TRIENNIAL INSPECTION, LEWIS LABORATORY
October, 1957 - High Energy Rocket Propellants
Part I

In the center of the room (POINT) is a rocket thrust chamber used for experiments with high energy rocket propellants. In the thrust chamber (POINT TO SCHEMATIC: TURN ON LIGHTS) chemical energy released from the combustion of a fuel and an oxidizer produces a high velocity jet, giving the rocket its push. In the complete system the fuel and oxidizer are fed into this thrust chamber by means of turbine driven pumps. There are many fuel and oxidizer combinations that can be burned in these engines. This is a spectrum of the relative energy that various fuel and oxidizer combinations will import to a missile. The base point at one is a typical solid propellant.

Solid propellants are in large use today in assist take-off devices and in missiles such as Honest John, and the Nike Booster. Red fuming nitric acid and dimethylhydrazine is used in the second stage of the Vanguard satellite vehicle. Oxygen and rocket jet fuel is the combination used in our intermediate range and intercontinental ballistic missiles such as Jupiter, Thor, Atlas, and Titan.

These propellants represent the present state of the art. The Intercontinental ballistic missile and the Vanguard satellite vehicle represent what can be done in the way of long range vehicles using these propellants. The Vanguard is a 3-stage vehicle that will hurl a 20 pound payload the size of a basketball into a satellite orbit 300 miles above the earth. The first stage burns oxygen and jet fuel (POINT TO TANKS). When these propellants are exhausted this stage drops away and a small solid propellant rocket puts the satellite into its orbit. Note the large proportion of this vehicle that is propellant - about 88 percent.

Part I Continued

There are other higher energy propellant combinations that we can consider for future rocket vehicles beyond Vanguard but considerable research is needed to put them into practical use. For example, ammonia, fluorine, hydrazine-fluorine, hydrogen-oxygen, hydrogen-fluorine, and hydrogen-ozone. We are interested in these propellants because they can put higher speeds into a payload, thus giving longer range, or can give the same range with less propellant.

As an example of what we might want to do with these higher-energy propellants let's consider a manned satellite glider. Suppose it is to be hurled into an orbit 1,000 miles above the earth. Note it has wings for the return glide to the earth. Using a conventional propellant combination, for example, oxygen and jet fuel, the vehicle might look like this, with 3 rocket stages (POINT).

On the other hand suppose we had selected a high energy propellant say fluorine-ammonia (POINT TO BOARD) and used the same manned satellite glider (HOLD IT UP). The higher energy of this combination may result in a total vehicle-glider plus boosters - like this (POINT) which may require less than half the weight, size, and thrust of the former one. The larger vehicle using present day propellants may be so large as to be impractical.

When we try to apply these high energy propellants to practical rocket systems we run into problems that are the result of unique properties of each of these propellants.

For example, on the fuel side we see hydrogen (POINT), which we liquefy at the very low temperature of -423°F, even then it has a very low density, only about 1/10 that of jet fuel, so that large, well insulated tanks are required. On

Part I - Continued

the oxidant side is ozone (POINT). Techniques for satisfactorily stabilizing ozone must be developed. Jarring it or heating it or contacting it with the wrong material causes it to detonate violently. And there is fluorine, the most potent oxidizer in the whole periodic table of elements (POINT). Mr. Kinney, the next speaker, will discuss these problems in more detail and the kinds of work that we are doing at this laboratory to put high energy propellants into practical use. Mr. Kinney will be assisted in some demonstrations of the problems by Mr. DeWitt.

PART II

Because fluorine is so prominent on our list of high energy propellants (POINT) we have selected it to illustrate our research. The very thing that leads to selection of fluorine for high energy propellant combination also makes unique problems in its use; it is a very powerful oxidizer.

Let us consider first the problem of containing fluorine in tanks, lines, valves, pumps, and other parts of a rocket feed system. There are two aspects to this problem: 1) selection of material; 2) techniques of using materials. Consider selection of materials. Our research has found a number of materials satisfactory for construction of tanks, lines, impellers, and parts of valves (POINT); for example, we use nickel, monel, stainless steel, copper, and brass. Invariably, we need seals or packings for valves or pumps. Because fluorine is such a potent oxidizer very few soft or rubber-like materials are available for this service. Now for gaskets, packings, etc. - you normally think of asbestos as being quite satisfactory being fireproof and inert to corrosive fluids. Here is a piece of asbestos (HOLD IT UP). We wish to blow some cool raw fluorine gas against it from a tube like this. Because fluorine is so poisonous we can't do this right in front of you, but we put a piece of asbestos just like this one in this box with a window on it. Mr. Schmidt will open a valve letting fluorine blow against the asbestos. See what happens.

