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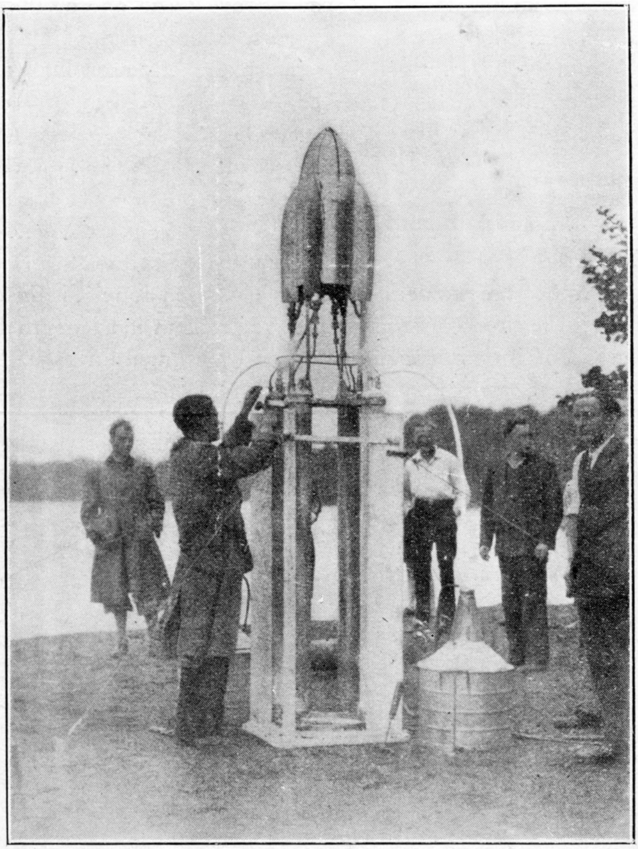

See "The Story Of European Rocketry"

Editor's Foreword

The summer season of 1935 has witnessed an undeniable heightening of general interest in the embryo science of rocketry, reflected in the attitude of the press and in the appearance of expository articles in magazines and journals.

This rise in interest has been accompanied by an advance in the field of actual achievement. Since the June issue of *Astronautics*, the Society's Experiment Committee has conducted two more series of motor tests (the technical report of the first of these is elsewhere in this issue). The second series—which will be reported in the winter issue—was especially rich in useful results, and has strengthened materially our grasp of the problem of motor design. At the time of writing still another group of motors is being prepared for tests, and start has also been made on the stability experiments with dry fuel models.

The highpoint of the Autumn news was of course the announcement that the Daniel and Florence Guggenheim Foundation would continue its support of Dr Robert H. Goddard's experiments His testing field will undoubtedly prove to be one of the most important salients in the "attack on the stratosphere", though Dr. Goddard is naturally cautious in predicting just when he will be prepared for an altitude shot. "What is to be accomplished during the coming year cannot, however, be predicted, for...things are certain in experimental work only after they have been done", is his comment on the problem in a letter to the editor.

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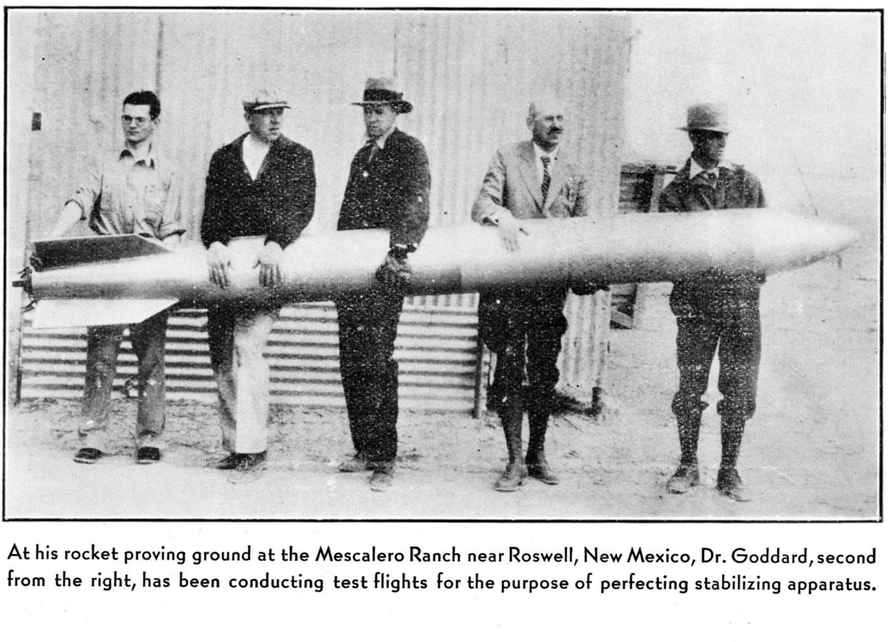


At his rocket proving ground at the Mescalero Ranch near Roswell, New Mexico, Dr. Goddard, second from the right, has been conducting test flights for the purpose of perfecting stabilizing apparatus.

Report Of Motor Tests Of June 2nd

The second series of rocket motor tests was conducted by the Experimental Committee at the Crestwood proving grounds on June 2nd, 1935. The information sought was, as follows:

(a) Effect on performance of varying the throat area and initial pressures.

(b) Heat resisting value of nichrome compared to aluminum for the nozzle metal.

(c) Effect of injecting fuels toward the back of the combustion chamber instead of toward the nozzle.

(d) Heat resisting value and strength of a carbon motor.

(e) Relative value of alcohol and gasoline as a rocket fuel.

Figures 1 to 5 show the graphs plotted from the data obtained by photographing with a moving picture camera the five gages representing the chamber, fuel and liquid-oxygen pressures, the jet reaction and their corresponding time-dimension.

Conditions of Tests

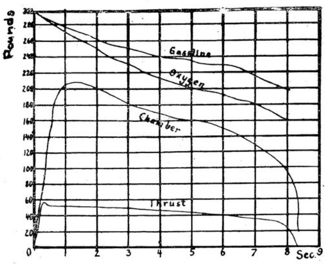
The amount of liquid-oxygen used in all the runs was one quart, or about 2.6 lbs. The amount of fuel used in the first run was one pint or about .7 lb. of gasoline; 1½ pints, or about 1.1 lbs. of the same fuel for the next four runs; and 1½ pints or about 1.3 lbs. of denatured alcohol for the last run.

