late only to questions of style, occasionally touching the picturesque wording of a phrase or sentence—nothing more.

The Memoirs will stand as we know them—an unsurpassed story of how a printer and shopkeeper in Philadelphia rose to be one of the world's great figures, and "the most complete representative of his century that any nation can point to," while underlying the whole narrative runs a dispassionate self-analysis that only could be made by an impersonal, impartial scientist or scholar, and has never been excelled, if it has ever been equalled.

A NEW THEORY OF COMBUSTION IN DIESEL ENGINES.*

BY

MAX G. FIEDLER,

Vice-President, Fiedler-Sellers Corporation.

Lecture before The Franklin Institute of Philadelphia, on Thursday evening, May 4, 1939, at 8:15, by Max G. Fiedler, Vice-President of the Fiedler-Sellers Corporation, W. Chattin Wetherill, Vice-President of The Franklin Institute presiding.

Subject: "A New Theory of Combustion in Diesel Engines."

CHAIRMAN WETHERILL: The meeting will please come to order. Mr. Secretary, is there any business?

SECRETARY: No, sir.

CHAIRMAN WETHERILL: If not, it becomes my great pleasure to present to you the speaker of the evening. He is going to talk to us on the new theory of combustion in Diesel Engines, and I am right here to say that that is no mean assignment. Anyone who can come forth with a new theory in this day and generation certainly has my profound respect, and I am sure he will have yours, also.

Max G. Fiedler is a native of Germany. He is a graduate of the Berlin University, 1920, where he specialized on internal combustion engines. He came to America in 1928 and he brought with him some of the engines that he had been working with, over there. He brought these engines to the laboratories of the Scientific School of the University of Pennsylvania. Professor Sloan of that laboratory, who is in the audience, tonight, has very vivid recollections about it—before the meeting is over, I hope he will make his contribution.

The results of these tests that were performed at the University of Pennsylvania were very convincing. Mr. Fiedler was not a charlatan, and as a result of these experiments his

* Presented at a meeting held Thursday, May 4, 1939.

work has attracted the interest and the attention of most of the important minds in the internal combustion fields since that day.

Mr. Fiedler has now associated himself with the Fiedler-Sellers Corporation, where he has been taken into the firm—and again, that is no mean achievement. Therefore, I can assure you, Ladies and Gentlemen, that Mr. Fiedler comes to you tonight—even though he comes with a new theory of combustion for Diesel engines—he comes carrying a good deal of scientific weight in back of it. I am sure there are going to be some of you who will disagree, because of your preconceived ideas on this subject, with what he has to say. After all, he made a remark, coming to the lecture this evening, that I thought quite important. He said, "It is extremely difficult to try to convey in 45 minutes what has taken me 20 years to find out."

Now I believe Mr. Fiedler has something important to tell us. I hope that when he gets through with what he has to say you will feel entirely free to discuss this matter. That is the purpose of The Franklin Institute—to afford you that opportunity—and Mr. Fiedler, I am sure, joins me in the expression of that hope. Therefore, Ladies and Gentlemen, it is with the greatest of pleasure that I present to you at this time Mr. Fiedler, the Vice-President of the Fiedler-Sellers Corporation, who is going to talk to us on a new theory of combustion in Diesel Engines.

MR. MAX G. FIEDLER: Mr. Chairman, Members of the Institute and Guests: I am quite overwhelmed, not only by the introduction that I received here, but also by the large attendance. I did not think that anything I had to say would arouse so much interest.

I want to thank The Franklin Institute for giving me the opportunity to talk to you tonight, and I want to thank you for coming. As you know by the invitation, I am going to talk about the Diesel engine, the prime mover that has ever since its conception received a tremendous amount of publicity.

You will also, I think, recognize from the invitation that I do not quite concur with you in the high opinion of the Diesel engine and the large amount of credit that has been

given to that type of prime mover—anyhow, not up to date. In fact, my personal opinion is that that type of prime mover has been a great disappointment. I have had this opinion for quite some years, but I did not think that the time was ripe to present it to the public. I do think, today, that the Diesel engine is at the turning point. In spite of all the publicity and all the good will, money and research that have gone into that type of prime mover, it has not produced accordingly. It will either have to produce in the future or it will disappear from the world, as an engine.

Now I could give you what I have to say in the form of a paper. I could give you the facts and the high points in my paper and you would go home and say, "There is another fellow who read a paper"—you would just stick it in your pocket and forget about it. Therefore, I have decided upon a different method. There is enough tragedy and disappointment in the development of that prime mover that it is worth telling in the form of a story, in fact in the form of a mystery story—that is really the better expression because: Why has the Diesel engine never produced?—Why has it always been a half-way affair?

I would like to ask that you be as open-minded as possible. I might say things tonight that may offend some of you. That, of course, is not my purpose. I have only one thing in mind and that is to bring to your attention what I know, as plainly and as easily for you to understand as possible.

If you are to talk about the Diesel engine, of course you have to start with Dr. Diesel. The high point is that Dr. Diesel conceived his idea after a lecture on Thermodynamics by Professor Linde. It took him time to get it clear in his mind before he presented his theories about the ideal heat-cycle to the engineering world.

Now a very peculiar thing happened—a rather unusual thing: Contrary to usual practice, Dr. Diesel was accepted right away; he was acclaimed. His explanation, his theories and his mathematical proof were so tremendous that nobody had any doubt that he was correct. He received, also—which is unusual—immediate financial backing, tremendous backing. In fact, the richest man in Germany backed him, and thus he was able to build the first engine.

This first engine was destroyed by an explosion. Now right there the history is rather hazy—the general engineering conception was that he was going to extremes, that he was using the highest possible pressures and that naturally an explosion could happen under those circumstances, and this could destroy the engine. I would like you to keep that in your minds—that there is an analysis already accepted by the engineering world that an explosion can destroy a Diesel engine.

The next big mystery is Dr. Diesel's death. He died by drowning. Some stories have it that he was murdered; some say that he committed suicide. The story that he was murdered is very unlikely. The idea in back of that is that he was perhaps giving away information to England, which information he should have given only to his own country, Germany. However, there was no logical reason for murdering him. All of his ideas and his theories were widely printed; there was no secret about them.

He had not proved himself to be a successful designing engineer. For some reason, however, his Diesel engine right away received a tremendous amount of credit. For example, it is generally believed that the Diesel engines were the cause of the success of the German submarines. The first submarines and in fact the most successful one during the World War was the U-9 driven by a hot bulb, kerosene engine. It was only later that the Diesel engines were installed in submarines.

That is the story of Dr. Diesel in a few words. Instead of telling you more about Dr. Diesel, I am obliged to talk about myself. I don't like to do that, but I have, for some reason, been introduced into this Diesel problem. I did not do it by choice. A few high points at the beginning of my life are interesting perhaps because they fit into the clues we want to analyze later on.

I served with the German Navy during the World War and I was attached to a formation that had a great number of different types of patrol boats—we called them "Submarine Chasers"—which had gasoline engines, hot bulb engines and Diesel engines.

I remember one incident: I was assigned to a boat which had two air-injection Diesel engines. On the first trip out we operated only on the starboard engine. I asked about the other. The answer was that we only needed one on that trip and that the other wasn't any good, anyway. I said, "What is wrong with it?" They said, "We don't know, but every time we start it something happens."

Well, I just couldn't leave that engine alone, and against orders, one day, after I had looked it over carefully, I started it, with very tragic results. One man was almost killed—the cylinder head was blown off the one engine, and the relief valve caused considerable injury to my assistant. There was a big investigation and the investigation as usual brought out everything except that in which I was interested. Why was the engine destroyed? It was brought out that I was much too young to handle a power plant like that, and that it was against orders. But, finally, the storm blew over.

I was not satisfied in my mind, however, and I went to the Chief. I went into the Lion's Den, and asked for permission to ask a question. In the German Navy you needed permission to ask a question. My question was: "What happened?"

The Chief looked at me—I will never forget that look; it was the most surprised look—and said, "You gave that engine too much fuel," and before I had a chance to say, "Well, now, the explosion occurred before she had any fuel at all," I was dismissed—and that was the end of that chapter.

Now this analysis is still good today. You ask a Diesel engineer, when you get a violent knock in starting the engine, and he will tell you that the knock is due to too much fuel. But let's think it over for a moment. We know, from experience with gasoline engines, that under certain conditions, sometimes even at starting, all the fuel that can possibly be consumed can be set off in an engine and still doesn't wreck the engine. But the Diesel engineer comes along and says: "You put too much fuel into the cylinder which causes a violent reaction and destroys the engine." This just doesn't seem logical. This contradiction between the things that we have learned in gasoline engine experience and the popular conception of Diesel combustion was first impressed on my mind during my naval service.

I later joined the naval air force. I am telling you all this just to illustrate the fact that I was again in a branch of the service in which motors were predominant. And, when the war was over, and while I was still studying, I designed an engine which I thought in those days was better than anything on the market.

To start out, I am going to begin with that engine, because it is the basis of all my future designs.

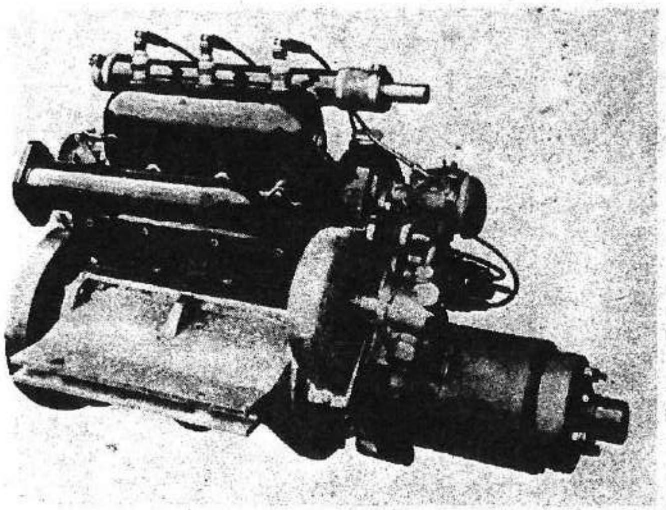


FIG. 1.

Fig. 1. This engine was designed for a light car, in Germany. The displacement is 61 inches and it delivered 30 h.p., which is quite a remarkable performance. The front end that you see here is a little disturbing—that is a marine conversion, and the extension in front is an electric reversing unit. This means that this engine does not need a reversing gear. Simply by pressing a button it will go backwards and forwards. This little engine was brought out commercially, and was a success—there is no doubt about it. It was brought out in a little car designed by myself

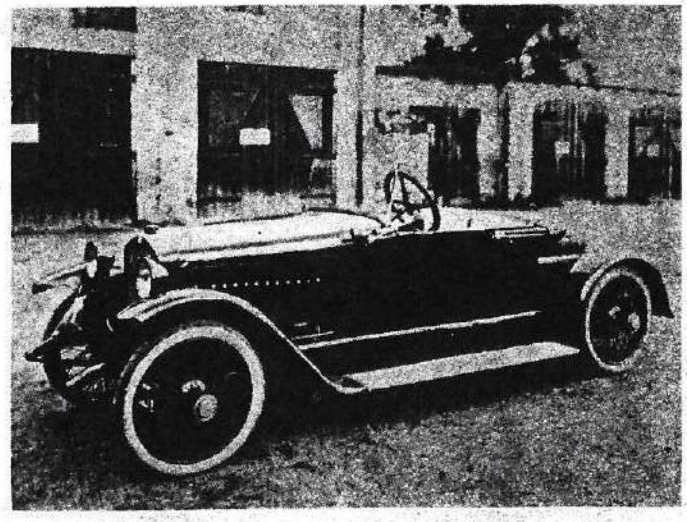


FIG. 2.

in 1921, and as you see, this car still looks rather nice—that is, it is not too out of date (Fig. 2).