Actually, there is only one plastic available for fluorine service. That material is a polyethylene plastic, a plastic that is already fluorinated. However, is has serious limitations to its use. A rubber-like material for gaskets, seals, and packings represents a continuing need.

Part II Continued

Let us now consider the techniques of using materials. For example, take the matter of cleanliness. Here is a piece of steel. This end has been kept very clean; this end, I've been handling - I now have put some grease on it just from my fingers. Here is a double tube that could blow fluorine on both ends of this strip (DEMONSTRATE). I'd like to blow some fluorine against both the clean and the dirty end but again because fluorine is poisonous, I can't do this right in front of you. The same kind of steel strip and two tubes just like these are set up in this demonstration box. Mr. Schmidt will blow some fluorine through these tubes against both ends (WATCH). You see that the handled end, the end with the bit of grease contamination, burst into flame. In using materials for fluorine service, practices must resemble those of the hospital operating room, rather than those of the machine shop to prevent the slightest contamination. Actually our mechanics use rubber gloves in handling material that is being put into fluorine service.

So the things that we have learned about containing elemental liquid fluorine are to select suitable materials, to apply them correctly, and to use techniques that scrupulously avoid even slight contamination.

Looking at the engine again, we see the injector. In this part of the engine, the fuel and the oxidant are brought together to prepare them for combustion. We want to know how to design this injector so that the propellants will burn efficiently during the very short time they are in the chamber. This time is of the order of 1/200 of a second.

An approach that we are using to this problem has been to isolate and study the elementary parts of the injector systems, and here (demonstrating) is a single element from this injector. It's a small part of the injector, you can't see it very well, but it simply consists of a small number of fuel and oxidizer holes.

Different injection spray patterns can be realized by the method of locating these holes. The object of working with single element injectors is to determine the best injection spray pattern to properly mix the fuel and oxidizer. We have been conducting studies with single injectors. The hardware looks like this.

In this next slide are illustrated typical data from an injector element study (explain the slide and data). This illustrates the kind of information that we are getting.

But high thrust rocket engines require large flow rates from many combinations of single elements. With these injectors the individual sprays will simply interact with one another. The result of this interaction has been studied in engines like this one containing six elements (show).

Finally, injectors for engines of a practical size containing perhaps hundreds of such elements are studied. Like this one (show). The new facility in which we are seated is used for studies of these injectors, in fact, this one will be put into here next week.

A third important engineering problem is that of cooling the engine when we have the high temperature of fluorine supported combustion. In the left-hand side of the demonstration box is a simulated rocket engine. Its chamber is made of transparent plastic like the tube I am holding. Mr. Schmidt will ignite the engine and run it on hydrocarbon-oxygen. Then after the engine is running, he will introduce fluorine along with the oxygen. You will be seeing the flame without and then with fluorine. We have a water-cooled temperature probe in the flame to indicate changes in temperature, it will read on this dial. (Mr. Schmidt Demonstrates). Actually fluorine supported flames may be as much as 2 or 3 thousand degrees hotter than oxygen hydrocarbon flames which at 5000°F are already difficult to cool. Incidentally, this is one of the few times that a group has ever witnessed fluorine combustion in rockets.

The problems that we have discussed have been materials for the feed systems and techniques of using them (point out on engine). The problem of learning how to design injectors for efficient combustion; and we have pointed out the cooling problem. These are but a few of the many problems associated with high energy propellants. The design of gas generators, turbines and pumps was not discussed. Nor did we discuss exhaust nozzle design or engine control; to name a few of the other problems that are inherent in an engine of this type. Actually, each of these is under study at this laboratory. Time does not permit discussion of these, but we have a motion picture which shows typical facilities and activities associated with research on them (movie). Eventually, all of the individual findings on how to use a high energy propellant must be fed into a research study of the complete rocket engine system. That is when you find out whether or not the individual problems have really been solved and that is when you find out the new problems that arise from putting all the parts together.

The facility that you are visiting now is designed to explore the problems of high energy propellants with engines of practical scale, and with all of the assembled components. It complements the smaller facilities that have been in use for the last few years. I would like now to introduce to you Mr. Rothenberg who will describe this new facility for you.

PART III

Here is a view of this facility. We can best describe it be telling you how we use it.