The highest pressure of nitrogen gas placed behind the fuel, in Run 4, was 450 lbs. per sq. inch gage. The same amount of pressure was built up behind the liquid-oxygen by completely sealing the tank and allowing it to absorb heat from the surrounding air. When this pressure was reached, a circuit was closed, firing a fuse inserted in the nozzle. The moment the fuse was seen to be burning vigorously, the quick release valves were opened simultaneously, by a simple tug of a string. The pressure used in all other runs was 300 lbs. per sq. in. and the same procedure of firing the motor was followed in each case.

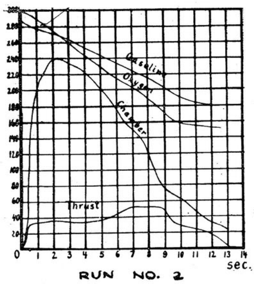
The combustion chamber consisted of an aluminum cylindrical portion, 2″ diameter and 3″ long, capped with two hemispheres of 1″ radius. The fuel inlets and external connection to the hydraulic plunger screwed into one of these and the nichrome nozzle into the other. The inlet and throat diameters varied for the different runs and so are given in Table 1 with the summarized data. The other dimensions were: Thickness of chamber walls, ¾″; outside diameter of nozzle, 1-5/16″; total length, 4″, consisting of a curved converging part 1″ long, made to imitate the contracted jet, leading from the chamber to the minimum diameter at the throat, and the diverging frustrum of a 12 degree cone, 3″ long, with a mouth diameter of 1-1/16″.

Conclusions

(a) The 450 lb. pressure run gave the smallest impulse. Since this high pressure is an added danger, and much progress can be made by using 300 lbs. per sq. in., as a standard, it is suggested that higher pressures be discontinued for the present. The ⅜″ diameter throat gave the longest time of combustion, and the second highest impulse. This should certainly be tried again, with alcohol instead of gasoline.



RUN NO. 1



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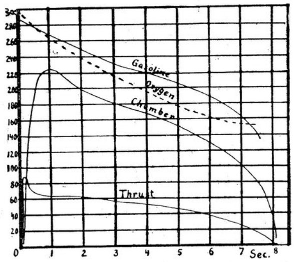
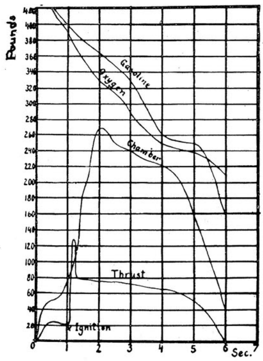
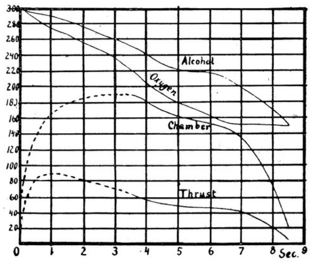


RUN NO. 3



RUN NO. 4



RUN NO. 6

Fuel, Oxygen and Chamber pressures in Lbs. per sq. in. gage

Thrust is given in pounds.

Curves Prepared from Photographic Records

Summarized Data

Run Number	1	2	3	4	6
Initial fuel pressure, lbs. sq. in.	300	300	300	450	300
Diameter of liquid oxygen inlet, in.	1/8	1/8	3/16	3/16	3/16
" " fuel inlet, in.	1/16	1/16	1/8	1/8	1/8
" " nozzle throat, in.	1/2	3/8	1/2	1/2	1/2
Maximum jet reaction, lbs.	57	54	90	128	90
Average " " "	42	35	48	57	57
Duration of Combustion, secs.	8½	13	8	6	8½
Impulse, lb. secs	357	455	384	342	485
Jet flow, lbs. per sec.	.39	.28	.46	.62	.46
Jet velocity, ft. per sec.	3450	4000	3340	2940	3970
Fuel input, ft. lbs. per sec. (thousands)	1155	1185	1920	2570	1520
Thermal Efficiency,	.073	.063	.042	.033	.075

(b) The nichrome nozzles stood up remarkably under the intense heat (*c.* 2000 degrees C.). In fact, the nozzle used in Run 1 was used over again in Runs 3, 4, and 6, showing only a small amount of scoring. These nichrome nozzles were definitely superior to the aluminum nozzles used in the first series of tests, which burned out completely during each run.

(c) Injecting the gasoline and liquid oxygen toward the rear in Run 1 gave results not much different from those of the other motors. While the design cannot be definitely condemned, the

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The Story of European Rocketry

by Willy Ley

No complete report of the origin and development of modern Rocketry in Europe has so far been published in English. It is our pleasure to print this necessarily very condensed translation prepared for us from one of his manuscripts by Mr. Ley.

After the World War European rocketry began anew in 1923. Professor Hermann Oberth, the great theoretician of rocket principles, published his book "Die Rakete zu den Planetenraumen" (The Rocket to Interplanetary Space) and suddenly everybody who was able to read it realized how great the idea was.

Oberth found many followers, among them Max Valier, who later became the first martyr of rocketry, and Johannes Winkler, who founded together with Valier the 'Verein fur Raumschiffahrt' (German Rocket Society) and who shot the first liquid fuel rocket in history.

In 1927 Max Valier interested Fritz von Opel, a manufacturer of cheap automobiles (he was sometimes called the "German Ford"), in the publicity value of rocketry and von Opel had with Valier's assistance the first of the much discussed rocket cars built by his engineers. The rockets were simply powerful powder rockets, made by Fr. W. Sander, the owner and chief engineer of a pyrotechnic factory at Wessermunde in Germany. The first runs of these cars had just taken place when we assembled at Zoppot near Danzig for the Annual Meeting of the Scientific Society for Aeronautics. There I met for the first time Professor Oberth, who lived in Rumania. We spent a few very interesting evenings together and though I had revered Oberth as a great scientist, I found now that he was also a great man. Valier was in Zoppot but we had not time enough to spend a night together. On the last day of the meeting I received the first copies of my book "Die Moglichkeit der Weltraumfahrt" (The Possibility of Space Navigation). This book, which had been begun exactly one year previous, contained chapters by Professor Oberth, Dr. von Hoefft in Vienna, Count Guido von Pirquet in Vienna, Dr. Walter Hohmann in Essen on the Ruhr, Dr. Karl Debus in Regensburg, and, of course, three chapters of my own.