Now to give you an idea of the performance of this engine (Fig. 3). This curve was published in 1924 by

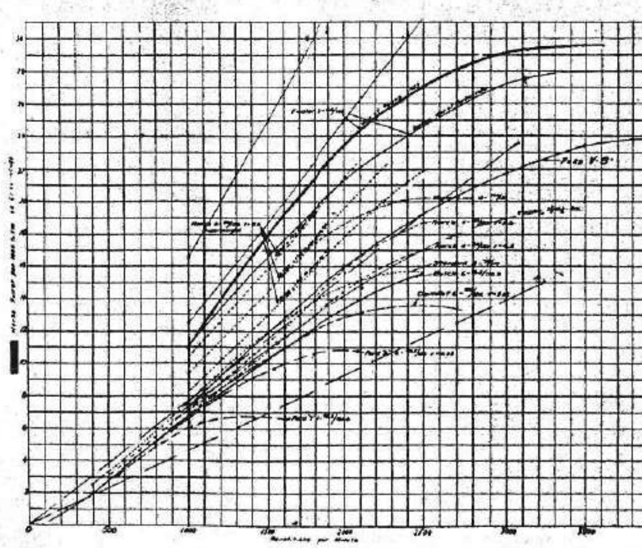


FIG. 3.

Professor Becker, of the Technische Hochschule Berlin Charlottenburg. He had investigated a lot of engines and he added the performance curve of my engine on this data sheet with a lot of other engines, and we have, since then, added other motors to it.

CHARTS: Here you see the old Model "T" Ford. I want to remark that these are all reduced to the same displacement,

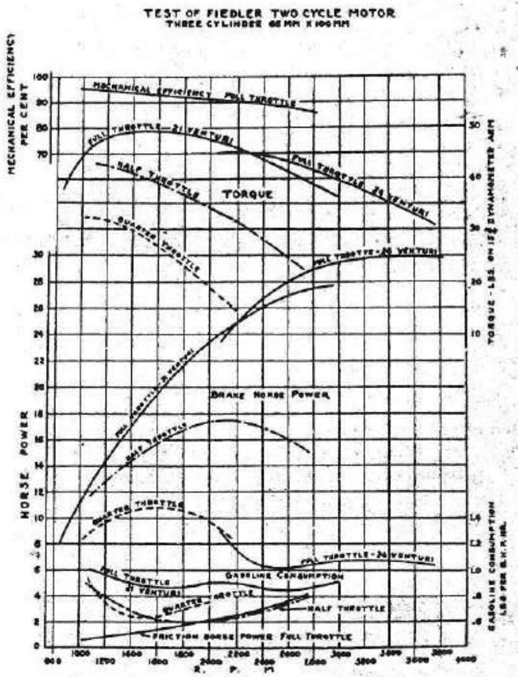


FIG. 4.

61 cu. in. Then there is the Model A, and there we have a Chevrolet—compression ratio of five to one. Then the Buick up there; and there is a modern German engine, overhead valves, tested with a ratio of 4.3 and 5.6 to 1. These lines up here are for the same engine supercharged with one-tenth, two-tenths, and three-tenths of an atmosphere.

Here we have a very late curve of the Ford V-8, and at the top you see the power curve of the 3-cylinder engine. That curve up there is a test run by the University of Berlin

in 1924. I brought some of these engines over and had them tested over here, and they performed a little better than abroad. I think this was due to the better gasoline we have over here, that is, the gasoline that was available in 1929.

Fig. 4. Here is an interesting thing; this is the latest test on that same 3-cylinder engine. You will see from these curves that the engine is sensitive to volumetric efficiency. You see that the size of the venturi in carburetor at high speed has a definite effect on the power output.

This was a problem for us to overcome, if we wanted an improvement in power at higher speeds (Fig. 5). I designed

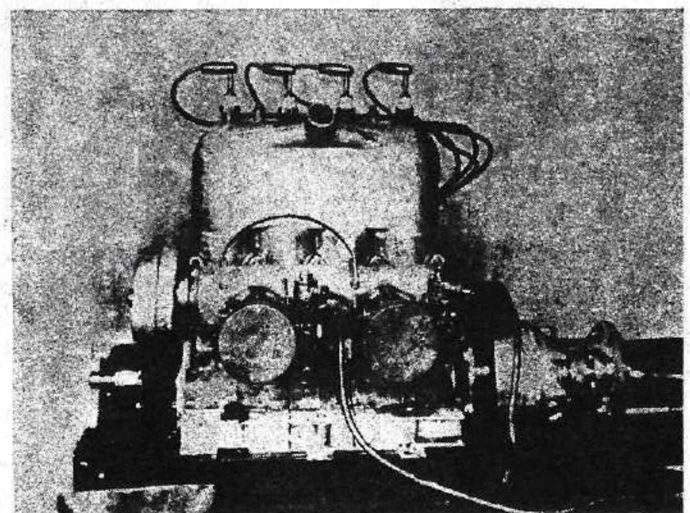


FIG. 5.

another engine that should have had high volumetric efficiency at higher speeds. This engine was commercially a complete failure, not because it was designed wrong, but, turning up to 8,000 revolutions per minute, being a 2-cycle engine, the magneto had to turn up to 16,000 revolutions. At that time there was only one magneto that could accomplish this, and then only spasmodically. You also see that the carburetors are out of proportion to the size of the engine. Nevertheless, the engine developed 80 h.p. with only 90 cu. in. displacement. As I said before, however, this engine was a failure. We tried to overcome the problem of volumetric efficiency by doing away with the carburetors and tried gasoline injection. This was in 1926. We didn't know, however, at that time, how to handle gasoline injection properly, and it didn't work out very satisfactory as far as regulation was concerned. We finally decided on mixture injection. We provided for a separate cylinder, which would draw in a mixture of air and gasoline, and inject this charge into the main cylinder, thus overcoming the difficulties with the carburetion. From this design eventually evolved the Diesel with which we have been experimenting in recent years.

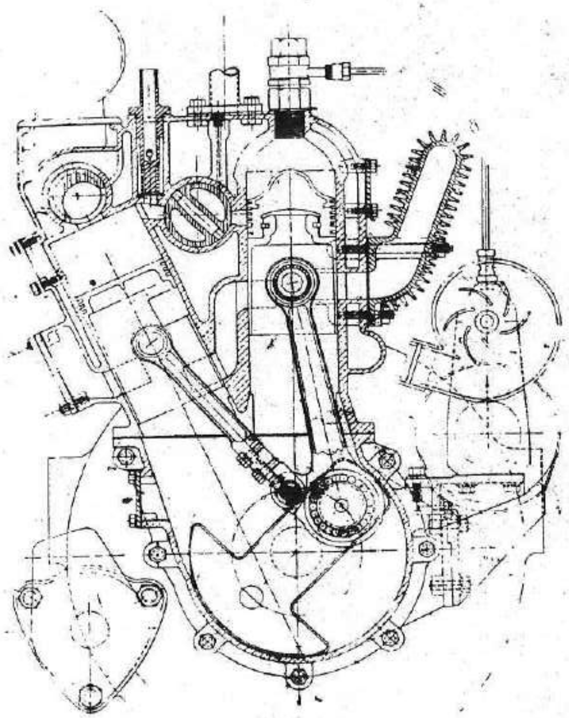


FIG. 6.

Figure 6 shows a cross section of that Diesel engine. On the left side is the supercharging cylinder, while the scavenging air furnished by both cylinders is compressed in the crank case. Combustion occurs only in the right cylinder.

Fig. 7. The engine itself is an automotive engine designed in 1929 and 1930, and that engine at the start was a complete failure. The failure was due to something that started us on the track of some research work that we have been doing in the past nine years, and which has become so very important. If you realize that in this engine design I had incorporated ten years of experience, you can imagine how heart-breaking the moment was when the engine started with a roar, and at the same instant the pistons would come out of the exhaust like a magnesium flare. Well, the answer

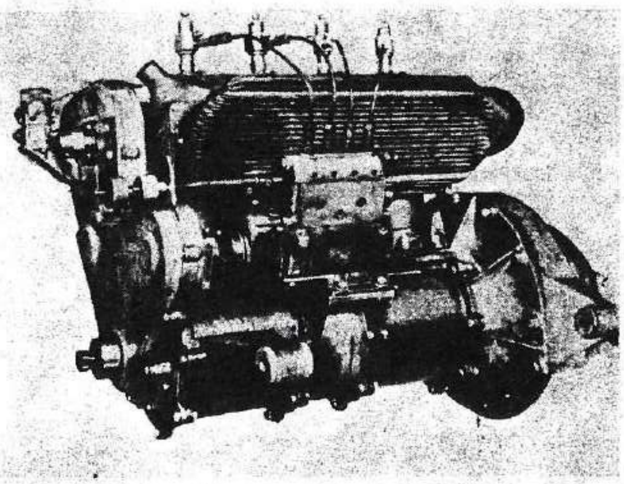


FIG. 7.

of the engineer was: "That man is crazy—in the first place, a 2-cycle engine cannot be cooled adequately; in the second place, he is supercharging it highly; and in the third place, he is making it a Diesel which is still worse, so the whole thing is absolutely impossible."

We ran about 200 sets of pistons through the engine, none of which lasted more than five seconds. Then I decided that the standard accepted theory was not correct. If there had been a high load during the time the pistons burnt, I would have understood it, but the pistons would come out even when the engine was still idling.

So, for this reason we started out on a new investigation. We first prepared the engine for all eventualities. We capped the pistons, installed special lubricators, and then we decided we would need an indicator in order to find out what happened inside the cylinder. The first indicator we put on was destroyed the moment the engine started. We hunted around and decided on the use of a Maihak Highspeed Indicator. There is an interesting story connected with that indicator. Some of you may have recognized cards like this one (Fig. 8).

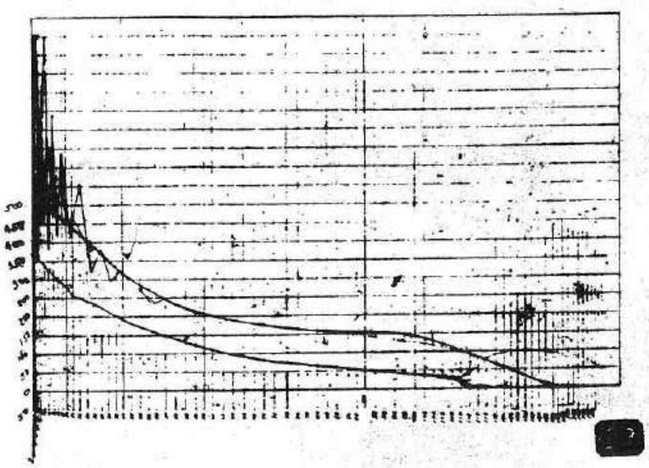


FIG. 8.

However, inasmuch as the paper is stationary at that point of maximum movement of the stylus, the pen scratches the paper and either breaks the arm or the paper flies off. The accepted explanation for those lines you see here is that they are caused by indicator vibrations—that is what the Diesel engineers said.

I was not convinced by this explanation. The indicator vibrations were not in any relation to the natural frequencies of the instrument. We therefore conducted some rather careful tests which convinced us that the indicator was trying to show us something that we apparently did not want to see.

Fig. 9. This card 90° offset shows the same characteristic. The dead center, however, is not at the left-hand side of the

card but in the center. The vertical lines represent degrees crank angle; the horizontal lines, pressure. The line at the top represents piston movement through upper dead center. Through this relation between indicator and engine, the indicator drum moves very fast during the time of combustion, which makes it easy to study the pressure in the cylinder at this vital point of the cycle.

These three cards are taken with the same indicator but with different assemblies. The one card is a 1 to 1, the next a 3 to 1; and the other a 2 to 1 piston assembly. You

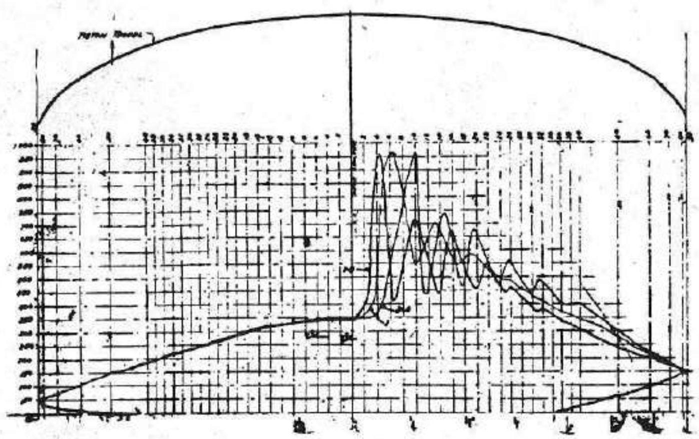


FIG. 9.

see that these cards can be pushed almost on top of each other and show absolutely identical characteristics. We put them out of phase so that this could be better distinguished.