You are seated here in the test cell. Outside and on the hill behind the test cell is where we store the fuels and oxidants. In preparing for a run we transfer these to propellant tanks located in separate concrete pits just behind you. The tanks are then pressurized with inert gas which is stored here.

For a closer look at the test area we will show you a sectional view of this much of the facility. Here again are the propellant tanks. The high pressure gas then forces the propellant to the vertically firing engine here.

Because we're in a fairly populated area, we must remove harmful exhaust products and silence the roar of the engine. Both these functions are accomplished by this scrubber-silencer; where these water sprays quench the exhaust and these absorb fluorine compounds which would be harmful to personnel if permitted to escape. About 50,000 GPM, introduced by many spray nozzles, is required for this scrubbing. The cleaned gases leave through the vertical stack.

These water sprays are also intended to provide silencing. In fact when we operated the facility this summer, we were very satisfied with the silencing we got.

Now let's go back to our first slide. Here is the scrubber-silencer we have been discussing. The water for it is stored in this 450,000 gallon reservoir and is gravity-fed to the scrubber. This arrangement takes advantage of the natural terrain, eliminating the need for costly, high capacity pumps. The waste water is collected in this detention tank where the fluorine compounds are chemically treated and removed. By collecting all the water we prevent contamination of this stream.

The operation of the facility is controlled from a station about 1/2 mile away, Part III - Continued

in the main laboratory area. Here is a photograph of the control and instrument center. You have already been here for the nuclear propulsion talk. The engine operation is performed from this control console. All engine data are recorded in this instrument section. You'll notice that we use TV to view the rocket during operation.

This concludes our discussion. Before you board the bus you will have a few minutes to look over the facility. As you leave by this door the scrubber silencer is to your left. Thank you.

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ROCKET INJECTOR RESEARCH
THE INJECTOR IS THE KEY TO ROCKET ENGINE PERFORMANCE. THE BULK OF ROCKET ENGINE RESEARCH IS INVOLVED IN FINDING BETTER INJECTORS.
NACA 1,000 LB ROCKET
20,000 LB ROCKET

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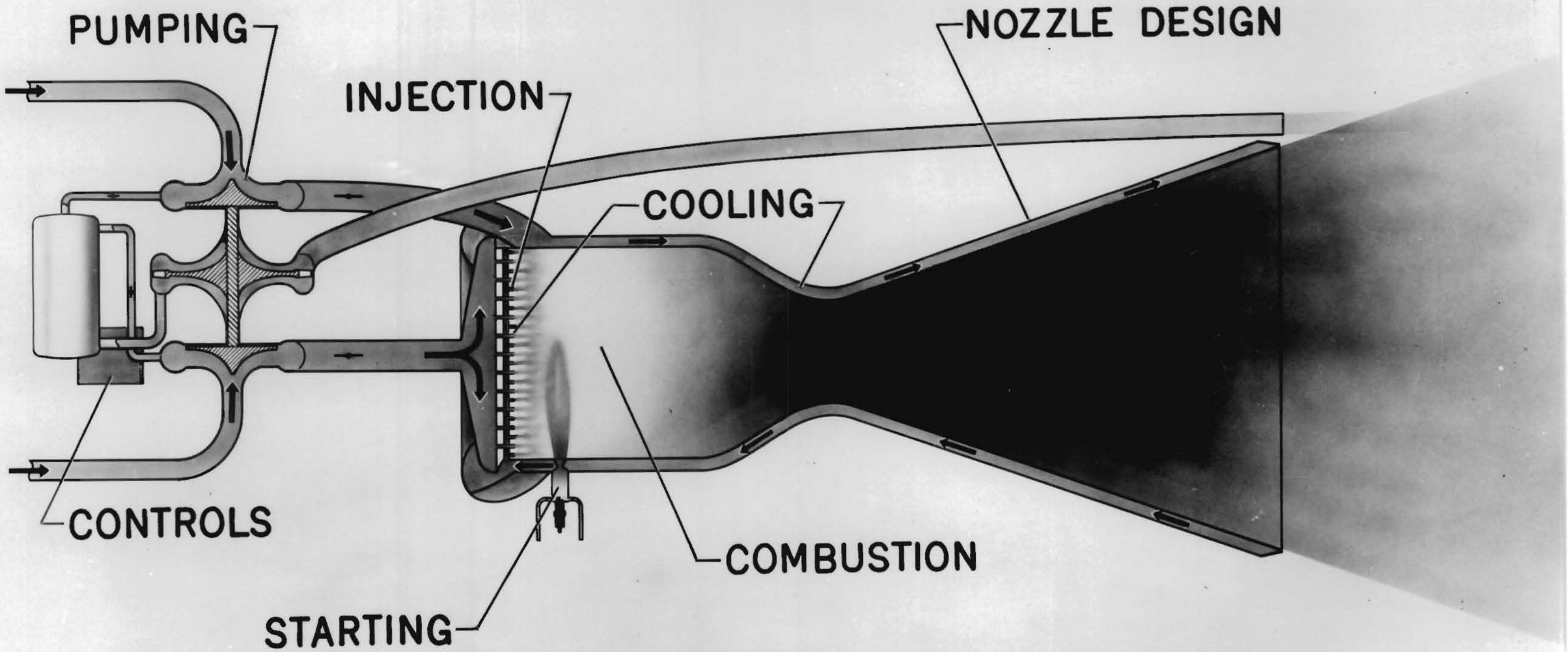
ROCKET ENGINE PROBLEM AREAS