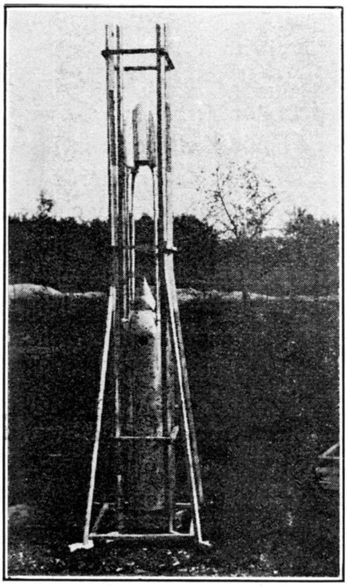
In autumn of 1928 the 'great break' came. Thea von Harbau, a well-known German authoress, had written a novel "Frau im Mond" (The Girl in the Moon). This novel had appeared in one of the weekly magazines with the largest circulation (Die Woche - The Week); it had also been published in book form with a foreword mentioning that our book had been its inspiration. And now her husband, Fritz Lang, the film director of the Ufa Films, Inc., was ready to turn it into a film. We were excited; millions and millions of people would not only hear about our problem but see it in most impressive pictures. And, what was the main thing, we would be sure that the picture was scientifically correct, for Professor Oberth had been called to Berlin to supervise it.

I felt confident, this film work *must* lead to the first actual experimenting and eventually the Ufa Film Inc. decided that they would spend money for an altitude rocket shot, to be made on the day of the world premiere of the film. Oberth immediately set to work and hired a few assistants, among them Rudolf Nebel who later founded the "Raketenflugplatz Berlin."

The fuel we chose was gasoline, malnly because of cheapness and availability. To the fuel liquid oxygen had to be added.

Here the resistance of the "experts" began. I use the quotation marks because rocket experts do not exist as yet. But there were real experts on liquid gases. They had no experience with the combustion in the presence of liquid oxygen but we thought they had, and they themselves believed that they understood it though they had no direct experience. Anyway they all advised us to abandon the idea. Gasoline or petroleum coming in touch with liquid oxygen would freeze instantly and form a dangerous explosive they told us, and they added, that we should know it. We felt in a difficult position. On the one hand everybody who ought to have some knowledge in the field advised us not to do it, on the other hand we simply had to do it or else abandon all our ideas.

Then the day of the first experiment came. It was very cautiously conducted, by letting a thin stream of an inflammable liquid enter an open iron bowl containing liquid air. (Liquid oxygen seemed too powerful and dangerous!) It burned wonderfully with a large flame and only one minor accident occurred —the expanding masses of gas gently pushed a window out. This simple experiment proved two things, first, that a liquid fuel, coming into contact with liquid oxygen and being ignited at the same time must not necessarily explode. The second thing was the discovery of a new scientific fact. When a droplet of a burning liquid is shot into liquid oxygen it "tears itself to pieces"; the whole droplet is so to speak pulverized into tiniest burning fragments in the shortest possible time. The practical value of this discovery was that the amount of fuel that can be burned in a given space in a given time becomes very large. Broadly speaking, any desired amount can be burned, which is very important for rocket construction.



An example of the larger nose-drive rocket constructed by the Verein fur Raumschiffahrt. This model is a later development of the rocket illustrated on the cover, which on July 14th, 1933, attained an attitude of 700 meters. The apparatus weighed 70 kilograms and burned 1.7 kilograms of fuel and oxygen per second, developing a thrust of approximately 200 kilograms.

The next step was made by Shershevsky by devising what was termed later the *Spaltduse*. The words means "slot-nozzle" because it practically consisted of two broad slots side by side in a heavy block of iron. The *Spaltduse* also burned satisfactorily, but the recoil it delivered was very small. Armed with the experience already gathered, Professor Oberth dared to design the first real rocket motor, consisting of blast or combustion chamber, injection ports, feed lines and exhaust nozzle. It had the original shape of a cone and was therefore termed *Kegelduse*. "Kegel" being the German for cone.

At this time Professor Oberth received an honor from France. Robert Esnault-Pelterie and the Paris banker Andre Hirsch had founded the so called REP-Hirsch Prize for Astronautics, 5000 francs to be given every year for the best work in this line. Professor Oberth's new enlarged edition of his book, which had just come out under the title "Wege zur Raumschiffahrt," received the prize and the prize was doubled as a special honor.

Oberth's *Kegelduse* brought the first official document rocketry received. Professor Dr. Ritter, chief of the *Chemisch-Technische Reichsanstalt,* in Tegel, near Berlin, testified that the *Kegelduse* "had burned under my supervision on July 23, 1930, for 90 seconds without any mishap, consuming 6 kilograms of liquid oxygen and one kilogram of gasoline and delivering a constant recoil of approximately 7 kilograms."

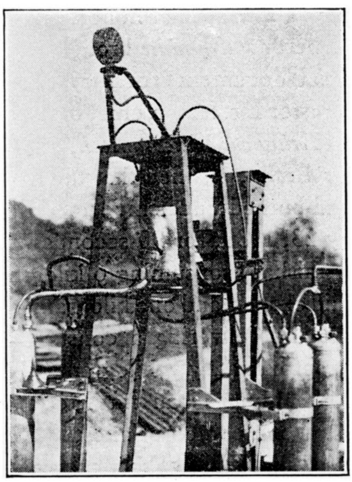
The film "Frau im Mond" had meanwhile come out and the planned record shot had not been made, simply because there had not been time to carry on the necessary amount of research when the Ufa finally had decided to bear the expenses. The tests of the *Kegelduse* had already been made under the auspices of the Verein fur Raumschiffahrt. The half-finished rocket designed by Oberth had been assembled by the Society but then its funds were almost exhausted. We suspected that experimentation with the "Oberth-Rocket" (she was about 7 feet long) might become too expensive and tried to find a way to make the experiments cheaper. Finally Rudolf Nebel arrived at the plan of the "Mirak." The word is a shortened form of the German *Minimum Rakete* which term designated a rocket for liquid fuels of the smallest possible size. It was only one foot long but to this a "tail" of three feet in length was added, used as fuel tank while the rocket itself or its "Head", as we termed it, was the oxygen tank. Oberth-Rocket and Mirak were ready for testing before the *Kegelduse* was officially certified, in the first days of May, 1930.