We made another check—we put the same indicator on a variable compression engine and started to jack up the compression until the indicator would show these pressure variation lines. They appeared instantaneously when the so-called Diesel knock was noticeable. So we were convinced that the instrument would show us something. I don't say it gives absolute readings, but you use an instrument in research work to show some condition that you can analyze. If the indicator shows a definite characteristic for knock, and another characteristic for no-knock, then it presents an indication of the conditions we want to investigate.

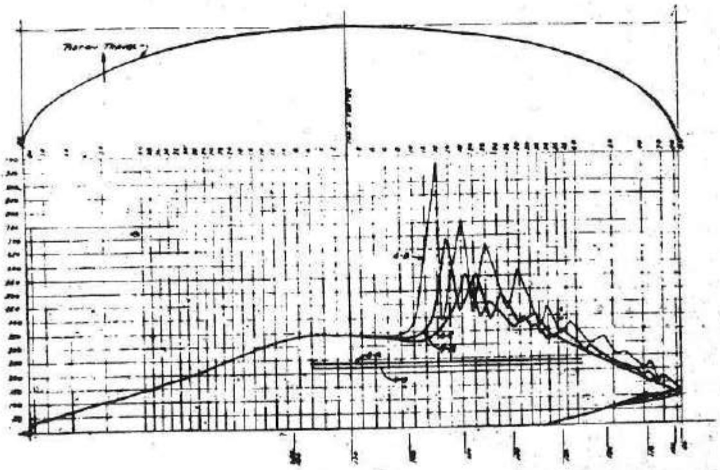


FIG. 10.

Fig. 10 shows a few loads on the engine with the standard injection valve. This is a valve or nozzle of standard recommendation. In other words it has an opening pressure of 3,000 lbs.; maximum injection pressure of 5–6,000 lbs. The holes are 3/10's mm. and the atomization according to the Diesel engineer's specifications, which should result in a

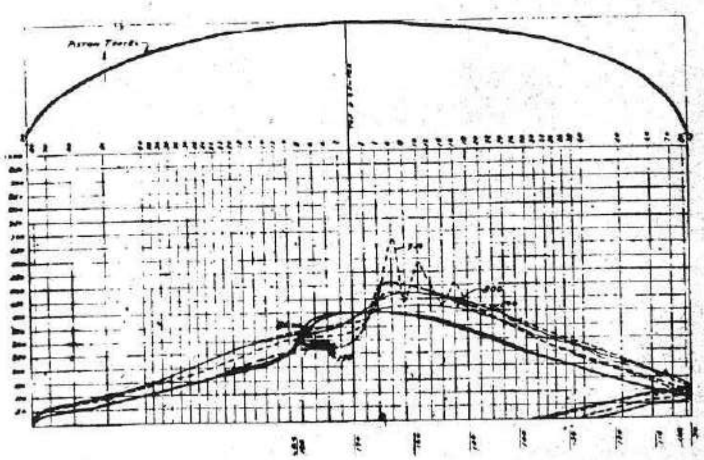


FIG. 11.

smooth combustion. However, the indicator shows very violent pressure reactions.

Then we take another card (Fig. 11) and all of a sudden the indicator shows something different. Now this was depressing because the nozzle in this latter case didn't fit the engine at all. We tried to change the characteristic by advancing the injection, and to our surprise it just dropped the peak pressure. The line marked 900 shows a change due to higher engine speed that was mystifying. The next card we tried to superimpose a diagram (Fig. 12) on a straight

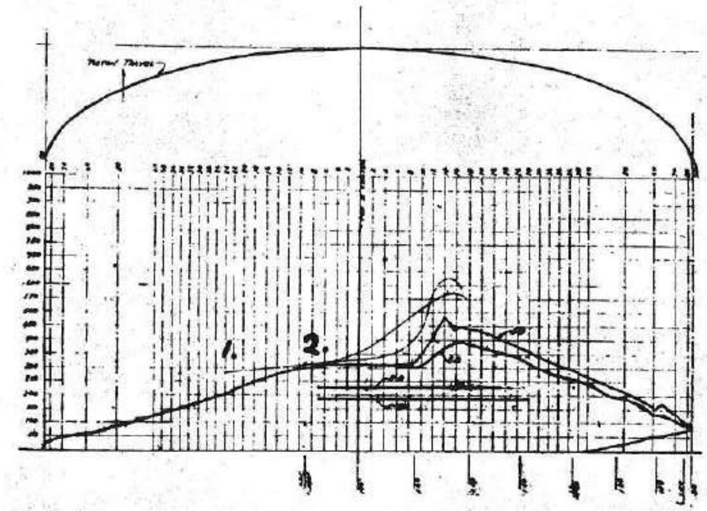


FIG. 12.

gasoline engine with one spark plug. Point 2 is the ignition point of the same engine with 5 spark plugs firing, and you get the corresponding pressure lines. You see that with more ignition points you get a sharper pressure rise, but you do not get the knock so typical of Diesel engines.

So the analysis that the rate of normal pressure rise is responsible for knock is also wrong. Then we started experimenting with changes in duration. There were indications that the combustion would not really start until the end of the injection, and we attempted to shorten the duration.

Figures 13 to 26 report checks on various injection characteristics.

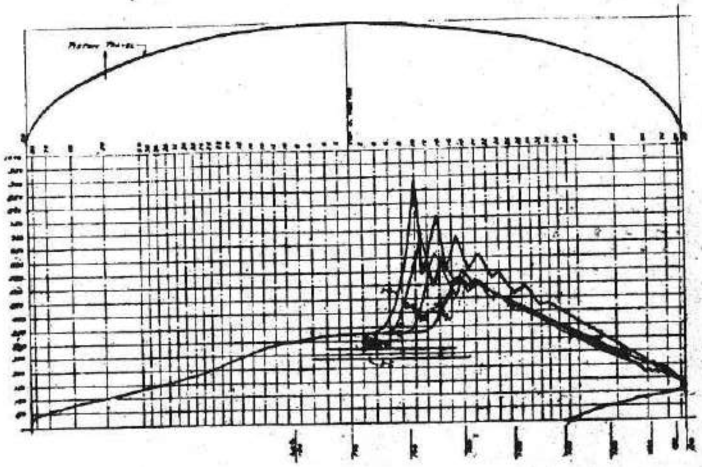


FIG. 13.

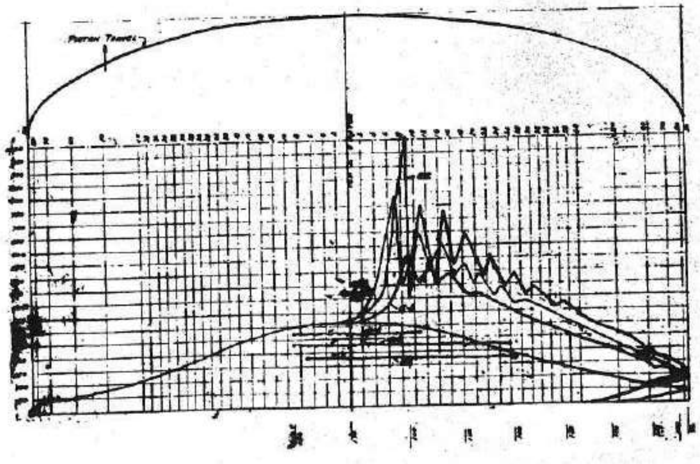


FIG. 14.

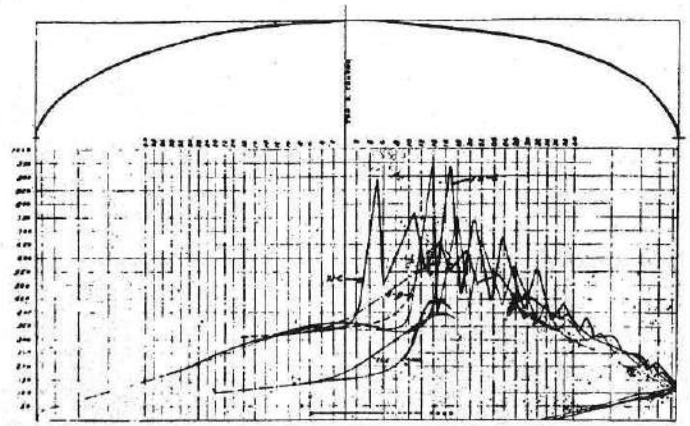


FIG. 15.

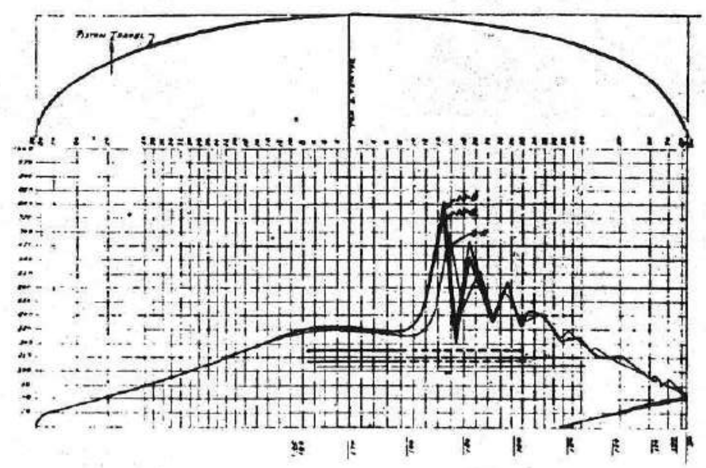


FIG. 16.

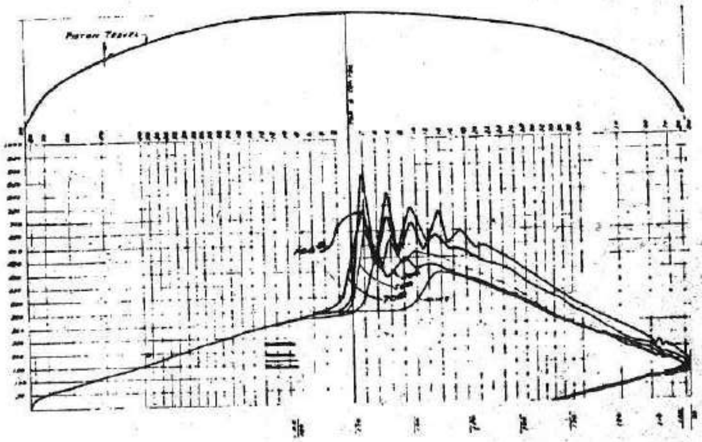


FIG. 17.

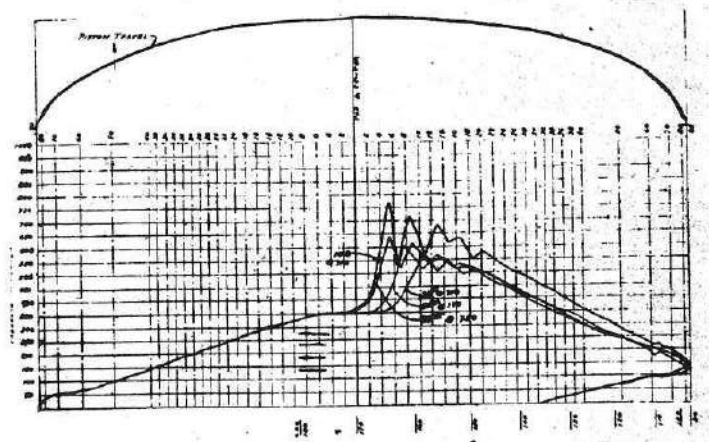


FIG. 18.

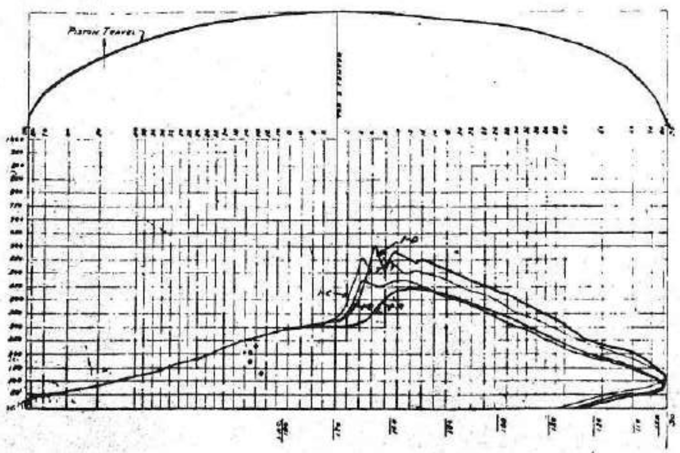


FIG. 19.

