departments began to hear about it and worry about it.

To my mind it is, of course, possible that none of the public or filling station employees, etc., has as yet been exposed over a sufficient length of time to show the effects of possibly slow accumulation of lead from this source, if such hazard exists. Still a period of over two and one-fourth years, including the nation-wide publicity of the past several months should have sufficed to bring out some mishaps and poisonings suspected to have been caused by tetraethyl lead, especially in susceptible persons, because idiosyncrasy to lead poisoning, even in minute doses, is rather common and also well discussed in the literature of the subject.

I think there is one thing about the animal experimental data which is not comparable to the public health situation. These experiments are all done in closed chambers. The public are not breathing exhaust gases under such conditions. They may be down in streets lined with tall buildings, but they are not in closed chambers retaining the poisonous products.

The CHAIRMAN. I see Doctor Nicoll, of the Health Department of the State of New York. Doctor Nicoll.

DR. M. NICOLL, JR.

Commissioner of Health, New York State Health Department, Albany, N. Y.

Mr. Chairman, I wish to urge that you be made the court of last appeal to consider the evidence that has already been presented and to collect further evidence which is apparently very necessary in order to arrive at a conclusion as to whether the use of tetraethyl lead is a public health hazard or not and advise the officers of the various States as to your conclusions. We should not expect you, sir, to arrive at a conclusion in the very near future. You should have time. Being a health official, I know that you have not any money available to do this work yourself, but you can call upon the other branches of government, private agencies, and university laboratories to render assistance.

Take the situation in the State of New York. The public health council of the State three or four months ago, as a result of all the

evidence that could be obtained at that time, forbade the use of the concentrated preparation, but did not prohibit the use of the diluted form under certain definite restrictions as to sale and distribution.

The city of New York, over which I have not jurisdiction, prohibited the use of any form of ethyl lead. In other words, a man filling his gas tank at Buffalo or Syracuse with this preparation and going down to New York City would be amenable to the rules of the Board of Health of the City of New York and be punishable by the city authorities.

Many city and State boards of health are in a quandary as to what action, if any, to take in this matter, or are in doubt as to the wisdom of action already taken. For this reason, whether you as Surgeon General of the Public Health Service have legal authority or not, I am very certain that your opinion, arrived at after careful investigation of all the facts, will be accepted by the majority of health officials.

Finally may I suggest that this matter be brought up at the coming conference between the United States Public Health Service and the State boards of health.

The CHAIRMAN. Doctor Nicoll spoke as nicely as though he were giving me a box of candy.

Is there any further discussion?

MRS. GRACE M. BURNHAM

Director Workers' Health Bureau

Mr. Chairman, I have looked over the program, and I do not exactly see where the Workers' Health Bureau comes in—either entirely under the heading of "Industrial aspects" or entirely under "Public health aspects"—so I have chosen to wait until the Public Health speakers have spoken.

The CHAIRMAN. It comes under the second heading.

Mrs. BURNHAM. The Workers' Health Bureau is interested in studying occupational diseases as they affect various groups of industrial workers and in working out programs of health control for those groups.

We are interested in the problem of tetraethyl lead and tetraethyl-lead gasoline in its different stages.

In the first place, we are interested in the factory production stages. In looking over the material which has been made public on the subject during the past six months we were interested in finding that there is no authoritative list of actual deaths and occupational-disease records which anyone can have recourse to. That is, no governmental agency has compiled from the data which have ap-

peared in individual reports or in the newspapers any authoritative lists of deaths or disease.

In cooperating in preparing the article on tetraethyl lead which appeared in the Medical Journal May 16 we had some doubt about the 60 cases of poisoning and 11 deaths which we enumerated. Yet this morning, after having heard the speakers from the various plants, I have added up 149 cases of poisoning; 43 at Bayway—or 48, as one gentleman says, including 5 deaths—28 at the du Pont plant up to May 16, 1924, after which we have no record; and 78 at the General Motor Co. plant up to date. That makes a total of 149 that we know of already.

Now, it seems that one of the immediate things to ask would be for the United States Public Health Service to get the medical records of these men that have been examined and compile them. We have heard reports here that men have been given medical examinations and have shown no symptoms, and then we have heard other reports stating that they did show certain symptoms.

If we knew the symptoms that the men did show, we could go over the number of cases and arrive at certain definite conclusions that would be authoritative. My suggestion is that the United States Public Health Service have made available to them immediately the medical records of all the men examined in all the plants where tetraethyl lead has been either manufactured or compounded or handled, and that from those records a statement be made as to the actual number of deaths and poisonings, showing also how long the men have been employed before they died or were poisoned.

I agree with the suggestion already made here that we also find out what happened to the men after they had been poisoned, and what happened to them after they had been laid off or discharged, whether they were reemployed in other industries, or whether they were permanently injured as a result of what occurred.

I was very much interested in looking over Commissioner McBride's report last fall, after the Bayway tragedy, to notice the seriousness with which the men who were responsible for the poisonings from tetraethyl lead regarded the situation.

Commissioner McBride said that there were certain precautions which had been taken to protect the workers.

Commissioner McBride made the statement that at the Standard Oil Co. plant "in many instances a medical examination was required twice a day" and that in the du Pont plant "a man would forfeit a full day's pay if he did not bathe every day." It seems to me that where a material handled is so poisonous that as a precaution a medical examination of the men employed is required as often as twice a day, we are faced with a very serious situation.

Somebody has suggested—I think it was Doctor Edsall—that in manufacturing poisonous material we can rely on control, and that if the risk or danger in tetraethyl lead applied only to its manufacture, it might not require prohibition.

We have reports from England that after 14 men died from the use of tetrachlorethane in airplane dopes the use of tetrachlorethane dopes was prohibited.

Representing the workers who must work, and who must take such conditions in their work as are offered to them, and considering that 11 men engaged in the manufacture of tetraethyl lead have already died in spite of medical examinations twice a day, we are confronted with a serious hazard in the manufacturing processes alone which calls for drastic action.

The next question which came up in the discussion to-day was the question about handlers of either ethyl fluid or ethyl gasoline.

It has been reported by the concerns in question that 20,000 filling stations are using ethyl gasoline, and have used it for a period of two years. And yet I have heard a report of only 30 medical examinations out of all the men in the country handling tetraethyl gasoline. I doubt whether the report of 30 examinations out of a total of 30,000 or probably 50,000 men using this material is significant.

I also want to call attention to the remarks that Doctor Kehoe made when he said that "the recognition of early symptoms is by no means easy"; and that the workers only occasionally show early signs of poisoning.