For the first week in May a German aviators society had planned an exhibit of airplanes and gliders on the Potsdamer Platz in Berlin and we were asked to collaborate. We did so, exhibiting our rockets and rocket motors at Wertheim's (a large department store at the same place) and Max Valier promised to join the exhibition with his latest rocket car, designed for liquid fuels. I remember distinctly our meeting, when Valier enthusiastically told us the results of his latest tests. "There are only minor alterations to be made to have the car ready for the exhibit," he declared. Two days later we found urgent telephone messages on our desks when we came home. Max Valier had been killed by the explosion of the rocket motor of his last car.

Shortly afterwards Professor Oberth had to leave Germany and the engineers of the Society began the experimental work. In August, 1930, the Mirak No. 1 burned for the first time and proved that the thrust of its tiny motor was strong enough to lift it from the earth. This was not allowed, of course; we could not afford to lose our only Mirak. For this reason a transportable proving stand had been constructed which held the rocket back, only measuring its thrust. Eventually one tank burst and a second Mirak was constructed. But it was now evident that we needed our own proving ground, and Nebel succeeded in finding a plot of four square kilometers at Reinichendorf, near Berlin, that could be rented very cheaply and the second phase of our work began; the experiments on the "Raketenflugplatz Berlin", "Flugplatz" meaning flying field. The proving stand for the second Mirak was brought out and the launching rack of the Oberth-Rocket was used to build another larger proving stand. This second proving stand was to be used for ground tests alone; tests which have developed the rocket motor very quickly. By March, 1931, our rocket motors were delivering regularly thrusts of between 31 and 33 kilograms, the testing period was either 45 or 90 seconds. At the same time the tests with the second Mirak were continued, until the oxygen tank exploded for the second time.

A third Mirak was planned but while the two previous ones had rocket motors of the shape of the *Kegeldüse* (only smaller) the third Mirak was to have a motor of the new and powerful type. We estimated that this motor would carry the rocket about three kilometers in the air. (It was at this time that we received a visit from the president of the American Rocket Society, and his wife, Mr. and Mrs. G. Edward Pendray.) One of our engineers, Klaus Riedel, also announced to me that he had found a construction for a rocket, simpler and lighter than the Miraks. In order to distinguish Miraks, Oberth-Rockets and sky-rockets I termed the new type repulsor; a name which has been used for all the following constructions of the Verein fur Raumschiffahrt.

When the visitors from America had left, Riedel finished his first repulsor and made it ready for a first test. There was no special proving stand to hold it back, so Riedel made its whole construction much more massive than necessary. This "too heavy" Repulsor, when it was tested, lifted itself slowly from the ground and climbed to an altitude of about 2000 feet. Then its fuel



Proving stand number 4, designed to test complete rockets of the larger size.

supply gave out, the Repulsor dropped back and was partly destroyed as it had no parachute for actual flights.

Nine days later, on the 23rd of May, 1931, Repulsor No. 2 was ready for flight. It did fly but at an altitude of about 170 feet it tilted over and shot with full power horizontally across the Raketenflugplatz. At the border of the proving ground the fuel was exhausted, the Repulsor continued its flight steadily like a projectile, reflecting from its smooth aluminum fins the red rays of the evening sun. We wondered about the outcome of this experiment and were—I have to admit it—very much afraid when we followed the path of the Repulsor which had disappeared from sight. Finally we discovered it, dangling badly broken in the branches of a high tree.

But this experiment decided our further policy. Mirak No. 3 was abandoned and a third repulsor built. It flew vertically and without accident, as far as the repulsor was concerned. But when the parachute was thrown out the rope which connected the shrouds of the parachute and the rocket broke and the repulsor dropped from an altitude of about half a mile to the earth, burying itself deep in the ground. We then paid special attention to these weak points, parachute release and parachute construction, and the next flight was a complete success.

Research had always to be done in different directions and from this time on was quite extensive—the staff grew, sometimes sixteen people were busy out there at the Raketenflugplatz.

The achievements of the experimental work of the German Rocket Society performed in the period from August, 1929, until June, 1933, can be summed up as follows: Four proving stands were built, one for the Miraks; one for motors alone, this was the one which served for most of the tests. Proving stand No. 3 was also for motors alone, it was portable, to test the motors to be used in smaller repulsors to be shot outside the Raketenflugplatz. This proving stand was not much used, because only very few shots were made outside our proving ground. Stand No. 4 was to test whole rockets of the heaviest type and with a recoil of close to 200 kilograms. We had six launching racks of various sizes. We built two Miraks, one Oberth-Rocket, more than thirty repulsors and six heavy liquid fuel rockets. The Miraks burned about sixteen times, aside from this approximately 490 ground tests and about ninety shots were made. To this the six flights of the heavy rockets have to be added.

The rocket motors delivered thrusts of 30-32 kilograms, 55-65 kilograms and about 210 kilograms; this largest type, however, did not work as efficiently as the smaller ones. The greatest altitude of a repulsor was about one mile, the greatest distance approximately three miles. The heaviest rocket weigned about 72 kilograms, the distance it covered about half a kilometer

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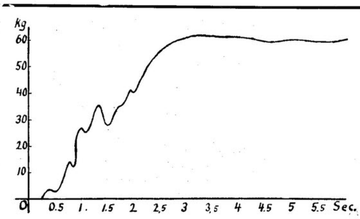

A thrust curve of one of the larger motors which burned 0.32 kilograms of fuel and oxygen per second.

The Velocity-Ratio Efficiency

A Mathematical Discussion of One Phase of the Rocket Efficiency

by Alfred Africano, M. E.

Ass't. Engineer, Interborough Rapid Transit Company, N. Y. C.

This paper discusses three methods of calculating that efficiency of the rocket which depends only on the ratio of the velocity of the rocket to the velocity of the jet relative to the rocket.

The first method uses a value for the output which satisfies the definition of work—force times distance, but considers the input to vary. This is incorrect for the assumption of a constant jet velocity and throat area as under these conditions the input per second is constant. The second method uses a constant input and a more definite output —the difference between the input and the absolute energy left in the trailing exhaust gases. By dividing the output of the first method by the input of the second, the writer obtains a third method for comparison.

The velocity-ratio efficiency by this last method is a simple straight-line formula; it is the tangent to the efficiency curves of the preceding methods. The efficiency calculated by this method is simply twice the velocity-ratio. However, it must be rejected at once because for values greater than one-half the efficiency would be over 100%, or inconsistent with the law of conservation of energy. Its value is in showing up the effect of the decreasing mass of the rocket and in answering the question: Is the kinetic energy gained by the unconsumed fuels to be considered as available for propulsion or not?