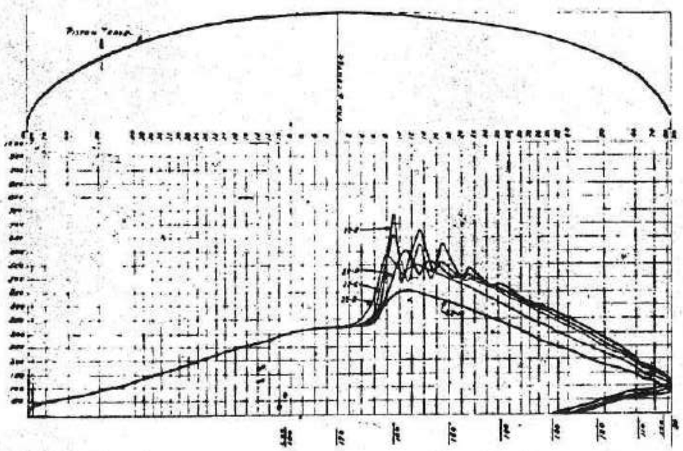


FIG. 20.

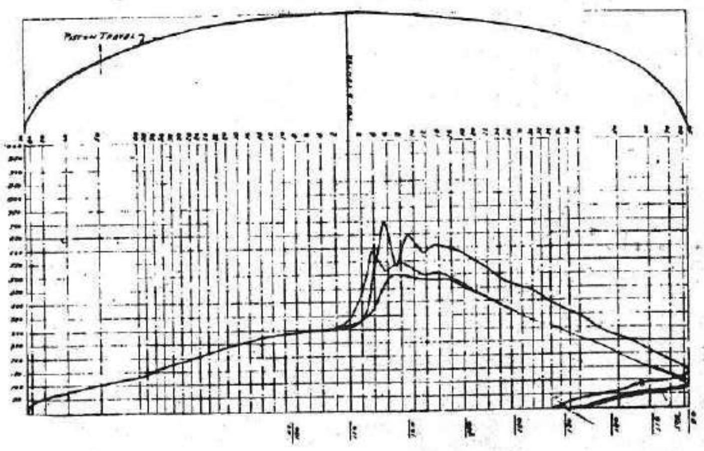


FIG. 21.

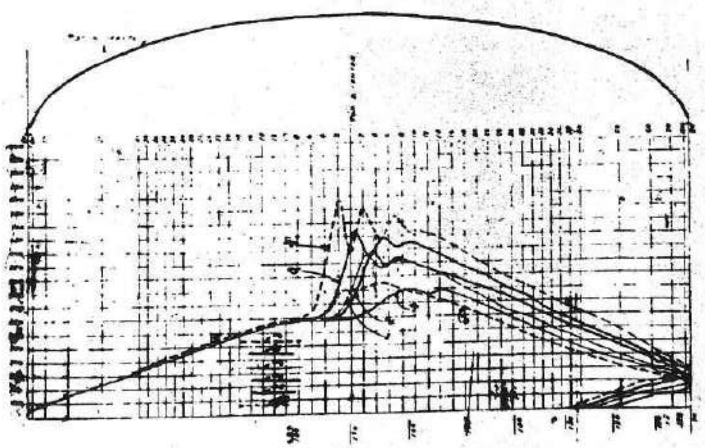


FIG. 22.

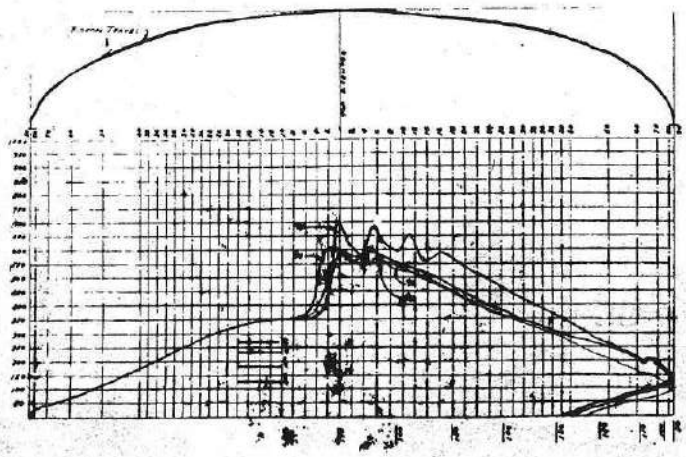


FIG. 23.

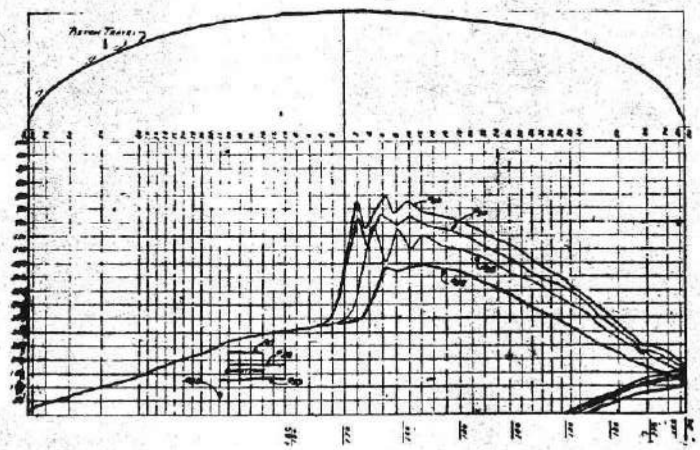


FIG. 24.

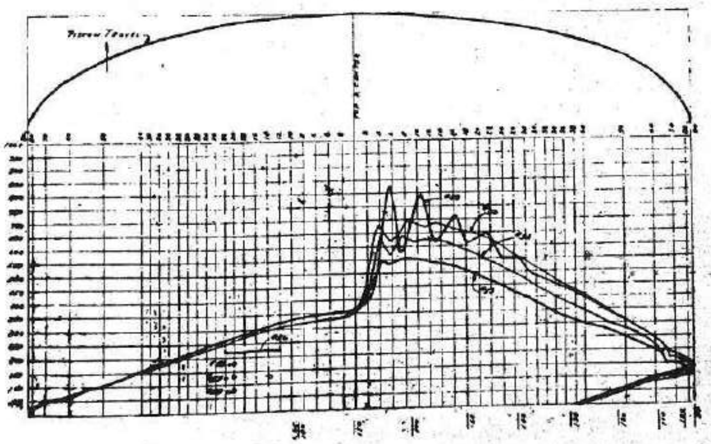


FIG. 25.

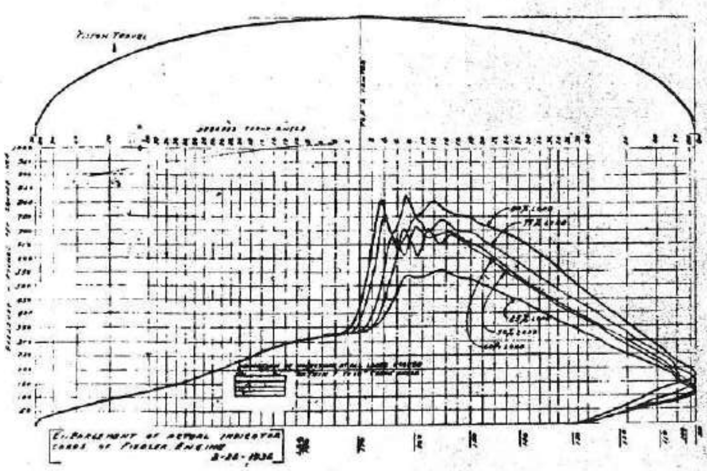


FIG. 26.

Fig. 13. Multiple hole nozzle, 1,800 lbs. opening pressure.

Fig. 14. The same nozzle but higher opening pressure. *Knock is more pronounced due to higher pressure and greater degree of atomization.*

Fig. 15. Check on rate of pressure rise for violent knock. *Rate not more than in gasoline engine without knock.*

Fig. 16. Long duration and high injection pressure. *Causes ignition delay and in combination with fine atomization strong knock.*

Fig. 17. Phase cards with short duration and medium nozzle pressure. *Combustion characteristics good at low loads but disappointing at higher loads.*

Fig. 18. The same conditions but change in orifice. *Gives improvement.*

Fig. 19. The same valve but change in combustion chamber so spray is located farther away from cylinder walls. *Decided improvement.*

Fig. 20. Same condition with increased injection pressure. *With increase in atomization, combustion becomes worse, knock stronger.*

Fig. 21. Same condition but larger orifice; meaning less atomization. *Decided improvement.*

Fig. 22. *More improvement due to increase in orifice length; better penetration and mixing of fuel in air.*

Fig. 23. *Less spray holes gives improvement in spite of higher injection pressure:* fewer ignition points.

Fig. 24. *More improvement due to still larger and longer holes.*

Fig. 25. *Further improvement with same condition due to very heavy injection spring:* better control of injection.

Fig. 26. Shows best performance at that date.

This investigation showed that to get good combustion everything had to be done that was contrary to generally accepted practice.

First—the spray holes had to be kept very large. In this case, for a fuel quantity injection per stroke of 100 cu. mm.—6 holes of .8 mm. diameter were used. The holes had to be especially long. A length-diameter of approximately 8 to 1 was used. Due to very heavy special springs, the injection pressure for all loads could be kept as low as 1,200 lbs. per sq. in.

(*To be continued in February issue.*)

A NEW THEORY OF COMBUSTION IN DIESEL ENGINES.

BY

MAX G. FIEDLER,

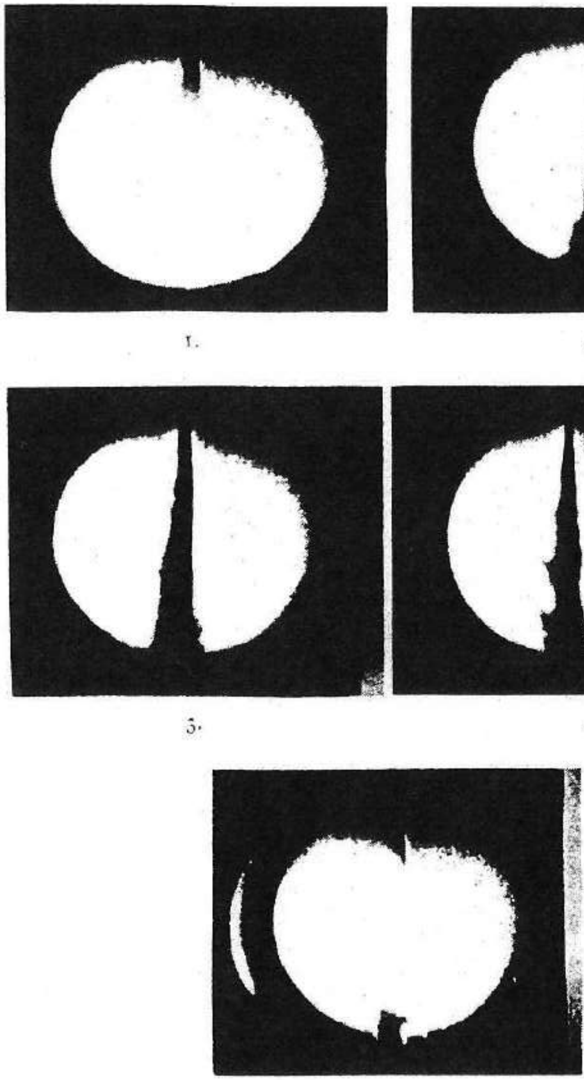
Vice-President, Fiedler-Sellers Corporation.

(Continued from January issue.)

What were the industry's engineers doing? They were building Diesel engines, and the general conception was that they ought to know all about it. I went to many lectures—one in Philadelphia—hoping to learn something. The lecturer usually started out and said, "Now, we have a Diesel engine of great economy, and so forth—they are a little heavy, but I'll show you what they do." And he would show a picture of some kind of pre-combustion chamber, and another and still another, and by the time he was through he had shown some 20 different chambers, and I was on the verge of saying, "Why do we need all these chambers? Why does everybody do something different—what is wrong with the situation? None of these chambers is really any good."