We who are working in industry know that the average worker is not an industrial diagnostician. We do not want the worker to be a diagnostician, because if he is he may diagnose his case wrongfully. We also know, we workers, that the average physician is not familiar with the signs of occupational diseases. He has to be educated to that. He does not know the group of symptoms which make up tetraethyl lead poisoning. You take constipation, or you take decreased red corpuscles, or you take pallor, or you take a low blood pressure—you take all those things and put them together; and an expert in occupational diseases may recognize them as an incipient occupational disease; but the ordinary medical practitioner and the ordinary worker would not recognize such a condition as an occupational disease, or if he did recognize it, you would call him pathological.

The point I want to bring out is this: That you can not rely on negative evidence in a hazard which goes the length and breadth of the country, and which may affect, in industry alone, almost a million workers.

I have figures from the United States Census Bureau for 1920, which show that there are 280,000 chauffeurs; 31,000 garage laborers;

411,000 draymen and expressmen; and, taking the Ethyl Gasoline Corporation's figures, at least 40,000 service-station operators, which totals up to about 767,000 workers who would be directly affected—not counting those engaged in the manufacture of tetraethyl lead.

Now, I believe that we should separate out from the public health hazard the hazard to teamsters and chauffeurs and traffic "cops," if you will, all those who work for 8 hours a day or 12 hours a day in an occupation which exposes them constantly to exhaust gases in stations and on crowded thoroughfares and traffic jams, so that they will get more than their proportion of any poisonous materials which come out in exhaust gases.

And I agree with Doctor Edsall that, until a thorough examination has been made of a representative group of workers exposed to the exhaust gases contained in tetraethyl lead gasoline, over a period of time sufficient for them to absorb this material, with the necessary tests of feces and urine, to determine whether there has been any lead absorption—until such examinations as those have been made, we are not justified in saying that there has been no poisoning just because the workers themselves have not reported symptoms of mild poisoning.

And finally, we have the case of the public—the public health hazard, which has been discussed in a very satisfactory manner by Doctor Henderson and Doctor Edsall and Doctor Emerson, who stated that, in addition to the risks which so many of our workers in industry (who are also part of the public) already have to undergo from lead, you are adding daily the possibility of a tetraethyl lead risk which will ultimately bring the lead beyond the stage where it can be resisted.

I believe that the Public Health Service is the agency through which a thorough scientific investigation of this entire matter should be carried out. I believe that this investigation should be made entirely out of public funds; and I think that the United States should be self-respecting enough to realize that, when there is a public health hazard involved which affects the entire population, that hazard ought to be investigated out of public funds and by a responsible public agency.

I believe that after such an investigation is made, another conference should be called, which should be a public conference, and at which labor should be represented, to which this report should be made. And I believe that until that time, and until the manufacture, distribution, and use of tetraethyl lead has been proved conclusively to be safe, its use should be discontinued.

The CHAIRMAN. I think you are estimating the chauffeurs very low. I think there are about 50,000 of us who do our own driving here in Washington.

Mrs. BURNHAM. Well, we always believe in underexaggerating.

The CHAIRMAN. I will ask Mr. Berres, secretary of the metal trades department of the American Federation of Labor, to address the conference.

MR. A. L. BERRES

Secretary, Metal Trades Department, American Federation of Labor.

Mr. Chairman, I want to express to you the appreciation of the American Federation of Labor for the invitation to be present. This discussion here has been very interesting to me, because there have been so many things said that I did not understand.

I do want to say, however, without having had an opportunity to look into this matter carefully, that there has been enough said here to-day to warrant those having authority to do something at least in the shape of vaccinating this patient now under suspicion.

I feel that, as has been stated here by some of the previous speakers, until such time as it can be definitely determined that there is no hazard in the manufacture and handling of this gas, its use ought to be prohibited.

I appreciate what it means to take the "knock" out of a motor. But we are more concerned about taking and keeping the knock out of the human being than we are in taking the knock out of motors.

From that point of view, Mr. Chairman, the American Federation of Labor would attack the use of this gas. We feel that where the health and general welfare of humanity is concerned, we ought to step slowly.

I want to take advantage of this time to say that, notwithstanding that we are often charged with being against progress and efficiency, that is not true. We are against any progress and efficiency that carries with it serious injury to the human family.

If we can get progress—and we can, because I have no doubt that some of the gentlemen here are thoroughly capable of finding a method by which this gas can be used without injury to those handling it—we welcome progress if it does not mean injury to the human being.

With those thoughts in mind, I wish to express the hope (and I believe I voice the sentiment of many of those who are here) that this gas will not be used until a thorough and comprehensive investigation and study is made as to just what does happen to those directly engaged in the manufacture and handling of tetraethyl lead and tetraethyl-lead gasoline, and in fact to the general public.

I have often found myself in traffic jams—and while I do not know anything about chemical action, I have felt that something would have to be done in order to do away with the bad effect of monoxide gas in the public automobile jams.

The only thing we wish to say at this time, Mr. Chairman, not having had opportunity to study this subject, is to urge that, until a comprehesive study can be made to determine whether or not this gas in injurious, its use be prohibited.

I would like to suggest to those present at this meeting that, inasmuch as certain gentlemen have, I believe, on a former occasion agreed not to use this gas pending a study of it, that we jointly request them not to use this gas until we can determine whether or not it is injurious to those who must come in contact with it.

The CHAIRMAN. Is there any further discussion?

DR. YANDELL HENDERSON

Professor of Physiology, Yale University

There is a technical point on which I think I can throw a little light, by analogy.

Doctor Hayhurst referred to a number of reports from practicing physicians regarding the health conditions in Ohio.

Now, I feel fairly sure of what I am going to say, and that is this: That not one good practicing physician in a thousand would recognize a slight degree of tetraethyl lead poisoning when the lead is inhaled. If he had a good medical education and if he knew the man had a stomach ache and certain other symtoms of lead poisoning, he could size it up as lead poisoning. But if the material is inhaled—and its symtomology is altered when it is inhaled, because of its wider distribution in the body—it is extremely likely that nine hundred and ninety-nine ordinary physicians out of a thousand would fail to recognize the condition as lead poisoning.

I base that assertion upon observations which I have made in the town of Danbury, Conn. Probably everybody has heard of the "Danbury Hatters," and the cases of mercury poisoning there. That is a fairly close analogy. That has been going on for a long time. Some of us have been trying to find out some way of improving the situation.

