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

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

In the interest of completeness I might say that one case occurred the plant, approximately two months ago, of rather unusual type. his man, who had shown no signs or indication of poisoning whatever, developed a type of infection resembling epidemic influza, which was at that time in the community in which he lived. e was sent home and was apparently convalescent when he developed what was either an acute tetraethyl lead intoxication or an fluenza encephalitis. The diagnosis in this man's case is a matter f doubt, and it is quite impossible for me to say whether the contion is lead poisoning or infectious encephalitis. At any rate, the an recovered from the maniacal condition. When last seen he as in a good physical state, but had some mental abnormalities. ince that time there has been no evidence of poisoning in any of hese men. The number of men who have been employed over this eriod of time is in the neighborhood of 100. So altogether, of the en employed in the plant since August 1, there have been 18 cases. his indicates the possibility of a reduction of hazard in the blendg of ethyl fluid to the point of almost complete disappearance, nd there is every reason to think that by further close observation, y the closest attention to details of discipline and careful warning f these men, that the hazard at this point may be reduced to a oint 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 experimentation 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 oyer 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	None
	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 colic, loss of appetite, or other symptoms usually associated with lead poisoning.
6. Chemical analysis of animals that died or that were killed gave 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.