I went to one such lecture where I hoped to get the answer, and the answer was this: Everything that is good for a Diesel engine is bad for a gasoline engine, and everything that is good for a gasoline engine is bad for a Diesel engine. I felt very depressed. When the discussion came up one engineer would say, you need high compression—make it as high as possible. The next would say you only need 400 lbs. The next would say, "I get away with 120 lbs." Or one would say, "We need long duration"; another that we need short duration, etc., and I was so distressed because I felt that friends of mine, engineers, would go back and having those discussions in mind would go to the industry and necessarily unsuccessfully spend more money and time. So in one of these discussions I got up and said, "Gentlemen, I have to say something that you will not like, but anything you have said here is contrary to my experience."

This was taken rather as a joke; so I tried to give another lead. I said, "Gentlemen, what do these irregular pressure lines mean?"

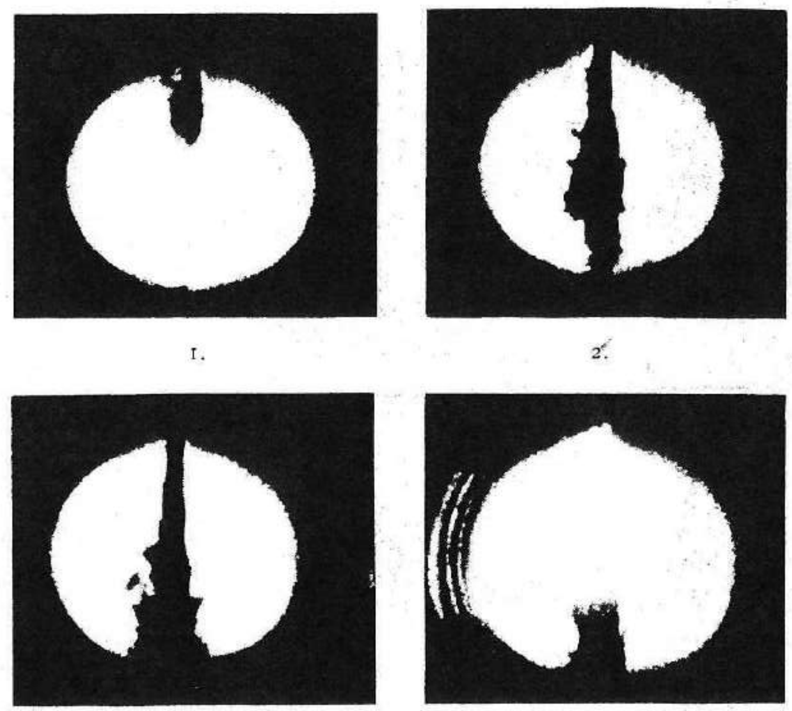


1. 2. 3. 4. 5.

Single spray small orifice.

The answer was, "Oh, those are indicator vibrations; if Mr. Fiedler would put a weight on the end of the indicator arm, these vibrations disappear."

So, you see, the engineers, at that time, were sitting on the indicator, making the indicator say what they wanted it to say, what they wanted to see; making the indicator show



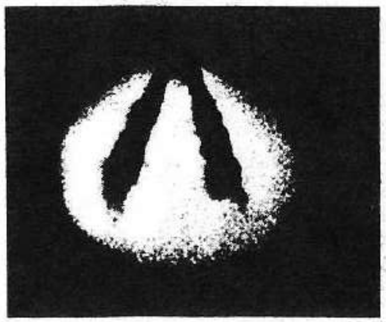
1. 2. 3. 4.

Single spray large orifice.

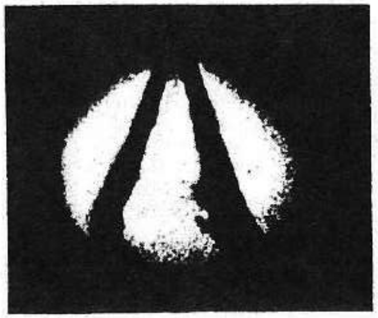
them what they wanted to see; not what the indicator was trying to show them.

I have a film here that I want to show you. It was taken by the N.A.C.A. I saw it, and the peculiar thing was that what the engineers wanted me to see, I didn't see at all. In fact, it wasn't of any importance—but what I saw which was of extreme importance they didn't pay any attention to.

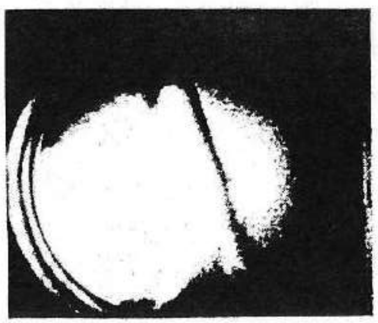
If I showed the film as it was taken, it would lose its effect, so I have rearranged it. You will first see appearing on the screen a white disk, representing the combustion chamber. Then you will see the discharge of a single orifice into that chamber, under high compression into extremely high turbulent air. You will see a single spray discharged



1.



2.



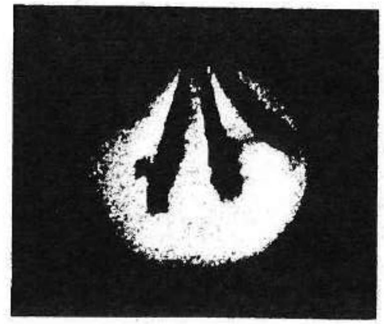
3.

Double spray.

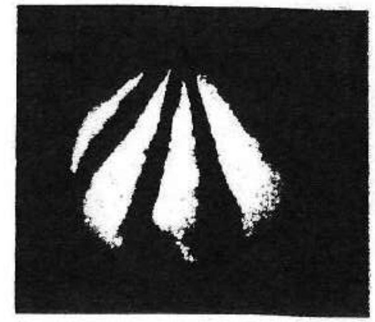
out of a small hole, then out of a larger hole, and then out of two and four holes, and so forth. I would like you to watch that spray very, very carefully, because it gives a clue to what happens, and to what was apparently overlooked for years. I would like to have that film now.

. . . The film followed during which Mr. Fiedler made the following remarks . . .

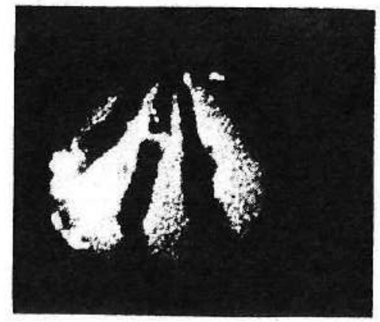
You see that the spray penetrates the whole chamber a that the turbulent air apparently has no effect on the spr formation itself. You also see that there are no indicati of the hydrocarbon igniting in spite of the fact that t air temperature is way above the flash point of the i jected oil. This condition holds true for every nozzle, an



1.



2.



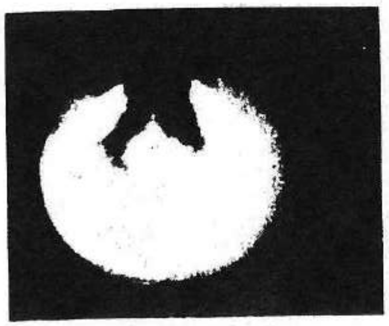
3.

Four spray holes.

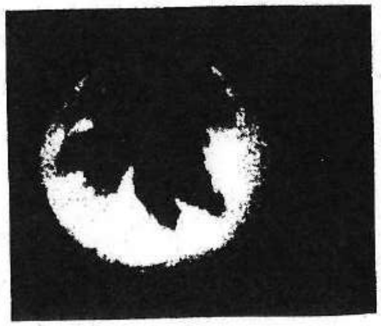
although the size of the orifice (referring to the first an second series of single spray hole injections) has an effect o the characteristic of the spray, it does not seem to have an effect on the ignition point.

Most interesting is the film of the 4-hole discharge. Yo will see that somewhere in the chamber with no relation t the actual spray, white spots appear indicating a part reaction. This part reaction will give us another clue which we will analyze later.

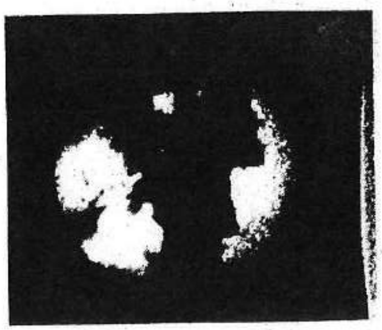
Even the last series, which represents a slot valve, and in which case you know the fuel spray is very finely divided and very thin so it can be easily reached by air, shows that



1.



2.



3.

Slot nozzle.

the temperature and surrounding air has no effect on the spray, and does not induce combustion.

. . . End of film . . .

Now Gentlemen—what you have seen there—I don't know if you realize it or not; but that spells the doom of the Diesel cycle, and I will explain why.

When Dr. Diesel had his first idea, the fundamental efficiency of his cycle depended on the possibility of adding

heat at maximum temperatures and pressures at the rate of conversion, meaning at the rate at which the heat would be converted into power. This meant that he was going to

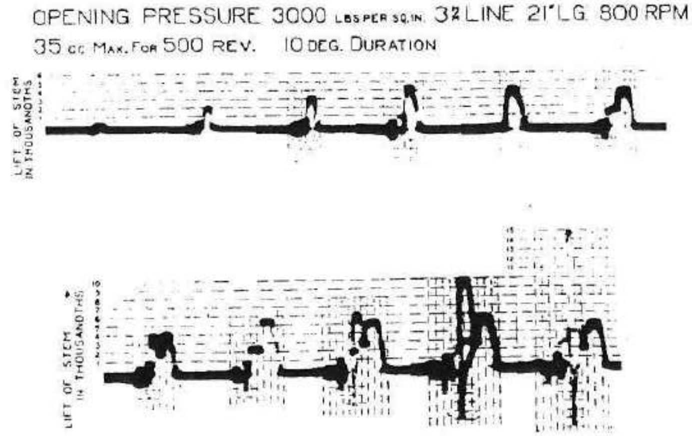


FIG. 27.

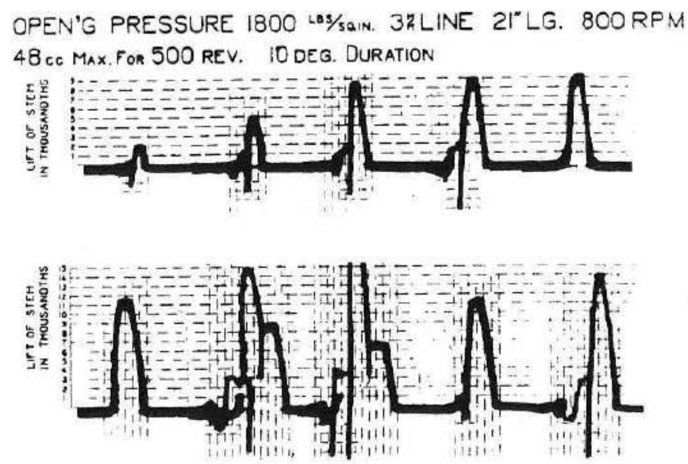


FIG. 28.

control combustion by the rate of admission of the combustible matter into the combustion chamber. Nobody at that time—they might have doubted everything else Dr. Diesel said—doubted that if you have air at temperatures of 2,000 or 3,000 degrèes, as he was playing with, that anything that burns, injected into this air would immediately ignite and cause

OPEN'G PRESSURE 1625 LBS/SQ.IN. 3/8 LINE 33"LG. 475 RPM

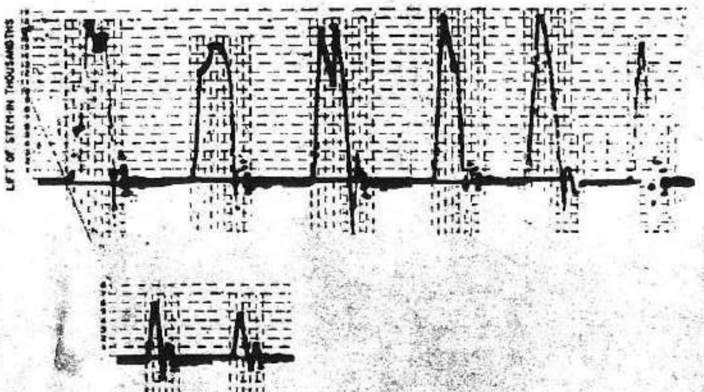


Fig. 29.