The difficulty has been that, even when a man's condition was so bad, and his hands were shaking so terribly that he could not reach out and take a glass of water and put it to his mouth, the ordinary physician could not recognize that as mercury poisoning. And what we have had to do was to get physicians who can diagnose it and recognize it; and now that they have physicians who can recognize it and know that it is mercury poisoning, and who will so testify before the compensation commissioner, the compensation commissioner can award compensation; and the insurance company has to pay the money; and it comes back on the manufacturer, and con-

ditions are improving. So we believe that we are cleaning up that situation.

But the first thing we had to do was to realize that the general run of physicians did not recognize that form of poisoning when they saw it. And so I think it is fairly clear that we can not expect the ordinary practicing physician to recognize the symptoms of tetraethyl lead poisoning at this time.

For that reason, it is very important that the medical data with regard to these occupational diseases should be collected, and that the medical profession should be educated, through the United States Public Health Service, so that the medical profession can diagnose lead poisoning in all its forms and manifestations.

I would suggest, Mr. Chairman, that you ask Doctor Hamilton to address the conference upon this subject.

The CHAIRMAN. Doctor Hamilton and I have had conferences, both here and abroad, and I know that she always has something worth while to say; and in regard to this particular subject of tetraethyl lead poisoning I think she can tell us something about her observations. I wish she would say something to help us on this problem.

DR. ALICE HAMILTON

Professor of Industrial Medicine, Harvard University

Mr. Chairman, I do not think I have anything at all of value that I can add to what has been said. I would only like to emphasize one or two points that have been brought out.

One is the fact that lead is a slow and cumulative poison and that it does not usually produce striking symptoms that are easily recognized.

The other is that if (as does seem to have been shown) this is a probable danger, shall we not say that it is going to be an extremely widespread one, an extraordinarily widespread one?

Now, as Doctor Edsall has said, you may control conditions within a factory. But how are you going to control the whole country?

Speaking for myself, I do not know of any lead trade which (although it has been improved under modern methods and scrupulous care) has been made entirely safe. There may be one. I do not know of any, however. There is always some lead poisoning in connection with every lead trade, even when it is done in a factory under medical supervision and with a very conscientious employer.

If we were to assume that all of the precautions would be taken with this new form of lead that could be taken, it would mean eternal vigilance—and we all know the American temperament too

well to believe that that eternal vigilance will be kept up all over the country.

I would like to make a plea to the chemists to find something else, and I am utterly unwilling to believe that the only substance which can be used to take the knock out of a gasoline engine is tetraethyl lead.

May I draw a comparison by showing what happened in England when they faced a very much more serious emergency than we are facing here?

We all know that in 1916, England had every reason to ignore minor dangers in her effort to produce fighting planes. Well she was covering her fighting planes with a tetrachlorethane dope.

Now, that poison caused a toxic jaundice, and sometimes a fatal form, among the dopers. But how many cases were there? Only about 92; and only 12 of them died. And yet every time there was a death, a question was asked in Parliament, and the ministry of munitions had to answer that they had put their chemists to work; and that they hoped very soon that they could announce that they had found a substitute for tetrachlorethane; and in 1917, when England was frightfully hard pressed for fighting planes, they made the announcement, after only 12 deaths had occurred, that they had found a substitute; and that from that time on no tetrachlorethane solvent would be used in connection with any fighting plane in England.

Now, we can not say that we in the United States are up against any emergency like that. And yet we have already equalled that death rate.

If the English Government could consider such sickness and death as serious even in war times and if the British chemists could find a substitute, I think it is not unreasonable to ask that our chemists set about it to do away with tetraethyl lead, by finding something else that will do the same work.

The CHAIRMAN. I notice a gentleman here who has been an industrial officer of a great State for a good many years. I will ask Doctor Patterson to address the meeting.

DR. FRANCIS P. PATTERSON

Philadelphia, Pa.

Mr. Chairman, for a period of 18 years—first of all, as an industrial physician and then as the head of the department of industrial hygiene for the State of Pennsylvania—I have come very intimately in touch with the problem of lead.

And when we strip the various chemical terms that we have used here of their verbiage and analyze them, we find after all that this tetraethyl lead is just a question of lead itself.

Now, I am sure that we all here know that lead is an industrial poison. I do not think anybody will be so foolish as to claim that it is anything else. I am sure that we all appreciate that, so far as the manufacture of tetraethyl lead, carbonate of lead, or any other form of lead are concerned, it is a matter for the individual States to regulate. The individual States have the power to regulate how tetraethyl-lead gasoline shall be distributed in garages; how it shall be handled in filling stations and other places where you get gasoline. There is in the last analysis only the problem of one more lead trade to consider.

Now, Doctor Hamilton will bear me out when I say that lead is in wider use than all other industrial poisons. And it seems to me that the amount of lead which goes into the making of tetraethyl lead in the manufacture of gasoline is a very negligible factor compared with the world-wide use of lead in the various industrial processes of to-day.

I am quite sure that if any group of people come together and say, "You must find a substitute for the lead storage battery; it is a terrible thing; it is an industrial poison; you must absolutely do away with it all over the world"; or if they should say, "You must do away with lead paint, because painters will paint houses and they will take a chew of tobacco while they are working, and they will take a chew of tobacco when their hand is covered with lead paint, and they will put their hands in their mouth and swallow a certain amount of the paint"; or if they should say, "People will turn on the illuminating gas and commit suicide, and therefore you must stop the manufacture of it"—I am quite sure that, in view of the fact that you have a wide distribution of all these various poisons, if you do away with one of them you should do away with all of them.

It seems to me that the way to approach the question of the addition of one new lead trade to the many hundreds of lead trades that are now in existence, is to look at it from the standpoint of common sense and not to be stampeded.

And I am convinced that with modern methods of street flushing that are certainly used in all our large cities, that this vast accumulation of lead that we have heard about will be destroyed; we have heard about the vast accumulation of lead between Twenty-third Street and Central Park in New York City; and that will probably be flushed down into the gutters, and into the sewers, and will form a very suitable deposit in the bottom of the Hudson River and the East River.

I am also perfectly sure that no corporation which is engaged in the manufacture of any compound of lead is anything but deeply conscious of the risk that it is taking in having it handled by its

employees; and is going to take every precaution possible for the purpose of protecting these employees from the hazard of their occupation.

I believe that if somebody should say that we should wipe out every one of these lead trades today, there would be almost an uproar. It seems to me that the sensible thing to do is to approach this entire question by applying to it the test of experience that we have gained in the handling of other lead compounds; and I am quite sure that if that is done the time will arrive in which you will find a method in which tetraethyl lead can be used quite as safely as the storage batteries are used to-day.