It is shown that Equations 1 and 3 include this energy; Equation 2 does not. When it is considered that the slightest internal force will separate two bodies that happen to be traveling together, no matter what the speed, and that the only effect on the forward body is this force—it seems clear that the absolute energy of the lost mass is of no further use. Therefore, Equation 2 is concluded to be the correct form for calculating the velocity-ratio efficiency.

First Method

From the definition of work, "force times the distance through which it acts," the useful work done per second can be considered as the jet reaction times the velocity of the rocket. If the only loss is the kinetic energy left in the gases of the jet, and this is supplied as additional input,* the velocity-ratio efficiency is

$$E = \frac{\text{Output}}{\text{Input}} = \frac{\text{Output}}{\text{Output} + \text{Losses}} = \frac{Fv}{Fv + \dfrac{m(c-v)^2}{2}}$$

$$= \frac{mcv}{mcv + \dfrac{m(c-v)^2}{2}} = \frac{2cv}{c^2 + v^2} \qquad \text{where}$$

*This view is held by Oberth, Chatley, Roy, and others.

E = instantaneous velocity-ratio efficiency, percent

F = jet reaction, lbs., (= mc)

v = velocity of rocket, ft. per sec.

m = mass of gases flowing through nozzle per sec. (slugs per sec.)

c = velocity of jet, ft. per sec. (constant)

The substitution of mc for F follows from the fundamental relation, the jet reaction is the product of the mass flow per second times the jet velocity.

Dividing both numerator and denominator of the last expression by c^2, and substituting r, the velocity ratio, for v/c, the simplified formula becomes

$$E = \frac{2r}{1 + r^2} \qquad \ldots\ldots (1)$$

which is plotted in Figure 1.

This is the instantaneous efficiency at any particular value of the velocity-ratio, r. Although it may reach 100% when r=1, it must first pass through the intermediate velocity-ratios with their corresponding low efficiencies. Therefore, more important than the instantaneous efficiency for determining the performance in a given interval is the average efficiency of the interval. This can be expressed for any curve as the mean ordinate, M.O., or the area under the curve divided by its length along the horizontal axis.

The area under the curve from r=0 to any value of r is found first, by integrating a differential element of area between the limits zero and r. (If the rocket is given an initial velocity by means of a catapult the limits would be from r_1 to r_2)

$$A = \int_0^r dA = \int_0^r E dr$$

$$= \int_0^r \frac{2r}{1+r^2} dr = \log_e (1+r^2)$$

The mean ordinate is

$$M.O. = \frac{\log_e (1+r^2)}{r} \qquad \ldots (1a)$$

Equation 1a is also plotted in Figure 1. Since there is a maximum average efficiency it is important to know at just what velocity-ratio this occurs so that the rocket can be designed to reach this final velocity-ratio at the end of combustion.

Equating the first derivative of equation 1a to zero for a maximum,

$$\frac{2}{1+r^2} - \frac{\log_e (1+r^2)}{r^2} = 0$$

This last equation is a bit difficult to solve, but by integrating graphically in Figure 1 a first approximation can be obtained. Successive trials result in the solution r=1.98. This value of r substituted in equation 1a gives for a rocket without initial velocity the maximum average velocity-ratio efficiency

$$\text{max. E aver.} = 80.5\%$$

Second Method

The total energy in the jet available per second is half the mass-flow per second times the velocity squared. Considering this as the total input per second and again the residual energy in the jet as the only loss,* the velocity-ratio efficiency is

$$E = \frac{\text{Output}}{\text{Input}} = \frac{\text{Input} - \text{Losses}}{\text{Input}}$$

*For vertical flight the term mgh, the potential energy of the gases, should be included, but introduces complications not within the scope of this discussion. For horizontal flight, however, the method is exact.

$$= \frac{\frac{mc^2}{2} - \frac{m}{2}(c-v)^2}{\frac{mc^2}{2}}$$

$$= \frac{2cv - v^2}{c^2} = \frac{2v}{c} - \left(\frac{v}{c}\right)^2$$

Replacing v/c by r,

$$E = 2r - r^2 \qquad (2)^*$$

For 100% efficiency in this case,

$r = 1$, as before.

To get the mean ordinate,

$$A = \int_0^r (2r - r^2)\,dr = r^2 - \frac{r^3}{3},$$

$$\text{and} \quad M.\,O. = r - \frac{r^2}{3} \qquad (2a)$$

For maximum M. O.,

$$1 - \frac{2r}{3} = 0, \quad \text{or } r = 1.5$$

and max. E aver. = 75%

Equations 2 and 2a are plotted in Figure 2.

Third Method

Using the input of the previous method and the output of the first method, the efficiency is

$$E = \frac{\text{Output}}{\text{Input}} = \frac{Fv}{\frac{mc^2}{2}}$$

$$= \frac{2mcv}{mc^2} = \frac{2v}{c}$$

$$\text{or} \quad E = 2r \qquad (3)$$

$$\text{and} \quad M.\,O. = r \qquad (3a)$$

Since Equation 3 can be valid only for values of r equal to or less than one-half, giving over 100 % efficiency for greater values, it must be rejected. It is clear that the equation contains some source of energy not in agreement with the fundamental laws of physics.

Comparison of the Three Methods

By grouping Equations 1, 2 and 3, the clue to their discrepancy is immediately apparent. The term 2r occurs in all three. The term r^2 subtracted from the 2r of Equation 3 gives Equation 2; and the same term plus one divided into 2r gives Equation 1. What is the significance of this term?

A simple transformation, multiplying its equivalent, $(v/c)^2$ through by m/2 shows it to be the ratio of the kinetic energy of the lost mass to the kinetic energy of the jet. Therefore, in Method 3 the output Fv, must have contained this energy, thus canceling the r^2 of Equation 2; and in Method 1, in addition to this error, the additional error of adding the same lost energy to the jet energy placed another r^2 in the denominator. The double error can be easily demonstrated by multiplying $\frac{2cv}{c^2+v^2}$ through by m. The result is

$$E = \frac{mcv}{\frac{mc^2}{2} + \frac{mv^2}{2}}$$

very similar to an equation by M. Roy in *Technical Memorandum*, No. 571, N.A.C.A. Since the mass of the rocket decreases m slugs per second, the term $\frac{mv^2}{2}$ represents the ft. lbs. per second separating from the total kinetic energy of the rocket.