OPEN'G PRESSURE 1625 LBS/SQ.IN. 3/8 LINE 33"LG. 950 RPM

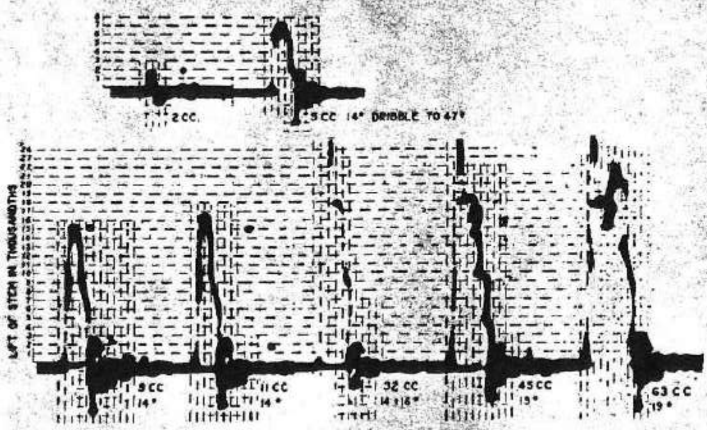


Fig. 30.

combustion, and it is almost fantastic that this vital error in Dr. Diesel's plans was overlooked.

The realization that combustion could not be initiated by introducing combustible material into high temperature air was very depressing to me. I would not have had any hope that there would be a solid injection engine that could have any permanence at that time if it had not been that occasionally we would see cards that looked presentable. Why, we didn't know. We already knew that we had to do everything radically different from accepted practice to get indications of good combustion. For instance, use 4 or 5 mm. fuel lines as

Run # 477

Type of Nozzle	[redacted]
Type of Cam	STANDARD
Spring Size	[redacted]
Dia. of Line	4 m/m
Opening Pressure	100 KG
Inj. Pressure	
R.P.M.	850
Quantity	20½ c.c.
Duration (Stroboscope)	6°
Inj. Start	0

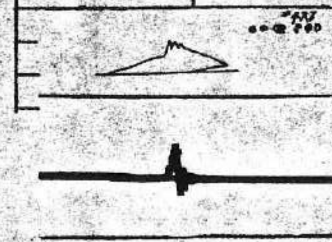


Fig. 31.

Run # 478

Type of Nozzle	[redacted]
Type of Cam	STANDARD
Spring Size	[redacted]
Dia. of Line	4 m/m
Opening Pressure	100 KG
Inj. Pressure	
R.P.M.	850
Quantity	29 c.c.
Duration (Stroboscope)	8°
Inj. Start	0

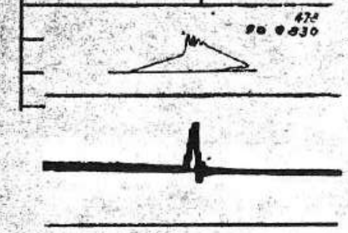


Fig. 32.

against the recommended ones of 1 or 2 mm. inside diameter; use low injection pressure, and heavy springs; tremendously out of proportion, heavy springs on the valves. But we didn't know why.

So we decided to follow these very meager leads and built an apparatus which consisted of a box; in this box was a stroboscope, and on top of the box was an optical indicator. We photographed the stem movement of the valve itself while we were looking at the spray that was produced by the nozzle. I will show you now some of these photographs that we took of valve stem movements (Figs. 27, 28, 29 and 30).

These are the records of this procedure. Figures 31 to 35 show various loads at approximately the same speed. There was noticeable detonation although not violent enough to be destructive. Figures 36 to 39 show the same records with a different valve combination. The performance of the engine

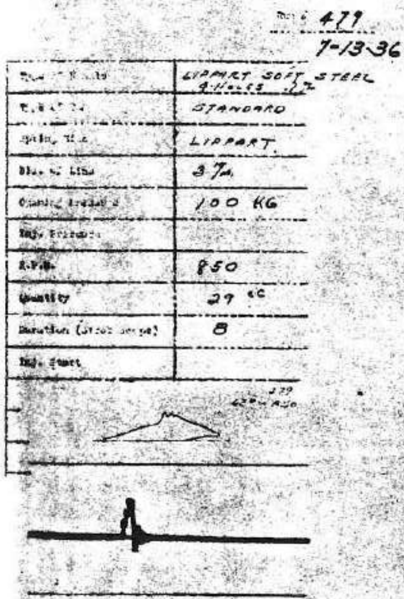


FIG. 33.

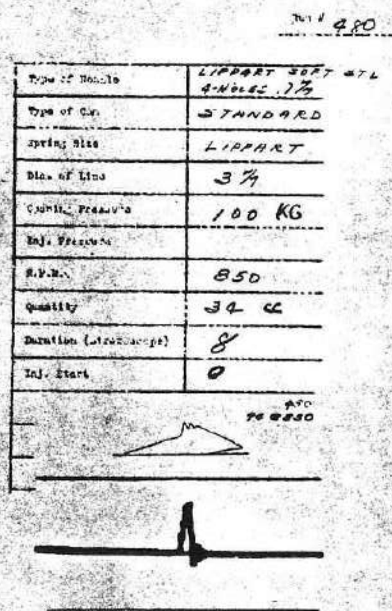


FIG. 34.

was better and any noticeable knock or detonation had disappeared. We arrived at this valve combination by looking at the spray formation and out of a whole group of valves, this particular valve gave us a definitley different characteristic. This induced us to try this combination and the diagrams show the results.

Now let us see what we learned. We learned first of all we had to have instantaneous injection and had to try and avoid too much atomization. That apparently was poison. We had to see that the spray did not hit any hot spots in the cylinder. In fact the spray should not come close to any hot centers.

Then we started thinking that something must happen to the fuel itself when we injected it; and it just so happened that I met a very outstanding chemist and I asked the following question. "I am puzzled. I don't know what it is

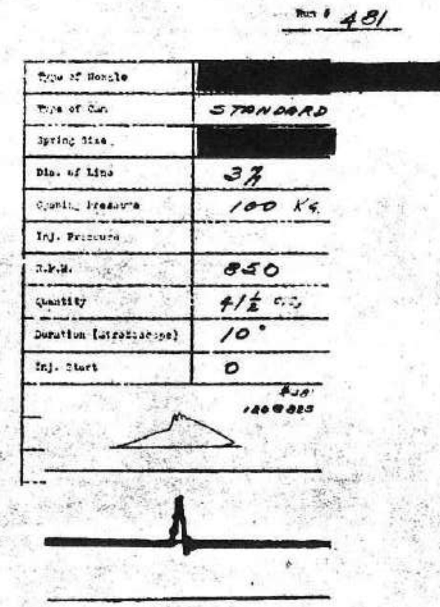


FIG. 35.

all about. Anything we find in our investigation is absolutely contrary to the standard conception, but it works."

He took out a piece of paper and said, "When you get detonation, do you get these zig-zag lines?"

I said, "Yes. Why do you ask?"

He said, "I would imagine if you had a hydrogen explosion that that is the kind of card you would get."

And then we went home and took out a handbook and looked up under the page "Combustion" and were slightly baffled. It was right in front of our eyes. It said if you take hydrocarbon and mix it with air and bring it up to certain temperatures, you get complete combustion, but if you expose the hydrocarbon to temperatures without the proper air being present, then the hydrocarbon will dissociate into free hydrogen, marsh gas and carbon. The carbon comes out of the exhaust and the hydrogen after it has formed the correct auto-ignition mixture, will cause detonation.

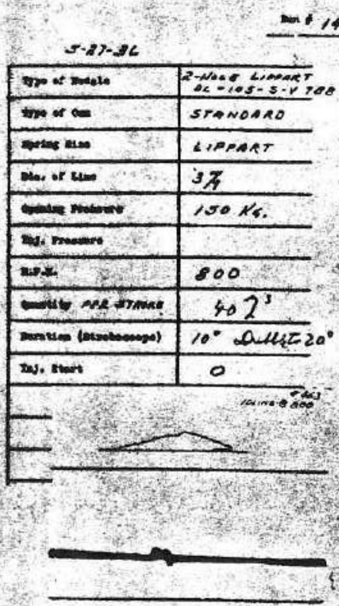


FIG. 36.

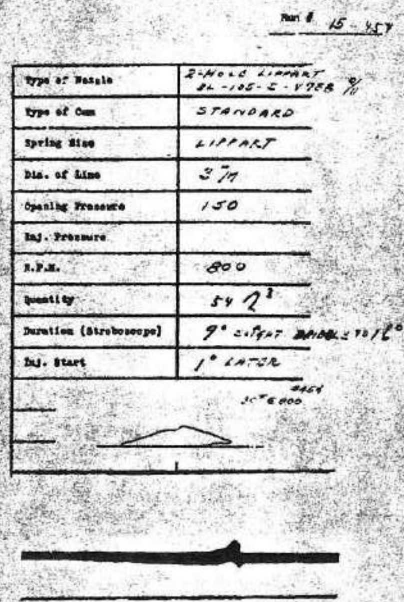


FIG. 37.

Now how does this fit into the picture? Let us take the standard Diesel engine. You will see that we poked the fuel into the combustion chamber in the form of a stick. Now we have all held a stick over a fire when we were kids—and this is what happens. The stick starts to discolor; then gradually fumes start bleeding off. These fumes will not catch fire unless you hold the stick farther away, where there is oxygen available. Then they will puff off. If you keep it up long enough your stick will be in your hands in the form of a stick of carbon.

That is exactly what we have been doing in the case of the Diesel engine—we have been sticking a piece of hydrocarbon, finely atomized, into air of approximately 1,000 degrees, and have forgotten all about our experience with gasoline engines.

Some of you might remember when you had to carry a little squirt can around to start your gasoline motor. You

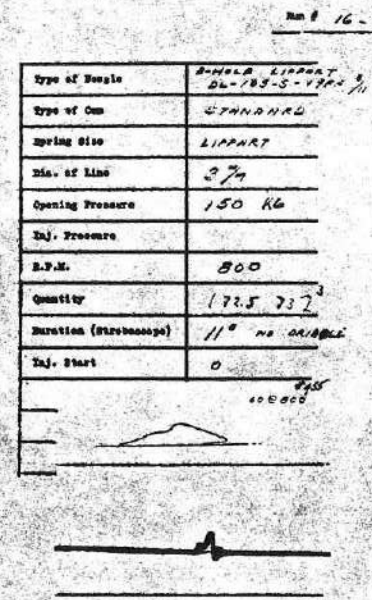


FIG. 38.

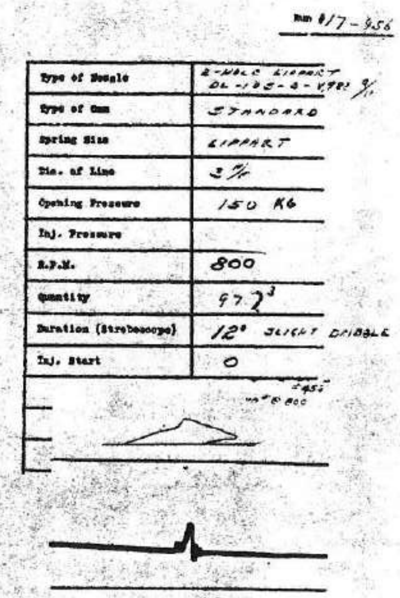


FIG. 39.

remember two squirts were just enough. If you made it two and a half the motor would not start. Why? Because it did not make the correct mixture in the cylinder. Today we have a starter. We push on the starter, pull the choke, and if that doesn't help we get somebody to push us.

In the Diesel engine we have an identical combustion reaction—we can't expect any combustion until we establish an auto-ignition mixture, because we don't have even a spark, and if we don't establish an auto-ignition mixture before the hydrocarbon reaches its critical temperature we bleed off free hydrogen and get the so-called Diesel knock. That explanation seems simple now that we know the answer and since we know that it is correct. We know now how to make the engine work in that way, but imagine the damage that such a simple, wrong analysis has done to the industry.

Take the Diesel equipment industry. Years ago a man with tremendous foresight knew there would be a field for Diesel engines and started building injection equipment. His firm, and ultimately other firms on a license basis, built this equipment mechanically perfect but to the specifications of the industry and with the wrong conception of Diesel combustion. What happened? Some manufacturer of gasoline engines said, "I think the Diesel is here to stay—I ought to get busy building Diesel engines. Well, I can build everything but the injection equipment—I'll buy it from this firm and profit by its experience."