The CHAIRMAN. We will be glad to hear from Mr. Wolman.

Mr. WOLMAN. I am here entirely as an observer, Mr. Chairman, and have attempted to follow, more or less intelligently, many of the things that have been going on. And I will gladly report what is said and done here to the State and provincial health officers.

The CHAIRMAN. Is there anybody else who would like to address the meeting?

Doctor HAYHURST. Mr. Chairman, may I just add a word in regard to our analyses in Ohio?

They were not made by ordinary practicing physicians. They were made by order of the health commissioners of the various cities and by use of their regular personnel, i. e., full-time men, especially in the larger cities. They were not made by questionnaires but by methods very similar to those by which the investigation was made in the city of Detroit, where all of the filling-station men, and in our case, many of the garage men were covered.

Doctor Rockwood, for instance, was himself for two years with our State Survey of Industrial Health Hazards and Occupational Diseases. He reports very briefly, as he always does in his correspondence, and says (under date of May 11, 1925), "Our investigations have been negative in this matter, although we have given it considerable attention."

This is for the city of Cleveland. Now, to me, that statement of Doctor Rockwood's covers a good deal.

In the city of Cincinnati, Doctor Peters says (under date of May 12, 1925):

> Some little time ago, at the time when this matter first came up in New York City, we made an inspection in every filling station in the city of Cincinnati, interviewing the employees. In no case did we find any employee knowing of any case of ill health attributable to tetraethyl lead gas. We have had no case in this city coming to our notice, even from hearsay sources, since that time.

THE CHAIRMAN: Commander Wilson, of the Navy, I hope, will have something to say to us.

COMMANDER E. E. WILSON
Bureau of Aeronautics, Navy Department

Mr. Chairman, I regret that I have not been here all day, and I may discuss something that has already been discussed by the conference.

The question of tetraethyl lead and the use of ethyl gas as fuel for the engine in aeronautics is one that is very important, and one that will be increasingly important as the quality of motor gasoline falls off.

In the aircraft engine, of course, the question of power is everything, and the question of fuel economy is everything, because the weight per horsepower of the engine and the weight of the fuel required for a given range is reflected back in the weight of the structure.

During the last two years we have been very much interested in the development of fuels for high power. We have tested "doped" fuels and have been at work in the development of special fuels of high nonknock value.

Among these special fuels we have tried two which were manufactured from crude oil by special processes differing from that of straight gasoline. These have been used in the service, and the reaction of the personnel to these fuels was very unfavorable. The odor was very bad. The toxic qualities were supposed to be very bad, and the net result was that we had to withdraw those fuels from the service.

On the other hand, we have used large quantities of tetraethyl lead with complete success, and so far we have had no reports of any difficulties.

Last year we ran some 10 endurance flights during which we used 750 gallons of ethyl gasoline per flight. This was "doped" by the men themselves. The gasoline was doped to three or four times the normal strength for commercial gasoline. There were no reports of any difficulties at all on that, although the men knew that a certain amount of danger was to be encountered.

Two weeks ago I made a 10-hour nonstop flight, in which we used tetraethyl lead in aviation gasoline, and during the 10-hour flight we were leaning over the fuselage with the exhaust gases coming over our faces. We felt no bad effects.

After that flight I was physically examined very carefully, and the medical report was that the doctor hoped that I was not as uninteresting in every way as I was pathologically.

This particular nonknock fuel, aviation gasoline with tetraethyl lead, is the only satisfactory fuel that we have at the present time.

I understand that in Great Britain, where they have been able to obtain high test gasoline from Sumatra, and can, therefore, get a higher-test gasoline than we can, they have not been forced into the use of such nonknock fluid. Lately, however, the supply has fallen off and they have become very anxious to get ethyl fluid.

After thorough investigation we are convinced that no danger can result from this fuel in aircraft, and that the hazard is so small as compared with the hazard from fire or crashes that wherever it is indicated we hope to be able to continue to use it.

It is of particular advantage on distant service, where we can not get the high-quality gasoline that we need, and we can get this tetraethyl lead fuel.

Therefore, as the result of considerable investigation, I feel that there is no difficulty whatever in using this fluid in aircraft. It is of great military importance that nothing be done to preclude our getting it, and we hope that a way will be found to render it possible for us to obtain this fuel in quantities from time to time.

The CHAIRMAN. Commander Wilson, may I ask whether your men are under medical supervision all the time?

Commander WILSON. Only general medical supervision. We warn them against the fluid; and whereas they were very chary about using these other gasolines that smell so bad, they had no hesitancy at all about spilling this tetraethyl lead, or ethyl gasoline, on themselves; and we even had difficulty in making them wash themselves off with soap after using it.

As a general thing, the operating personnel using a fluid of that kind would object immediately if they thought it dangerous.

Because of the publicity that has been given to the dangers of tetraethyl lead we thought that we might get some objection from the men to its use, but up to date no bluejacket has objected to using it.

The CHAIRMAN. Thank you very much for your statement, Commander Wilson.

Colonel Vedder, have you anything further to tell us? And may I ask for information whether you are still conducting your experiments?

Colonel VEDDER. We are not.

The CHAIRMAN. Doctor Hektoen represents the Academy of Sciences. I notice he is there at the door. Have you anything to tell us, Doctor Hektoen?

Doctor HEKTOEN. No, Mr. Chairman.

The CHAIRMAN. Doctor Hammer represents the Institute of Commercial Engineers.

Doctor HAMMER. Mr. Chairman, I have no experimental data to offer. I am not a physiological chemist, but, of course, I am very

much interested in the statements made here. I am sure some of them were only due to misinformation on the part of certain speakers who did not appreciate how seriously the chemists as a whole viewed the situation, and what very serious effort has been made from the start to find other things; or how completely the whole hazard has been reviewed by them and the responsibilities considered; or the extent of cooperation to which chemists are quite prepared to go to get out anything that is better.

Some reference has been made to an experience during the war at one of the arsenals that I do not think was quite the kind of experience that it was said to be; but I do not think it is proper to enter into that kind of discussion at the present time.

I am sure the American Chemical Society and the American Society of Chemical Engineers will be very glad to assist in any way in meeting the problems growing out of the use of tetraethyl lead.

The CHAIRMAN. Doctor Thompson represents the Bureau of Standards. Would you care to say anything, Doctor Thompson?

Doctor THOMPSON. I do not believe I have anything special to say.