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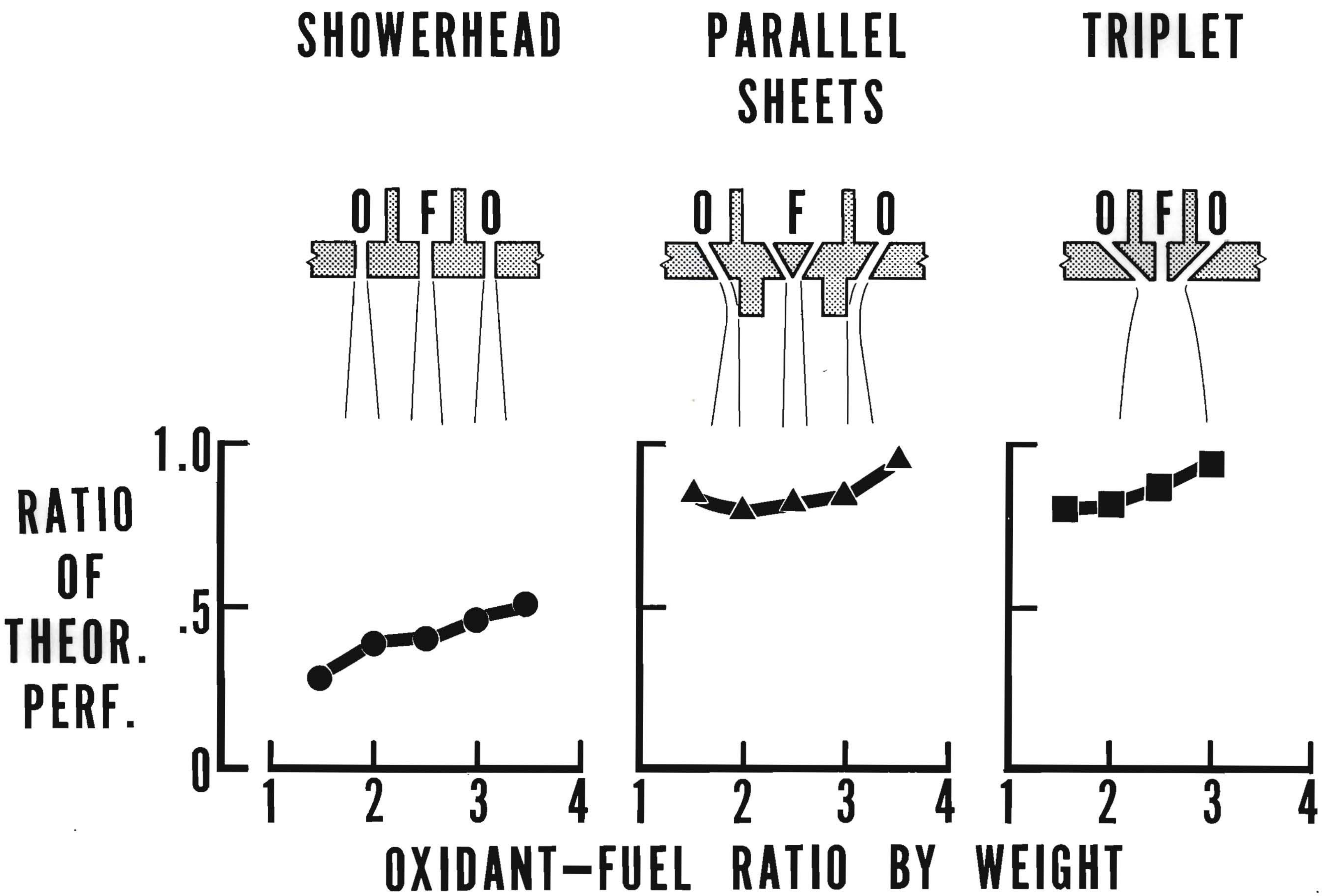
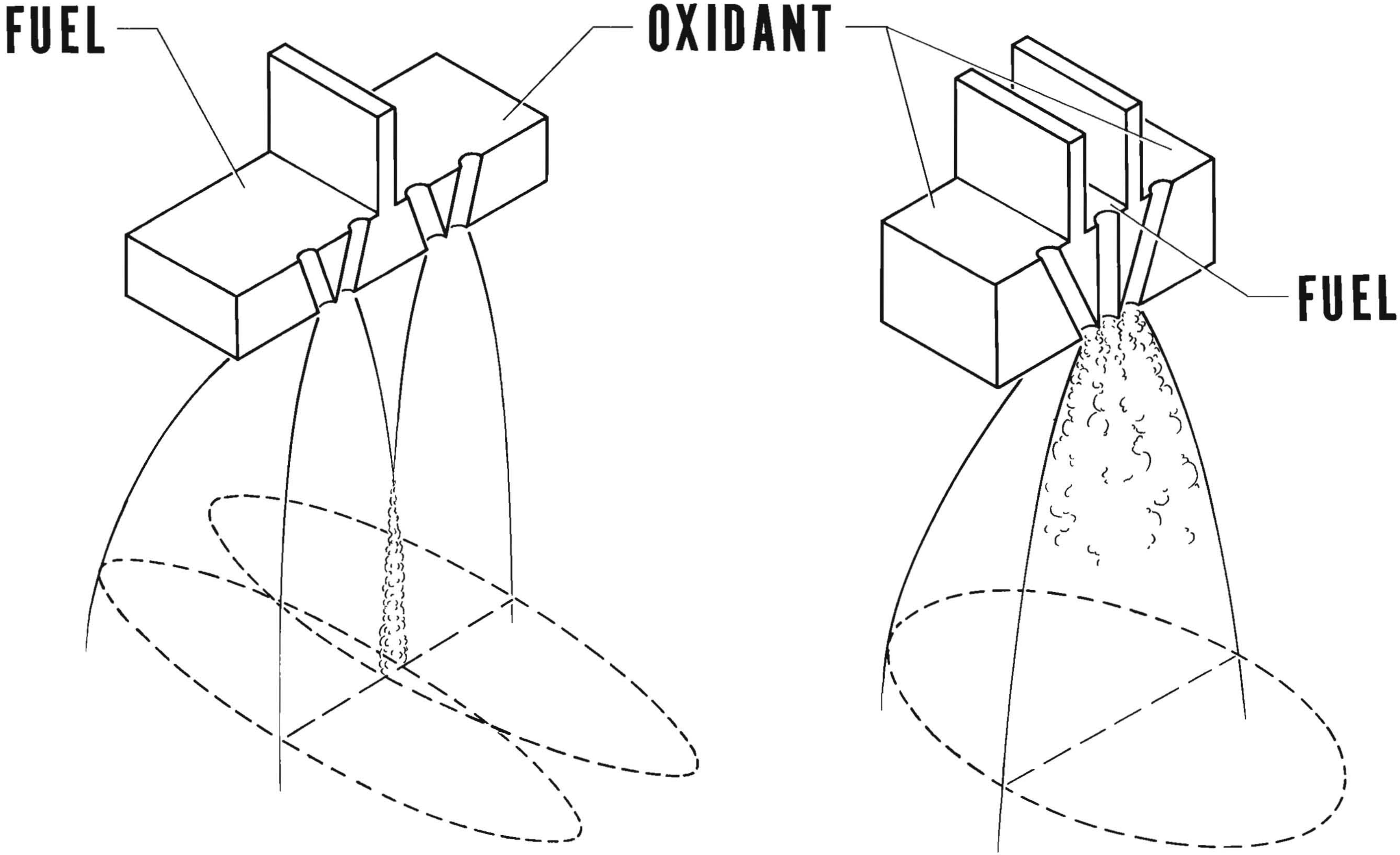
INJECTOR PERFORMANCE



INJECTOR ELEMENT SPRAY PATTERNS



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