The manufacturer would put the injection equipment on the engine and the performance would be terrible. The result was he would blame the injection equipment manufacturer. But the injection equipment manufacturer had given the industry what it demanded. That the analysis was wrong was not his fault. If the Diesel engineer had given him the right analysis he would have manufactured the other equipment. But this mistake has in effect cost the industry millions of dollars because as in this one case, as in many others, the engine that was supplied with that standard injection equipment automatically could not give satisfactory performance.

I will now show you a slide of our nozzle development (Fig. 40). It shows several phases of the nozzle development which we had to go through before we reached the final stage.

No. 1—is a standard valve and corresponding indicator card. No. 2—is the first modification. This modification already gave good cards at low speed. No. 3—is the next modification, after which we started building our own valves. Finally we came to No. 7 which seems to be the best that we can do today. Now to give you an idea how disastrous this whole situation has been, I would like to show you another slide. I don't know if you'll recognize it.

Fig. 41. In 1930 an outstanding firm announced, "We have the Diesel aircraft engine—we have an engine that will revolutionize air transportation." And among the publications was this—(Diagram)—I have saved it—they stated. "We have developed the aviation Diesel cycle." The only trouble with this diagram is that there are only two possible points which are correct, the highest and the lowest, and the engineer connected these points to suit himself. The tragedy lies in the fact that millions were spent by this firm and en-

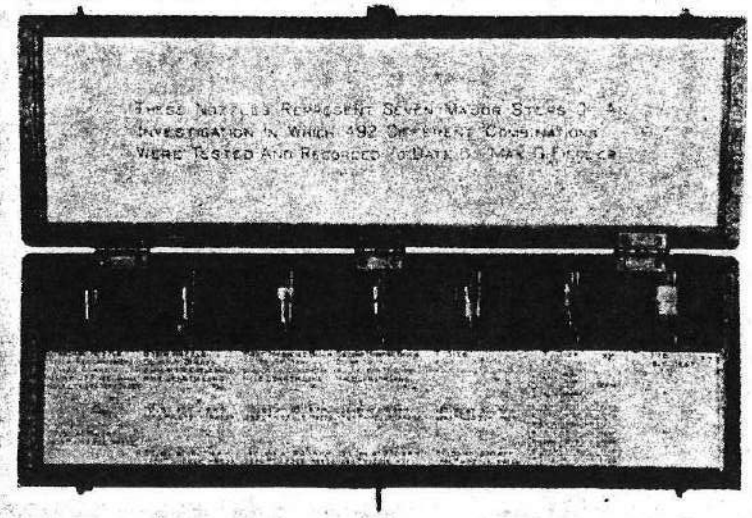
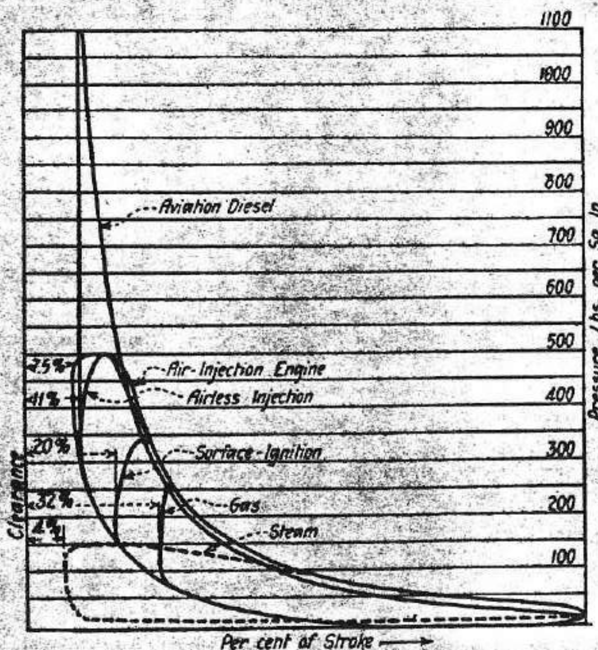


Fig. 40.

gines actually built on that cycle, and construction patents taken out which would permit the engine to stand up under these terrific stresses. It was not surprising that this engine was a failure. You cannot hold an engine together under combustion conditions that are accompanied by as violent detonations as in this specific case.

Now what is the value of all this information to the industry? We can say this much today—we can produce decent combustion. We know what it should look like on an indicator card and we know what causes it. We don't know everything: we have a lot to learn. It will take some time before we can be fool-proof, if ever, in our diagnosis. But let's keep the following conditions in mind.

Fig. 42. This one card is close to what the aviation cycle would look like if the engineer had drawn the correct diagram. The card on the right, superimposed, represents good detonation-free combustion.



Practical engine cycles

FIG. 41.

I showed these cards once before, and I was told they were faked. That is why the originals are reproduced on top. It might be interesting to know that they were both taken at the same engine speed, namely, 1,500 revolutions. The one card with violent pressure variations and strong detonation represents no load with a conventional injection equipment and nozzle. The other card represents 90 lbs. b.m.e.p. after only the injection equipment was changed.

Now I don't want you to say, "Send a nozzle and the engine will be perfect." The engine has to be analyzed—the combustion chamber has to be right, and you have to do some experimenting with the valves to locate the spray properly in the cylinder and avoid hitting any surfaces at all because if you hit surfaces you get vaporization of the fuel, and that vapor exposed to high temperatures will cause dissociation and the resultant Diesel knock.

If what I told you tonight means anything at all, I don't want you to feel that I take credit alone. I want to say

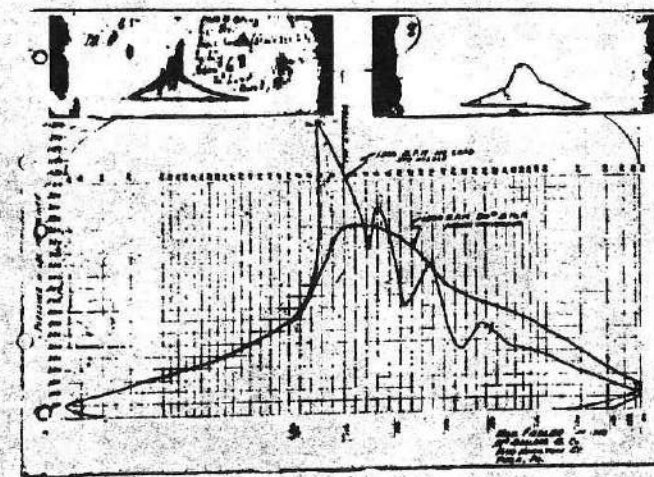


FIG. 42.

that a large amount of the credit goes to those who, at moments when I was almost despairing, believed in the sincerity of my work and due to their friendship gave me the courage to continue.

I thank you.

CHAIRMAN WETHERILL: Ladies and Gentlemen, the meeting is now open for discussion. Is there any discussion?

MR. H. FISCHER: I have been in the Diesel game since 1906. I was with a company which up to the time of the world war built about one million horsepower. The company during the war developed an air injection submarine engine of about 420 mm. stroke. The combustion of these air injection engines is the most perfect I have yet seen. You get an indicator card like that (drawing on board). I couldn't see anything wrong with that combustion—in fact I have not been able to find any engine able to produce this combustion. We atomized and mixed the fuel properly so the instant it left the nozzle it burned. In fact the nozzle opened here (describing from diagram) between 2 and 3 degrees top center, etc.

Of course people have the conception that in an open chamber engine we have to inject very fine, very finely atomized and I agree with Mr. Fiedler that this conception is wrong. His idea is quite right because you set up a high temperature and the fuel will dissociate as he has shown.

Now, I am representing a company which produces equally good cards—I can't duplicate them every time, maybe, but I have to congratulate the author for his excellent work, to be able to produce an indicator card with that very slow pressure rise in that open chamber type of engine.

CHAIRMAN WETHERILL: Is there any other discussion? If not the Chair recognizes Professor Sloan of the Mechanical Laboratories of the University of Pennsylvania.

PROFESSOR SLOAN: I don't know why I am asked to discuss this, because there is very little more I can add to what Mr. Fiedler has said.

He didn't draw your attention to something which possibly has some effect on the analysis of this last speaker's card here. He is dealing with a two-cycle engine running possibly 2,000 r.p.m. whereas the other gentleman speaks of a 4-cycle engine with half the number of injections per minute.

As I say, this man has given you a rather unusual type of paper this evening. I wouldn't call it a paper because he did not read it. But it is unusual in this respect. The majority of scientific discussions cover some one little phase of experimental work over a period of possibly anywhere from, in our field, maybe only three months, because we are constantly asked to write papers. He, however, tries to tell you in one hour what I know he has been working on over ten years, and it is remarkable and unusual in that respect.

He left out a lot of things—a lot of things he might have said. The development of his engine first, his first conception of it, and I will thoroughly endorse what he said about the little three cylinder gasoline engine that you saw on the screen. I was amused when he first brought it to our laboratory—I was amused when I heard it was coming to the laboratory, because we had at that time so many of the terrible crank case, two-cycle engines coming to the laboratory that I was thoroughly discouraged and had no desire to test the engine. When I first saw the engine I wasn't so sure, and when I saw it run, I was convinced that it was the best I had ever seen—and I haven't seen anything like it since.

When he started to work with the engine which he said was a failure—that is the one where he comes to use a mixture in a separate cylinder, and forces it over to the power cylinder—the first idea of course was to use gasoline. When he decided that that was the thing, that that particular construction could be used as the basis of high speed Diesel engines, I was myself staggered with the idea. I could not possibly conceive, in view of what we knew ten years ago about injection, what we were going to do about injecting oil into the cylinder and burn it properly at the speeds of 2,000 or 3,000 r.p.m. You, in the game, know, in 1928 there was no such animal on the market and nobody was dreaming of making 2,000 injections per minute into an engine. When I pointed it out to Mr. Fiedler that the tough part of the whole job is going to be the injection problem, he agreed at the time, but decided we would have to let that take care of itself when we got to it, hoping, I suppose, possibly, that somebody might have an injection system by the time he was ready for it.

Some time before that engine was made, I had the honor of having a chance to discuss it with a representative of one of the largest organizations in the country. This man is supposedly a high speed engine man, and while his reputation had been acquired in the gasoline engine field, he nevertheless had been charged with the duty of watching the developments in the Diesel field. I went thoroughly over the drawing—the engine had not been built at the time—and after a night's discussion he finally told me about 4:00 o'clock in the morning that he was sorry to see anyone spend so much effort on such an engine, because he was of the opinion it wouldn't even run.

I bring that to your attention for the following reason: I am surprised that the man, even though not a Diesel expert, should have overlooked the most important part of the whole thing. That was not the mechanical construction of the engine nor the method of supercharging, but the difficulty of obtaining an injection and combustion in such a cylinder head, such a chamber, at such terrific speeds. But it never entered his mind at all. He just had an idea because of the peculiarity of construction, it wouldn't run. I have often been sorry he couldn't have been standing beside us a while ago, and am sorry that we couldn't corral him about the "engine that wouldn't run."

Now, about this remarkable paper—not remarkable, but unusual. He hasn't told you all the grief, by any means. There is always one headache after another in the development of such a thing. But he has been in this work a great many years and I move, Mr. Chairman, that we congratulate him and thank him. (The motion was seconded and carried.)

Chairman Wetherill: Mr. Fiedler, you have our profound thanks.

The meeting stands adjourned.

. . . After adjournment the meeting was again called to order by the Chairman . . .

Chairman Wetherill: Mr. Berlyn, from Canada, has a few remarks he would like to make in discussion.

Mr. Berlyn: There are one or two points on which I would like to have Mr. Fiedler's views. I understand that he attributed the cracking, the distillation, the dissociation of the hydrocarbon fuel to its being injected into a volume of highly heated air, and that would imply that in order to avoid that process of dissociation it would be an advantage if the air were not so hot, or possibly a reduction in temperature of the air charge could be arrived at by reduced ratio or some change in the conventional designs, both of which alternatives might result in reduction of the thermal efficiency of the engine. If you increase, for example, the potentialities for heat flow from the air charge, you are throwing perfectly good heat away that you have paid for in fuel oil.