There is just one thought, however, that I would like to submit. I think the idea of the commissioner for the State of Pennsylvania ought to be emphasized, and that is that in looking at the question of the adoption or nonadoption of any additional lead industrial risks we should look at the problem in the large, rather than be swayed by prejudice. It is often much easier to see the concrete immediate dangers than to evaluate the perhaps more important industrial advantages. We do not like to match the life of a man against the life of a Nation.

Nevertheless, there are things to be considered on both sides; and I believe there should be a thorough investigation of the whole subject by the United States Public Health Service, which should bring out both sides of the question.

The CHAIRMAN. Is Doctor Gruse, of Pittsburgh, here? We want to get all the light on this subject we can.

Doctor GRUSE. I am here simply as an observer. I have nothing to say.

The CHAIRMAN. Is Miss Whitney, of the Bureau of Labor Statistics here?

Miss WHITNEY. I do not have anything to say, Mr. Chairman.

The CHAIRMAN. Is Doctor Corbin, of the New York Academy of Medicine, here?

Doctor CORBIN. Mr. Chairman, I have nothing to contribute to this discussion.

The public health committee of the New York Academy of Medicine has been very much interested in this subject, which we have studied purely from a chemical point of view. I can only add that,

if an investigation is made on a somewhat larger scale, I am sure the public health committee of the New York Academy of Medicine will be very glad to contribute its share to the scientific investigation of this product.

The CHAIRMAN. Thank you very much. Doctor Marshall, have you anything to suggest to the conference?

Doctor MARSHALL. I have nothing particular to add to the discussion. I have had no experience at all with the subject. It seems to me that the impression I have got from listening to the evidence presented is that there would be certain hazards from the use of this substance which would seem to involve the garage workers; that there is an amount of dust which is deposited in the chamber through which the air is rapidly circulating; and assuming that the same proportionate amount would be caused in the garage, it seems to me that in the garage there is a very distinct hazard attached to it.

As to the other aspects of the question, it seems to me that Doctor Edsall has very well summed them up: There is a hazard there, but how great a hazard we do not know yet.

The CHAIRMAN. Thank you, Doctor.

I see the National Safety Council is represented. Doctor Cameron, have you anything to suggest?

Doctor CAMERON. No; I am just here representing them.

The CHAIRMAN. Is there anybody else now before we close the hearing? Mr. Howard, of the Ethyl Gasoline Corporation.

MR. FRANK A. HOWARD

Representing Ethyl Gasoline Corporation

My associates of the Ethyl Gasoline Corporation, which includes the General Motors Corporation and the Standard Oil Co. (N. J.), and, in an indirect way, the du Pont Co., have asked me to make a brief statement concerning the position of our company regarding this meeting and the problem which you have to attack here.

I think Doctor Henderson correctly stated that we have a real responsibility. How great that is I do not think any of you gentlemen will ever be able to appreciate, because it has been so manysided.

Relatively speaking, the responsibility of Doctor Henderson, and of you gentlemen of the Public Health Service, is rather simple; that is, you have but one problem, and that is, Is this a public-health hazard? Unfortunately, our problem is not that simple. We can not quite act on a remote probability. We are engaged in the General Motors Corporation in the manufacture of automobiles, and in the Standard Oil Co. in the manufacture and refining of oil. On these things our present industrial civilization is supposed to depend.

I might refer to the comment made at the end of the war—that the Allies floated to victory on a sea of oil—which is probably true. Our continued development of motor fuels is essential in our civilization. And our dependence upon a continuing supply of petroleum has been a subject which interests everyone who has the interest of his country at heart. The President has gone so far in the past few months as to appoint a special committee, presided over by Doctor Work, to see if they could not exhaust all the possibilities of conserving petroleum in every direction.

Now, as a result of some 10 years' research on the part of the General Motors Corporation and 5 years' research by the Standard Oil Co., or a little bit more, we have this apparent gift of God—of 3 cubic centimeters of tetraethyl lead—which can be produced at a low figure, an inconsequential figure ultimately, and which will permit that gallon of gasoline, which we have recovered from the earth all over the world, because we import much of our supply and hope that we will import more in the future so that we will use less of our own supply, to go perhaps 50 per cent further, and, if our optimistic engineering friends are correct will make it go 100 per cent further in the long run.

Now, there is that situation. We are presented with that gift of God which enables us to do that. But there are problems connected with it; the engineering problem must be worked out, and the production of cars must be worked out.

And we are presented with this question at the start concerning the use of tetraethyl lead, the question of the health hazard. What is our duty under the circumstances? Should we throw this thing aside? Should we say, "No; we will not use it," in spite of the efforts of the Government and the General Motors Corporation and the Standard Oil Co. toward developing this very thing, which is a certain means of saving petroleum? Because some animals die and some do not die in some experiments, shall we give this thing up entirely?

Frankly, it is a problem that we do not know how to meet. We can not justify ourselves in our consciences if we abandon the thing. I think it would be an unheard-of blunder if we should abandon a thing of this kind merely because of our fears. We could not justify an attitude of that kind; I do not think anybody could. Possibilities can not be allowed to influence us to such an extent as that in this matter. It must be not fears but facts that we must be guided by. I do not think we are justified in trying to reach a final conclusion in this matter on fears at all; nor are we justified in saying that we will cease this development because of fears we entertain. This develoment must be stopped, if it is stopped at all, by proofs of the facts.

Now, on that point, I think this conferenec has had a wonderful effect. We have had presentations of facts on both sides.

But I must say—perhaps I am a little biased—that most of the facts presented have been in favor of the use of the tetraethyl lead product. Perhaps some of those present will object to this statement; but I am referring now to the experience in the use of the commodity. So far as the record of the use of the commodity for its intended purposes is concerned, I think we have had a 100 per cent record.

As against that, of course, there are many cases of experimental evidence indicating a possible hazard. All of those facts that we have available must be sifted and weighed. Unfortunately, to-day many errors have crept into our discussions. One quite apparent error that came up was in the statement that manufacturers of this commodity have to have their employees medically examined twice a day. Of course, this gathering is not competent to weigh all those facts and statements. But somebody must be found who is able to go into the questions of fact involved and to weigh the facts and determine whether there is anything serious in this hazard problem with which we are confronted now.

And I do not think there is any better suggestion that could be made than to have the Surgeon General of the United States Public Health Service assume the responsibility, if he will do so. I appreciate that it is a very serious and difficult undertaking; but if he will assume the responsibility of trying to get together and weigh all those facts, that will be the only way out of what seems a hopeless dilemma to us at this time, because we do not know what our duty under the circumstances is.