Perhaps the most striking illustration of the loss occurs when the velocity-ratio becomes greater than 2. In Figure 2 the graph shows that the instantaneous velocity-ratio efficiency is then negative. This is because the rocket is losing fuel having a higher kinetic energy than can be given to the remaining mass by further acceleration. The velocity continues to increase at the expense of the total kinetic energy.

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*This equation appears in "Das Problem der Befahrung des Welt Raumes," by Capt. H. Nordung

Since there is no foundation for assuming that this energy is recoverable as additional input, and since Method 2 rejects it, Equation 2 is the only satisfactory solution for the instantaneous velocity-ratio efficiency.

Application of Formulas

For the rocket motors tested on April 14th and June 2nd, giving an average reaction of 40 lbs. for ten seconds, the average acceleration of a 15 lb. rocket (inclusive of 3 lbs. of fuel at the start) would be 2g. Therefore, its final velocity in a vacuum would be 2gt or 640 ft. per second. Since the jet velocity is

$$c = \frac{F}{m} = \frac{40 \times 32}{.3} = 4300 \text{ ft.}$$

per second, the final velocity-ratio is .15, giving final efficiencies from the three methods of .293, .298, and .300 respectively.

The average efficiencies for the ten second interval would be .149, .143, and .150 respectively.

It must be emphasized that this average efficiency of about 15% is only one of the several separate efficiencies* which together make up the over-all or absolute efficiency of the rocket. Imperfect combustion in the rocket motor prevents the maximum temperature from being reached. In addition, dissociation at these high temperatures keeps the chemical reaction from being completed.

The next loss is at the nozzle. The limiting velocity of flow is the speed of sound at the temperature of the gases —unless the nozzle is designed for the theoretical expansion ratio. However, this is impractical at present, and in addition our experiments indicate for some unknown reason that short nozzles give higher and longer reactions than the more theoretical longer nozzles.

Then the actual kinetic energy of the jet (whatever its efficiency) is considered to be the input for Methods 2 and 3 in deriving the velocity-ratio efficiency.

The maximum velocity and altitude depend on the ratio of fuel weight to rocket dead weight (construction plus meteorological instruments). The jet reaction minus the dead weight is evidently the maximum weight of fuel that

(continued on page 18)

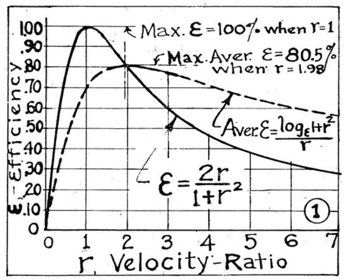

FIGURE 1

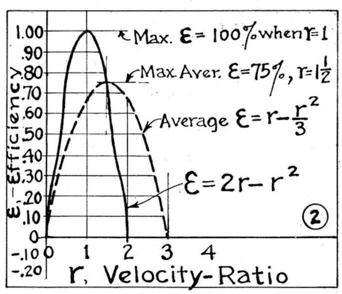

FIGURE 2

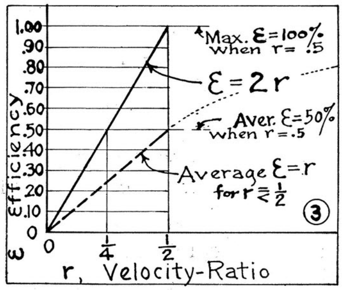

FIGURE 3

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*Mathematical discussions of these other efficiencies are being prepared.

The Cleveland Rocket Society

An Account of its Activities, Prepared by its Chief Research Engineer

by Ernst Loebell

The end of the year 1935 will see the completion of one of the most complete *Rocket Airdromes* in the United States. After great sacrifices of time, energy, money and tremendous voluntary work physically as well as spiritually by the active members of the Cleveland Rocket Society, the new proving field of the Society will enable its members to carry out the experiments and tests undisturbed by any weather condition or any of the four seasons of the year. Equipped with a 12 foot steel structure for mounting the rocket motor, a control trench 30 feet away from the framework and 6 feet deep, 7 feet wide, 23 feet long and covered with a solid roofstructure of 500 sq. feet and a nearby wooden building of the size 12 by 12 feet as a kind of laboratory and store-room, the foundation has been laid and the necessary requirements fulfilled, which alone will enable us to attack the problems of the rocket motor and work systematically and intensively on its solution from a true scientific and engineering point of view.

During the Winter of 1935-36 the C. R. S. will limit its research work to a few vitally important problems of the solution of the rocket motor: namely, to decide definitely which metal—if steel or light alloy—is best and only suited to a rocket motor; to determine the proper advisability of fuel mixtures from the thermodynamical point of view and its efficiency, because no rocket motor has been designed which utilizes to the full the tremendous power stored in a correct gasoline-oxygen mixture.

We have now two different types of rocket motor at our disposal; one of chrome-nickel steel and two of a radical different design and light alloy. The steel motor has water cooling, the light alloy motors have a special cooling system directly cast in the finned wall so, that they act at the same time as a calorimeter. Their cooling agents will be liquid oxygen and gasoline, which enter the combustion chamber through specially designed multiple orifices. The pressure in the fuel lines as well as in the combustion chamber, the increase of the temperature of the cooling agents as well as the temperature within the combustion chamber itself, the lifting power and other important observations will be relayed electrically to the instrument board in the control trench. All future experiments will be carried out with gasoline-oxygen mixtures and each test carefully charted and reported.

Since we have no electric current on our proving field, which is located about 12 miles east of Cleveland, we will attempt to install a small power unit of a one cylinder gasoline engine coupled with a generator, which would furnish us sufficient light in the building, control trench and instrument

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The Nomenclature Of Rocketry

by Noel Deisch

An inquiry into a minor but by no means unimportant perplexity attendant upon our new science by a former contributor to ASTRONAUTICS, and recipient of honorable mention in the REP-Hirsch award of 1928.

What do we call the thing which drives a rocket—a propeller? This is a good generic term so far as derivation is concerned, and though it has strong connotations of a helix through its association with screw propellers, its meaning could very conveniently be extended so as to embrace screw propellers, jet propellers, or that particular kind of jet propeller known as a reaction motor.

But just what is a reaction motor? Is the jet apparatus of a jet-propelled boat a reaction motor? If so an ordinary screw-propeller should likewise be considered a reaction-motor, since it comprises what is basically a pump, which in operation forms a very large jet, the reaction of which drives the boat. The difference lies roughly in the kind of pump and the size of jet.