Now another point, and that concerns cold starting. Now for some reason or other the people who buy Diesel engines set store by the attribute of cold starting. I am not so sure, myself, that it amounts to much because there are a number of admirable aids to starting which are marketed as proprietary articles, but certain designs of engines with pre-combustion chambers have been criticized that they are not cold starters really, and are fitted with a gasoline starting engine, and the cooling jackets of the starting engine are hooked up with the cooling jackets of the main engine. It has been said, in fact, that the function of a starting engine is not so much starting engine as a stove. It seems to me to be going a long way to start an engine that way.

But it seems to me if you are trying to avoid dissociation of the fuel into component hydrogen and methane and carbon, that the measures you will have to adopt would mitigate against the cold starting and possibly against the best thermal efficiency. I personally have found, for example, that an easy start can often be made on a reducted engine by increasing the fuel valve opening pressure. Anything, in fact, which will make a finer spray, which I believe is the condition which Mr. Fiedler would avoid because it is a condition conducive to dissociation of the fuel.

Now I would like to know if Mr. Fiedler is hopeful of retaining all the virtues of good cold starting and high thermal efficiency, which have been attributed to open combustion chamber Diesels of large size.

Mr. Fiedler: I think those were two very intelligent questions, and I thank you for asking them, because it brings out certain points I could not bring up before.

It is quite true that we try to operate at the highest possible compression ratios, of course in all of these kinds of problems we have to compromise. What we want to do, and what we have to do, to get decent combustion is to inject the hydrocarbon instantaneously. That is what we try to do. We want to inject it so it is in liquid form at the lowest temperature range possible so that it has a lot of time before reaching the cracking point. It should go in in liquid form in small drops, as small as possible although there is a limit to that. We know if you raise your venturi speed in a carbureter beyond a certain point, the atomization of the gasoline does not help the efficiency any more.

As far as the chamber itself goes, the ideal condition would be a chamber with a non-conductor at the surface backed up by a high conductor to prevent heat accumulation. We do not want hot surfaces, which are hotter than the air temperature at the time of injection. That is the important point. We don't want to raise the air temperature through hot spots in the chamber itself, and the cooler we can keep the chamber, the higher we can go with the compression ratio.

There is only one thing of importance; that is that the right auto-ignition mixture is formed before the hydro-carbon reaches the critical temperature. Now that, of course, ties in with the starting. I think it is correct that the salesmen invented that cold starting idea. As far as I know, there is no cold starting Diesel engine. The engine that carries the highest compression ratio is the Junkers—the cranking speed and starting compression are slightly over 360, and if the temperature gets down to 10 degrees above zero, that engine won't start if you crank your arm off. If you realize that, I would say a cold starting engine would be one starting at 10 degrees below zero, and you have to use engineering brains to overcome that condition. You should choose the compression for the best efficiency of the engine, and then find means for easy starting—because there is no cold starting Diesel.

I think that answers the two questions.

DR. MAGDEBURGER: I would like to rise in the defense of a mechanical explanation of the jigger lines on the card. I grant you you may be right, but why did the jigger lines appear on the indicator card of an air compressor (drawing) like this, for example—where they are evidently inertia effects of the valves, and for similar reasons they are evidently or quite possibly may be inertia effects on the masses of the indicator. That is Number One.

I want to ask you also for an explanation of why violent explosions would occur in starting, on the air injection engine, presumably all the air injection engines. The explanation we have was because (drawing) frequently the piston chamber is made like this, and a leaky valve accumulates quite a product up here. How does that fit in with your idea?

MR. FIEDLER: As you say, when you start a Diesel up you accumulate fuel by faulty injection or something. Now what happens? You have exactly what you don't want—you have fuel which has accumulated on some surfaces, you expose this to compression heat over a long time, during the whole compression stroke, and the result is you get vapor.

DR. MAGDEBURGER: Off the flat surface?

MR. FIEDLER: Sure, off the flat surface, and that is the vapor that causes the engine to knock.

DR. MAGDEBURGER: Violent explosion?

MR. FIEDLER: I say "knock"—of course, it might knock off the cylinder head. But that is a typical accumulation—you can produce it any time. That is the reason Dr. Diesel's engine was destroyed. He had that condition in his engine and the moment the vapor bled off enough hydrogen it caused the explosion.

DR. MAGDEBURGER: And what do you think of that inertia effect of the masses on the sudden pressure?

MR. FIEDLER: You mean what causes the jiggle? The mechanical effect on the structure or the inertia effect?

DR. MAGDEBURGER: The valve must be accelerated, when it is here it has to go down considerably before it is lifted (Referring to previous diagram).

MR. FIEDLER: This is the indicator card.

DR. MAGDEBURGER: And the same way when it is compressing.

MR. FIEDLER: Now don't you think that the air column might do that, due to the closing of the valves?

MEMBER: Yes, but it shows that same effect of acceleration of masses may exist, which doesn't require your explanation of explosion.

MR. FIEDLER: Yes, but at the time where there is a change let us say in the air column, but not in the combustion.

DR. MAGDEBURGER: That isn't a combustion chamber.

MR. FIEDLER: I know, but the air flutters, and that causes an air motion and the indicator registers. Isn't that correct?

DR. MAGDEBURGER: But the valves themselves flutter. Why wouldn't it be so at high speed?

MR. FIEDLER: We don't have anything that flutters. I want to show you something you might not have realized on the cards. You might have seen that the card looked like this (drawing) and coming down here, and you get a jiggle down here. We thought at first these little jiggles were due to the indicator. Then we checked it and found this point matched he point at which the supercharging port is uncovered. There is a vapor accumulation in the pocket and that causes he indicator to register in that manner. If an indicator can egister 40 lbs. difference in pressure at that point, it is going o be pretty accurate at high pressures.

Here's another thing. It doesn't make any difference if he jiggle lines are correct or not as long as they correspond o a condition which destroys the engine, and the indicator shows us this other characteristic when the engine runs smooth (Diagram). That is all we want to know—we don't care about the absolute indication of the instrument any more.

CHAIRMAN WETHERILL: May I ask this: If you take a pressure diagram on an Otto cycle engine (drawing diagram) with a knocking fuel, you get this wiggly line. Now if you put tetra-ethyl lead in the fuel you get that (describing)—all right, why is that? That is caused by the valves, isn't it?

MR. FIEDLER: That is not caused by the valves. Let's take (drawing) on "L-head" motor. Here are the valves. You buy your car and she doesn't knock. Then after a while she starts knocking and you go to the garage man and he says you have carbon in the cylinder and you will have to have the carbon removed.

"What does the carbon do?" you say. And the answer you get from an automotive engineer is, "It raises the compression." And they tell you that is due to accumulation of carbon in here. That is absolutely ridiculous because the amount of carbon is so small it won't have any effect on the compression pressure, but what it does do is that during the intake stroke your carbon deposit being here—the gas is drawn in during the intake stroke and part of the spongy carbon soaks it up. On the compression stroke that gas is given off as vapor, and if you look at photographs of combustion under these conditions you will find that it starts here (near the spark plug), and then suddenly you get a white flash over here (at the other side of the chamber). This last reaction causes the detonation. What happens if you add tetra-ethyl lead? We know now that we can take a hydrocarbon apart and put it together again in some other arrangement, using the catalytic action of certain substances. Well all you do with tetra-ethyl lead is you add lead as a catalyst,

and raise the critical temperature of the hydrocarbon so it will not give off free hydrogen at operating temperatures and then the knock disappears.

MR. BERYLN: I would like to make one observation on the matter of starting a cold Diesel. On a larger engine the area of the boundary walls to the volume of air is so much lower that the heat of charge is conserved to allow it to do a job of vaporizing the fuel. The condition of the engine makes a difference again. I had a small engine that was difficult to start in cold weather and I was curious to know how much could be achieved by polishing the boundary walls of the combustion spaces. I not only cleaned the lampblack off, but I polished it, buffed it until it looked like a mirror in one cylinder, only, and I put it together and started it. It ran lustily on one cylinder whereas the other three didn't pick up. I shut it down for a while and let the whole engine get cold and started it up again, and I had to run to 500 r.p.m. on one cylinder, which was overloaded, and then, one by one the other cylinders cut in.

On a subsequent shutdown I polished all of the walls and when I started it up again it hit on all cylinders, and at a low temperature—and we get plenty of opportunity to start an engine in cold weather in Canada, where lubricating oil has the viscosity of a phonograph record.

I would like to ask Mr. Fiedler a question that has been on my mind. In connection with Diesel knock Mr. Fischer referred to a very low rate of pressure rise as expressed in pounds per square inch crank throw. One has heard that if you can keep it below even 30 lbs. to the square inch that combustion will be quiet, and if the pressure rise rate is at or above 50 lbs. there begins the usual good old wallop in the engine. I would like to have his views on that. I would like to know what is the highest rate of pressure rise which Mr. Fiedler has achieved with quiet combustion.

MR. FIEDLER: We have a rather unusual answer to that. We find that the rate of pressure rise does not mean a thing. In fact we want to get as rapid as possible a rise because that means economy. Where you have to make a difference is in the definition of the pressure rise. Detonation is a reaction without volume at all, although at the point where the reaction occurs the temperature is so high that it burns any metal in the vicinity. The other reaction we want to try to complete as fast as possible and we control this rate by the number of holes in the valves because each spray forms its own ignition center. Each spray that hits the air forms a mixture, and produces an ignition center.

If you have a slow speed engine you want less spray holes because you don't want a knock—not a Diesel knock—but you don't want something that runs rough. But you can run into a condition where the engine runs away with the combustion and then you have to speed up the combustion—add more ignition center—like on the gasoline engine—add more spark plugs. But there are two reactions—detonation is so fast you can't control or record it; while a smooth combustion you can record, and I don't think you can make it fast enough.

I would like to go back to one thing—when Mr. Fischer talked of the air injection engine. That was interesting because it proves we are on the right track. With that engine you form a rich mixture of hydrocarbon and air, but in addition to that you expand your injection air into the cylinder, which has a definite cooling effect on the mixture which you inject, so you avoid vapor injection and, at the same time have established a rich mixture, and the injection product is in the direction of a rich mixture. What the ideal mixture ratio is, we don't know as yet. We have tried to run experiments, but have not completed them. The foregoing explains why the air injection engine runs so smoothly, and why it will detonate if you have a leaky valve—which happened in the case which I started to tell you about, at the beginning, this evening, where the engine exploded. We later found that the valve body had a crack, and although I hadn't given the engine any fuel, due to the priming of the system the fuel had leaked into the cylinder and on the first compression stroke there was enough vapor accumulation in the cylinder to destroy the engine.

MR. FISCHER: I wanted to say something about starting: We never had any explosion in here (referring to diagram he had previously put on board). Why? Because we separated the starting air from the fuel injection and air injection.

First of all we put the starting air on separately and so prevented any possible explosion. Of course we had explosions in the starting line. If you can conceive this engine—it was 33 feet long and you let the air in at 300 lbs., that causes compression, and the slightest trace of oil starts an explosion—and at the far end here we cause the damage. With respect to detonation: I forgot to mention before, if you have an indicator card (drawing) like this and you get here a sharp rise, and you have a 20 lb. pressure rise, that combustion will be harsh. If I have a card like this, where you get a slow lift like this—(drawing) it won't be as harsh as this first one. Now in the latter effect we got the combustion which Mr. Fiedler tried to explain. I believe we are similar on this type. I am showing our double load feature now (Making another diagram). That is our chamber (Describes engine from diagram). In other words, I push the burning fuel which is rich and which is lacking air and it rises slightly here, and when the air comes in and blows the rich mixture into that air, then you have the flame in front of the mixture, and it burns instantaneously and it makes a smooth combustion.

Now I always look at the L-head gasoline engine and when I hear it run I think, why can't we make a Diesel engine run like that. If you live with them of course you think it is good, so once in a while you have to go to the other engine and then you will know what a good engine sounds like.

CHAIRMAN WETHERILL: It is getting late. I am sure Mr. Fiedler will be glad to answer questions anybody may want to ask, but in view of the lateness of the hour I am going to adjourn the meeting and then you can hold forth in an informal discussion.

INFORMAL DISCUSSION.

MEMBER: On a gasoline engine the explanation of a knock is good, and to overcome it we go to a more aromatic type of fuel which doesn't knock, on the assumption that the aromatic type of fuel does not dissociate as do the paraffinic types. As we get to the Diesel, however, we do the reverse; we increase the paraffinicity of the fuel. I would like to ask