And I think, Mr. Surgeon General, that you would afford to us the best hope we have of a solution of the problem by helping us to determine what our duty in the premises is; and on behalf of the Standard Oil Co., the General Motors Corporation, and the du Pont Co., I assure you that every resource we have for supplying information will be placed at your full disposal in making such an investigation.

Mrs. BURNHAM. Mr. Chairman, in regard to the remarks of the gentleman who spoke for the General Motors Co., my statement that the examination of employees working on tetraethyl lead products was made twice a day was a public statement made by Commissioner McBride, of the State of New Jersey, after visiting the plant of the Standard Oil Co. and getting the information from the Standard Oil Co.'s physicians. I would like to read this statement:

> Before men were employed in the ethyl plant they were subjected to a very careful medical examination. In no instance was any man employed at this work without first undergoing this examination. After the men had

started to work in this department examinations were made weekly. In some cases, where it was deemed necessary, men were examined as often as once or twice a day. These examinations were very thorough and included blood pressure, examinations of the lungs and heart, and having the teeth examined.

While I am on my feet, I want to make the statement that this "gift of God," to which the gentleman referred, was not a gift of God when those 11 men were killed or those 149 were poisoned.

And I think the statement of my brother delegate, Mr. Berres, to the effect that the thing that we are interested in in the long run is not mechanics or machinery, but men, is a thing that we have to bear very carefully in mind in this age of speed and rush and efficiency and mechanics.

After all, if the human beings that are left are not able to enjoy all of this efficiency and speed, there is no use in having it. Our experience during the war with the draft ought to prove to us that the physical stamina of this country is going down. At that time one-third of the young men of the country in the best days of their youth were found physically unfit to be drafted to serve in the Army. And when a condition such as that is brought out, then it is time for us to take notice and decide in what direction we are going.

Doctor HENDERSON. Mr. Chairman, I would like to say one other word in regard to the statement of the gentleman representing the du Pont Co., the General Motors Co., and the Standard Oil Co.

He spoke as if the matter had just come up, and as if it was too much to ask that they stop the manufacture and sale of tetraethyl lead.

Now, that is not quite an ingenuous statement, because I have in my hands correspondence in which the first date is March 13, 1922. That is a little over three years ago. In that correspondence they asked me if I would investigate this matter. I believe that every other man pres nt who works in the field of industrial physiology and toxicology received a similar request.

We all, I think, indicated that we would be willing to make an investigation, provided we could do it freely, without any dictation, and simply to find the facts. In practically every case the person addressed intimated—as I did very strongly—that we looked at the matter as one that should be investigated from the standpoint of public safety. Then the Ethyl Gasoline Corporation dropped the matter. They did not have the investigations made.

We can not turn back the hands of the clock; we can not go back to conditions as they were three years ago. But we can at least ask that, in view of the fact that the Ethyl Gasoline Corporation neglected to have an investigation then which we were perfectly

willing to carry out, they should stop now until we have an opportunity to make it.

The CHAIRMAN. Is there any further discussion?

Miss SILVERMAN. Mr. Chairman, on behalf of the Workers' Health Bureau, may I read the report of Commissioner McBride, of New Jersey, which covers one of the statements made by the representative of the Standard Oil Co.? In the report with regard to the Standard Oil Co.'s plant, it is said—this is in regard to one of the men employed in this plant:

> This man had been employed in the production building as a general clean-up man. We were advised that he was uncleanly and would not wash as he should and as a consequence became affected and died. Every man now engaged at this work is compelled to wash frequently and bathe daily. If this order is disobeyed, they are made to forfeit any pay due them on any day the rule is disregarded.

I ask you gentlemen to consider the fact that you are asked to allow a man to be subjected to contact with a poison which is considered hazardous by the leading scientists of the country. And when you expose them to that poison out of which the manufacturers are making profits, the manufacturers penalize those men by making them forfeit a day's wage.

The CHAIRMAN. Are there any further remarks?

RESOLUTION

Doctor NICOLL. In order to crystallize what I have tried to suggest, I offer the following resolution, prepared by Dr. Haven Emerson and myself:

> It is the sense of this conference that the Surgeon General of the United States Public Health Service appoint a committee of recognized authorities in clinical medicine, physiology, and industrial hygiene to present to him, if possible, by January 1 next, a statement as to the health hazards involved in the retail distribution and general use of tetraethyl lead gasoline motor fluid, and that until such time distribution of this substance be discontinued.

Doctor PATTERSON. Mr. Chairman, arising to second the resolution which has just been offered, I first of all believe, and respectfully suggest, that that committee be rather limited in numbers, because I think that every one who has had experience in working with large committees has found that such committees are at best unwieldy. And I therefore offer an amendment to this resolution, that the committee be limited to seven members.

I furthermore suggest for your consideration that while this committee is at work the opportunity should be given to have practical experience placed before the committee as to what is the effect of the distribution of ethyl gas.

It seems to me that if this committee is to have any knowledge as to whether or not those in filling stations are going to be subjected to the hazard of lead poisoning, ethyl gas should be distributed to those filling stations.

And I have sat here all day long and certainly have had no one show me that any man who has walked the streets of any city in this country has ever become affected with lead poisoning by reason of the emanation of some fragments of lead from a motor which was burning ethyl gasoline.

In view of that fact, it seems to me that if the committee is to have the information it can only get it by the practical test of what the physical conditions are of those who are in contact with the lead, and that they can not get the information if the manufacture and distribution of this material is to be stopped.

The CHAIRMAN. Do you accept the amendment?

Doctor NICOLL. I do not, with the restriction on the last clause.

The CHAIRMAN. I mean as to number.

Mrs. BURNHAM. I have something to offer as an addition.

The CHAIRMAN. Doctor Patterson, if you reduce yours to writing, we can get it as a substitute for the original. Is there a second to the doctor in the case of the original resolution. Doctor Patterson has introduced a substitute as follows:

It is the sense of this conference that the Surgeon General of the Public Health Service appoint a committee of recognized authorities in clinical medicine, physiology, and industrial hygiene, seven in number, to present to him by next January 1 a statement as to the health hazard involved in the retail distribution and general use of tetraethyl gasoline as a motor fluid.

Mrs. Burnham is about to introduce a substitute.

Mrs. BURNHAM. An addition:

This investigation shall be paid for exclusively out of public funds and not by private interests involved, and that the results be reported back to a public conference called for the purpose by the United States Public Health Service, at which labor shall be represented.

Dr. D. E. HOWE. May I make a suggestion? Do you want, Mrs. Burnham, to have a separate thing?

Doctor NICOLL. I do not. You know where you can get public funds.