Perhaps the distinguishing feature of a true reaction motor lies in this; that the material ejected *is carried along with the vehicle*, that is, that it is not a part of the circumambient, as is the earth against which an automobile propels itself, or water, which serves as reactant to a ship, or air, which serves in the same capacity toward an aeroplane.

But if we apply the term reaction motor to a rocket motor, just what, as an apparatus, do we accept it as including; the expansion nozzle, or the expansion nozzle together with the combustion chamber, or these together with the fuel tanks, pumps, valves, and what not that make up the complete apparatus? If we read the above question on various possible types of reaction motor, the difficulty of giving the term a satisfactory limited meaning becomes quite evident. On the whole it appears inadvisable to attempt to apply to the term reaction motor to any concrete form of apparatus, but rather to recognize it as a broad term like propeller, but of more restricted meaning. We have then:

Propeller: a device for imparting motion.

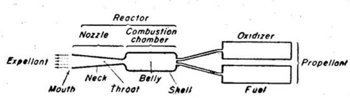
Reaction Motor: a propeller in which the reactant is carried along with the vehicle.

And immediately we meet up with the annoyance that "reactant" will be confused with "reagent", since we apply the same term "reaction" to one part of a mutual mechanical action, and also to a process of chemical combination, both types of which reaction take place concurrently in a rocket motor.

The term "rocket motor" is convenient as a term of rather uncertain meaning. "Motor" has come to mean broadly almost anything having to do with motion, and in its narrow mechanical sense it may mean any prime mover, or almost any kind of "engine" that is, machine. True, if somebody says "rocket motor" he can expect to give a fair idea of what kind of reaction motor he has in mind, i.e., a jet motor in which the jet is formed by the energy of chemical combination. But a "rocket ship" might be one propelled by a series of separate discharges, as from a machine gun, or conceivably by the expulsion of electrically charged particles (as proposed by Ulinski), in either of which cases the term "rocket motor" would not meet the definition as above given. Unfortunately also "rocket motor" like "reaction motor" is a double-worded term, and is thus inherently cumbersome. All things considered we had better leave "rocket motor" alone, as just now standing for something quite vague.

All of which is to say that we are in want of a term to denote a rocket motor comprising a combustion chamber and a nozzle.

Assume that we had such a term, then how to describe the apparatus itself? There are several parts which must be designated so often in any discussion that the need of good terms is very evident. To show this I give a diagram with provisional terms applied.



As used here, "reactor" is hardly a satisfactory term, being almost as broad as propeller. "Propulsor" which differentiates over propeller and is without previous association might conceivably be substituted; in fact it was so used in an article that appeared in the October 1932, issue of *Astronautics*. Again "expellant" would more logically be "reactant" but that this last is excluded for reasons above touched on. The outer end or external opening of the nozzle is called the "mouth", the inner bore the "throat", the material shell which forms this bore the "neck" and the internal portion of the combustion chamber the "belly"—these designations corresponding roughly to the mouth, neck and belly of a flask. Extending this terminology, the interior portion of the chamber adjoining or merging into the throat, which is very important in theoretical discussions of nozzles, might logically be called the "cardiac portion" and the opposite end near the fuel inlets the "pyloric portion", all of these terms conforming with the zoological system of enginering terminology now in wide use.

Another verbal difficulty is "fuel", which in rocket practice comprises both the fuel proper in the ordinary sense, that is, the reducing agent, and also by necessity the oxidizing agent. It is inadmissible to use "fuel" in this extended sense, however, because everybody would continue to apply the word in its present restricted sense meaning reducing agent, and there would be confusion. It is all right to say "we are now using alcohol for fuel", but if one should say "we are now using alcohol and oxygen as fuel" the chemical men wouldn't like it—the purists at least. But then if one says "we are using alcohol and oxygen as reagents" it doesn't sound right either, since it is not specified that there is combustion. One can say correctly "as source of energy we use alcohol and oxygen", but that is pedantic and not fully expressive. The term "propellant" might be used to cover both ingredients, the fuel and oxygen, but we should bear in mind that this word is already used in explosives practice to denote the charge of powder that expels a projectile from a gun

Another difficulty is that "oxidizer" and "reducer" are not general terms denoting complementary reagents. We might conceivably (though not probably) have fuels which contain no oxygen, such as chlorine and hydrogen, or fuels in which the ingredients are already mixed, as in black powder or the explosive called Turpinite, which is a mixture of liquids, or in loose chemical combination, as smokeless powder. We do not feel that we are speaking exactly when we call powder "fuel".

What I have been trying to say is that a general one-worded term expressing "source of chemical energy" —or the broader conception served by the German word *Triebstoff*—seems to be wanting in the English language.

It is too bad that trends in language are such that we are stopped from devising some empirical terminology, such as that used in chemistry or some of the more rocondite branches of physics. Consider: The essential function of the combustion chamber is that of transforming the potential chemical energy of the fuel into thermal energy (which of course is really kinetic), and the essential function of the divergent nozzle is to convert this thermal energy of the heated gas into kinetic energy, that is to straighten out the random kinetic movements of the molecules of gas so that they are all unidirectional. The overall function of the complete apparatus is to derive a free mechanical force by the controlled degradation of the chemical forces resident in the propellant.

Very well then, the combustion chamber might be made into something like *chetca;* "che" chemism, "t" transformer, "ca" caloric; and the nozzle a *catkin* "ca" caloric, "t" transformer, "kin" kinetic. Note that the type of energy from which the conversion is accomplished comes first, the final state last, and that the transformer which acts as intermediary stands in its proper place in the middle. The material wall or shell in the two cases would be *pelca* and *pelkin;* "pel" pellicle; the inner surfaces, the *inca* and *inkin;* the outer surfaces *exca* and *exkin;* the included cubic spaces *intraca* and *intrakin;* etc. etc. The combined apparatus would of course be a *chetkin*, or more ostentatiously a *chemtrakinet.*

["It is a beautiful feature," Mr. Deisch concludes, "of such an organization as a rocket society that one can freely write such insanities with assurance that he will receive proper sympathy." This agreeable and stimulating discussion was not intended for printing, but it states some of the new problems of rocket philology so succinctly and ingeniously that it was judged well worthy of publication.]