Doctor HOWE. I will point out that inasmuch as there are certain chemical matters involved in this investigation there ought to be an accurate method of analysis made, and that you ought to consider having upon this committee, at least, a representative of chemistry.

The CHAIRMAN. Is there a second to the substitute of Doctor Howe, and is there a second to Mrs. Burnham's substitute?

Mrs. BURNHAM. Mine is an addition to the other resolution embodying all the things which Doctor Nicoll embodied originally, including the power of the Surgeon General to call on any technical assistance he needed. I simply added these two clauses instead of substituting my own motion.

The CHAIRMAN. Mrs. Burnham moves an amendment to Doctor Nicoll's original resolution, "That this investigation shall be paid for exclusively out of public funds and not by private interests involved, and that the results of this investigation shall be reported back to a public conference called for the purpose by the United States Public Health Service, at which labor shall be represented."

Mrs. BURNHAM. The other really covers the same thing as Doctor Nicoll's.

The CHAIRMAN. I think the first thing now probably would be to vote on Doctor Patterson's amendment to Doctor Nicoll's resolution.

Mr. BERRES. Will you tell us now whether you have the funds to make this investigation?

The CHAIRMAN. We have funds to collect the data, but as to funds for making an intensive investigation it would depend entirely on how much it costs. That is something the committee itself would have to suggest to us.

Mr. BERRES. You have the money now to let them proceed up to a certain point?

The CHAIRMAN. Yes; but as to the subsequent proceedings in the investigation it would depend very largely upon the nature of the investigation recommended by this committee. Is there any discussion of the amendment of Doctor Patterson to the original resolution of Doctor Nicoll?

Doctor HENDERSON. I sincerely hope that the amendment will not be adopted. It seems to me Doctor Nicoll's resolution as originally offered covers the matter extremely well. It states in a way plain to all that the sale of tetraethyl fluid should now be stopped. In view of the long delay that there has been in the institution of the investigation, we are not asking too much if we ask six or eight months to investigate it before it is sold again. So I hope Doctor Patterson's amendment will fail and that we will pass the original motion.

Doctor PATTERSON. Where is the clinical data coming from if the material in question is neither manufactured nor dispensed?

The CHAIRMAN. Is there any discussion of the original amendment or substitute? The question has been called for.

Doctor HENDERSON. I will answer that question. The Doctor had in mind a large experiment, including a considerable number of garages. This would necessarily involve a supply of ethyl gasoline to them. There is nothing in this resolution, as I understand it, to

prevent this, or to stop the sale of ethyl gasoline to the British Government or its use in airplanes. This resolution would simply stop the general sale of ethyl gasoline to the American public.

Doctor PATTERSON. The resolution simply provides that the material shall not be made.

A DELEGATE. No distribution.

The CHAIRMAN. The original resolution says "And that until such time distribution of this substance be discontinued." I think it is probably subject to the approval of the conference. It would be well for us to vote as a unit, just as we have invited you. I will get Doctor Thompson to call the different organizations represented. It is proper to vote on the amendment first. There are two amendments, both suggested by Doctor Patterson, one to limit to seven the number on the committee.

I would say as far as having a chemist on it is concerned I shall construe industrial hygiene very liberally so as to include a chemist even if it were not specifically included.

The second amendment is to eliminate the last clause "and that until such time distribution of this substance be discontinued," so that what you are voting on now is this:

> It is the sense of this conference that the Surgeon General of the United States Public Health Service appoint a committee, seven in number, of recognized authorities in clinical medicine, physiology, and industrial hygiene to present to him, if possible, by January 1 next a statement as to the health hazards involved in the retail distribution and general use of tetraethyl lead gasoline motor fluid.

Are you ready for the question?

Dr. HAVEN EMERSON. The mover and the seconder of the original resolution accept the amendment of Doctor Patterson, so that the only point at issue is whether the motion shall include the phrase "and that until such time distribution of this substance be stopped."

The CHAIRMAN. You are voting on the elimination of the last clause of Doctor Nicoll's resolution, and Doctor Thompson will call the roll. As a matter of fact, of course, this is an expression of opinion of the conference as to the cessation of distribution. There is no legal authority to compel that.

Doctor THOMPSON (calling roll). American Federation of Labor.

ANSWER. No.

The CHAIRMAN. It has been suggested that I again state that a person voting yes or no will be voting on the elimination of the last clause of Doctor Nicoll's original resolution regarding the cessation of the distribution of the substance, and a vote of aye is for the elimination of that clause; that is, the passage of the resolution with that clause eliminated.

A DELEGATE. If I am not out of order, may I ask again if distribution is to be interpreted as public sale? I would vote one way if distribution is to be interpreted to permit the sort of thing Doctor Patterson has in mind.

Doctor EMERSON. It was drafted by Doctor Nicoll and me. In the original resolution, by the term distribution, we intended the general public sale and distribution in retail commerce. It is inconceivable that any such committee could arrive at a conclusion without the opportunity of getting access for experimental purposes to the commercial material of tetraethyl gasoline as it has been used in the past by garages or elsewhere. Clinical tests of those using ethyl gasoline will have to be made, but we thought that these need not be made at the cost of resuming distribution universally of this motor fluid in the retail trade.

The CHAIRMAN. You do not intend to include in it cessation of distribution for governmental use—military or naval use—do you?

Doctor VAUGHAN. I propose an amendment to the amendment, which I believe will be acceptable to the gentleman who made the amendment, and I hope acceptable to the gentleman who drew the original resolution. If so, that will simplify it. In my mind it is impossible to recommend that something be discontinued which is already discontinued. The resolution calls for a discontinuation of the sale of ethyl gasoline, and it is not being sold at the present time; so I would move as an amendment to the amendment that the last phrase be changed so that the question of continuation or discontinuation of the use of ethyl gasoline be referred to this new committee for immediate report to the Surgeon General

Doctor PATTERSON. I accept it.

Doctor VAUGHAN. Final action to be taken by the Surgeon General. In other words, I think this committee of experts should decide this matter and not this conference.

That the question of the continuation or discontinuation of the use of ethyl gasoline be referred to this committee to be appointed by the Surgeon General for immediate report, and that final action depend upon the decision of the Surgeon General after receiving such report. Do you accept that?

Doctor NICOLL. No, I do not; I think it might be made more grammatical. Something discontinued that is discontinued; but if some grammarian will fix up that last sentence I will accept it. No; I do not accept it.

Doctor VAUGHAN. May I suggest something more grammatical:

That immediately after the appointment of this committee the committee meet and recommend to the Surgeon General at the earliest possible moment whether it will be advisable to permit the sale of ethyl gasoline during the

period from now until the 1st of January, awaiting the complete report, and that final action be left to the Surgeon General.