European dispatches announce that two members of the Nederlandse Rakettenbouw (Dutch Rocket Society) attempted to launch a mail-rocket across the English Channel but were prevented by the French government. It is not probable that this rocket was designed for liquid fuel, as the Dutch Society has reported no tests with liquid fuels excepting the flight last July of a model glider propelled by carbon dioxide.

The Story of European Rocketry

(concluded from page 9)

because unfortunately one of the roller bearings stuck and the heavy rocket pulled itself free only after a considerable time, coming out of the launching rack almost horizontally. About 75% of all shots were complete successes, in a few of them the parachute broke off, only once a motor exploded in flight. Another rocket of the same type ascended 700 meters vertically. The altitudes and distances may seem small in comparison with the thrusts of the motors as indicated in the ground tests. One of the reasons was that we had to keep the altitudes low because the proving ground was located very close to the German capital and there was no convenient access to the sea nearer than about 250 miles away.

The Velocity-Ratio Efficiency

(concluded from page 13)

could be lifted at all. Any more fuel would simply burn away, uselessly, until the total weight reduced to less than the value of the reaction. Increasing the jet reaction and decreasing the dead weight to a minimum are the two practical problems involved.

Finally there is the resistance of the air to be considered. Calculations taking this and all other variables into account by the method of numerical integration used in ballistics show that this loss may be as great as 50% for the Society's experimental rockets.

For comparison with the velocity-ratio efficiency the probable absolute efficiency corresponding to the rocket data used in the example should prove interesting.

For a vertical shot, the flight under power would be

$$S_1 = \frac{at^2}{2} = 3200 \text{ ft.} \quad \text{(in a vacuum)}$$

As a projectile,

$$S_2 = \frac{v^2}{2g} = \frac{a}{g} S_1 = 6400 \text{ ft.}$$

(in a vacuum)

Total = 9600 ft. (in a vacuum)

Assuming 50% loss due to air resistance or 50% "air resistance efficiency" the net altitude in air would be 4800 ft.

The useful work is the final weight of the rocket times its altitude, $12 \times 4800 = 57{,}600$ ft. lbs. The total (bomb-calorimeter) energy in 3 lbs. of gasoline-liquid oxygen fuel mixed in the correct proportion is 12,000 B.TU. or 9,350,000 ft. lbs.

Therefore the absolute efficiency is .006 or 6/10 of 1%, for this case.

The Cleveland Rocket Society

(concluded from page 14)

board as well as sufficient current for our recording instruments. With all these careful preparations and improvements of our proving field being completed by the end of this year and several rocket motors ready for experiments, we expect during the winter time some interesting and highly important results. However, no actual rocket flight is contemplated at the present time until the results of these forthcoming experiments convince us and prove to us from every engineering point of view the justification and success of such a flight.

Special Notice

A very recent letter from Robert Esnault-Pelterie informs us that the REP-Hirsch award has been renewed for 1936; material to be submitted before January 1st of that year. Further information will appear in the next issue of *Astronautics*. Members interested may in the meantime communicate with the Secretary.

Two New Russian Books On Rockets

In Soviet Russia two new books were recently published which are not entirely devoted to rockets and rocket flights, but contain so much about the plans and experimental activities of the various rocket societies and experimenters that they have to be included in the "rocket literature."

These books are written by Professor Nikolai A. Rynin, the well known Russian rocket expert. The first one has the title "The Attack on the Stratosphere" (Shturm Stratospheri). It gives a complete history of all attempts of mankind to the stratosphere, beginning with the first balloon flights of the brothers Montgolfier in France and the first gliders in Lilienthal in Germany up to the present day stratosphere balloons and stratosphere planes. The last part of the book is devoted to the rocket experiments and their probable contribution to the exploration of the upper air. Some material from past issues of *Astronautics* appears.

The other brochure by Professor Rynin, which comprises the pages 621 to 686 of a larger work in a separate printing is entitled "Methods of Reaching the Stratosphere." It follows the same line of thought, but is written in scientific language and discusses for example the plans and calculations of Dr. Sanger (see book review in the last issue of *Astronautics*) which are not mentioned in the popular book. The work from which this brochure is reprinted was edited and published by the Academy of Sciences in Moscow under the title "Reports of the Conferences of the Stratosphere Committee (of the Academy of Science)" The rumors that the Russian authorities have ordered the construction of a 34 kilometer altitude rocket, which were published in the New York Times and other papers in this country are probably based on a misunderstanding of some calculations published in this volume.

— W. L.

Editor's Foreword

(concluded from page 3)

In Cleveland also, valuable activity is reported. The Cleveland Rocket Society, under the guidance of Ernst Loebell, has completed a well-equipped proving field and will soon enter upon a program of ground tests. Mr. Loebell has kindly furnished us with a specially written synopsis of the accomplishments and plans of this Society, which appears elsewhere in this issue.

While active experimentation seems to be at an ebb abroad, interest is maintained and theoretical studies are carried on. The British Interplanetary Society continues publication of its Journal, and it is probable that in Paris an astronautical center will be set up at the Astronomical Society of France.

Peter van Dresser, Editor

Printed by Conrad H. Ruppert, Jamaica, N.Y.

Report of Motor Tests of June 2nd

(concluded from page 4)

additional complication without a corresponding benefit is not warranted.

(d) The carbon motor tested in Run 5 burst soon after ignition and no records were obtained. The carbon nozzle was badly scored, showing carbon has too little resistance to abrasion for this purpose. However, this test cannot be regarded as definitely disproving the possibility of using this material as combustion chamber lining, which is not subject to the same abrasive action. An enclosing shell of adequate tensile strength would be necessary.

(e) Run 6 with alcohol gave the best performance. Despite its lower calorific content, it gave the highest impulse and jet efficiency. Its superiority was demonstrated during its run, producing even combustion, with a blue or almost colorless jet flame, and a high awe-inspiring sound of almost constant pitch. In view of the satisfactory results of this test with alcohol, its use in an entire series of tests is planned.

It must be noted that the impulse alone is not a complete basis for comparison of performance in these runs. The relation of the two factors, reaction and duration of combustion, which together form the impulse, must be evaluated to determine the best performance from the point of view of application to actual propulsion of a rocket.

An interesting phenomenon observed was the rising of horizontal layers or waves of darker-colored flame, like nodes, up through the jet. It has been suggested that these are sound effects and may be used to determine the jet velocity. This idea and another for the same purpose—making a record of the sound of the jet—are worth investigating. — The Experimental Committee

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