The CHAIRMAN. You said you accept that?

Doctor PATTERSON. Yes.

Doctor NICOLL. I do not want to be stubborn about this thing, but we have listened for a good many hours and have reached, certainly, fairly definite if not definite conclusions and ideas on this subject, and I think that you could point out to the gentlemen of the Ethyl Gasoline Corporation and the Standard Oil Co., and manufacturers in general, whether it is advisable to continue the manufacture of this gas, in view of what we have heard. I think they will agree with me as a matter of policy, if nothing else, that it would be a great mistake not to stop it here.

Mr. HOWARD. We would be inclined to agree with you, but object most strenuously to this conference taking such action.

Mr. E. W. WEBB. In regard to the implied criticism mentioned by Doctor Henderson about the letter, the latter part of 1922, which he read, I think this conference should take note of the fact that the Bureau of Mines was requested by the Ethyl Gasoline Corporation and its predecessor to conduct examinations and experiments which they have undertaken; that Columbia University was likewise requested by the Ethyl Gasoline Corporation; and when it was brought to the attention of the Ethyl Gasoline Corporation very recently that there was a difference of opinion among men of prominence scientifically as to whether there was or was not a possible hazard in connection with the distribution of gasoline ethylized, a board meeting was called just as soon as I could get it together (a good many of them were out of town at the time), and the board unanimously decided, and I can say this without any question of contradiction, without any pressure whatsoever, to discontinue the sale of ethyl fluid to its customers.

Now, there has been no intimation by anybody representing the Ethyl Gasoline Corporation or its stockholders to-day that we intend to make and resume the sale and distribution of this product, and it seems to me this resolution carries with it an implied threat by certain gentlemen present that we must not even consider for a moment resuming its distribution, when there has not been the slightest intimation on our part that we would think of doing such a thing, which the Surgeon General knows, and I think I read it in the papers that this corporation told him that if there was any indication of a public hazard it would discontinue its sale. It seems to me if you then put it up to the committee to decide whether it should be continued or not, then we are placed in the awkward position of being forced to do something which we would voluntarily do, and I think it is very unfair to us at this time to take that position.

The CHAIRMAN. You are voting now on the question of the substitute amendment by Doctor Patterson. I will read it once more:

It is the sense of this conference that the Surgeon General of the Public Health Service appoint a committee of seven in number of recognized authorities in clinical medicine, physiology, and industrial hygiene to present to him, if possible, by January 1 next a statement as to the health hazard involved in the retail distribution of tetraethyl gas motor fluid.

And there you stop.

Those voting aye vote in favor of the resolution as I have just read it. Please be good enough to answer to your names.

Doctor HEKTOEN. I move that the amendment be laid on the table.

(Seconded.)

Doctor HEKTOEN. I had reference to Doctor Vaughan's amendment.

The CHAIRMAN. The same thing will be accomplished if they vote on this resolution as I read it, because that elimination is with reference to cessation or discontinuation.

Doctor HEKTOEN. Not altogether, because Doctor Vaughan's amendment includes other matters.

Doctor EMERSON. May I suggest this, that the resolution read as follows:

It is the sense of this conference that the Surgeon General of the Public Health Service appoint a committee of seven recognized authorities in clinical medicine, physiology, and industrial hygiene to present to him, if possible, by January 1 next, a statement as to the health hazard involved in the retail distribution and general use of tetraethyl lead gasoline motor fluid; and that this conference indorses as wise the decision of the Ethyl Gas Corporation to discontinue temporarily the sale of ethyl gas.

Doctor PATTERSON. I second that resolution.

The CHAIRMAN. Are you ready for the question? All in favor of the resolution introduced by Doctor Nicoll and seconded by Doctor Emerson and Doctor Patterson and Mr. Howard will signify it by saying aye.

(The motion was unanimously adopted and the resolution was carried.)

The CHAIRMAN. I express my appreciation of this confidence you have reposed in me and the responsibility which you have entrusted to me, and I wish to explain, first, that under the law the Public Health Service has not only authority but responsibility to investigate things. We have not police authority in this matter, and I want to ask from all of you your cooperation. It is a very important question and we need all the help we can get. I think you all realize, too, that it would not be wise for me to attempt offhand to pick out the committee, but I will try to do it to-night or to-morrow and let you all know by mail, if that is agreeable to you. It would be very difficult to name offhand the individuals. I shall

want to consult frankly such people as the American Medical Association and various professional organizations and get them to suggest some nominees for the committee. I do not think we can do anything, and the committee certainly can not do anything, without the cooperation of you gentlemen who represent the manufacturing and distributing ends, and I am quite sure that we can count on you.

Doctor PATTERSON. Mr. Surgeon General, before this meeting adjourns I would like to express upon behalf of myself, and I am quite sure everybody present, the very deep appreciation we are under to you for the most fair and excellent manner in which this conference has been conducted.

The CHAIRMAN. I thank you. Has anybody any objection to the addition to the resolution as passed, as suggested by Mrs. Burnham, saying that this shall be done with Government funds, and report back to a future conference?

Doctor PATTERSON. Not if you can get the money.

The CHAIRMAN. We will do the best we can, with the Comptroller General's help. Is there any further suggestion before the conference?

Doctor PATTERSON. I move we adjourn.

(Seconded.)

The CHAIRMAN. I want to express my appreciation to those professional gentlemen who have left their universities and have come down here. Unfortunately, the Government has no authority to pay even their railroad fare. There is a great deal of hardship not only in that way but in leaving their work during the time the university is in session, when they have other work to do. We certainly appreciate their coming very much.

(There was no objection made to the inclusion of Mrs. Burnham's amendment in response to the Surgeon General's inquiry for objection. The resolution referred to, including such amendment, was adopted, and is as follows:)

It is the sense of this conference that the Surgeon General of the United States Public Health Service appoint a committee of seven recognized authorities in clinical medicine, physiology, and industrial hygiene, to present to him, if possible, by January 1 next, a statement as to the health hazard involved in the retail distribution and general use of tetraethyl lead gasoline motor fluid; and that this conference indorses as wise the decision of the Ethyl Gasoline Corporation to discontinue temporarily the sale of ethyl gas; that this investigation shall be paid for exclusively out of public funds; and that the results of this investigation shall be reported back to a public conference called for the purpose by the United States Public Health Service, at which labor shall be represented.

(Thereupon, at 5.45 o'clock p. m., the conference adjourned.)