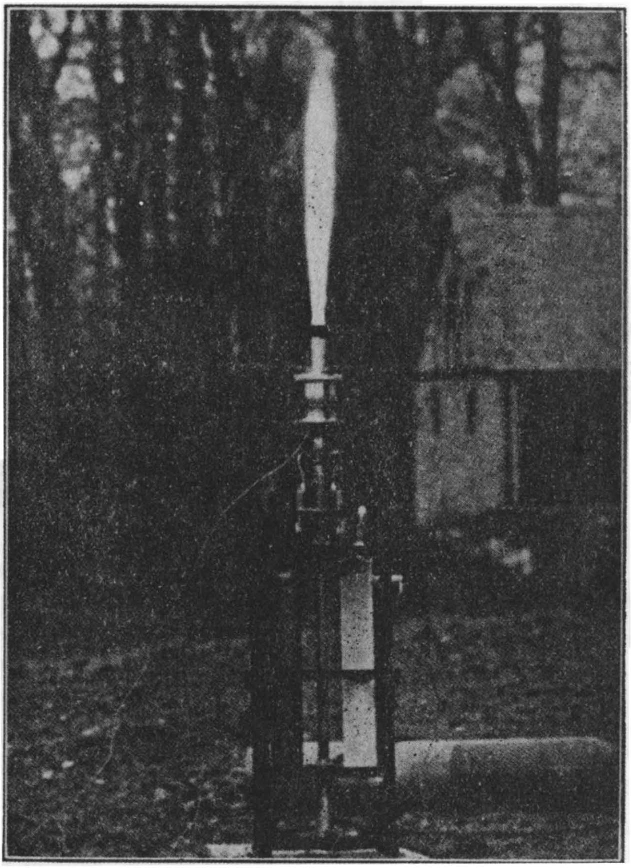
ASTRONAUTICS

Official Publication of the AMERICAN ROCKET SOCIETY
formerly American Interplanetary Society
147 West 86th Street, New York City

Number 31 June, 1935



The New Proving Stand in Operation

Gain in Membership Matches Striking Improvement in Experimental Technique

Things have been happening this winter and spring that mean decided improvement in the general health of the Society and unquestioned advancement in the science of rocketry.

During the fiscal year ending March 31st, membership increased by nearly fifty percent. This gain was, of course, matched financially, and the Society finds itself, even after a period of considerable expenditure for experimental purposes, with a substantial increase in the cash reserve divided amongst its general, experimental and library funds. The library department, under the management of Miss Gregory, has in fact multiplied its own funds through the sale of books on rocketry, while adding consistently to the number of valuable reference works on hand.

A Good Program of Meetings

During the winter and spring three well attended and interesting meetings were held. At the first, on February 8th, Mr. Nathan Carver lectured, with apparatus, on the application of short-wave radio to rocket control and tracing, and Mr. Alfred Africano gave an interesting mathematical and physical analysis of rocket trajectories and the effects of air resistance.

The second meeting on March 8th was a large one announced to the public through posters and the press. Willi Ley, secretary of the German Rocket Society and veteran experimenter, gave an illustrated lecture on "The Conquest of Space by Rocket." This was followed by extracts from the UFA film "From the Earth to the Moon" in the production of which Herman Oberth was technical advisor with Mr. Ley as assistant. There was also a small exhibit of motors, rockets, the proving stand, and charts. The meeting was attended by eight hundred people.

At the annual business meeting in April, regular elections took place. President Pendray was retained in office, Mr. Carl Ahrens was elected Vice President, and Dr. Lichtenstein yielded the secretaryship to Mr. Max Krauss, but remained Treasurer. The Board of Directors was expanded from five to seven, and members elected to it were: Mr. Alfred Africano, Mr. Carl Ahrens, Dr. Samuel Lichtenstein, Mr. Laurence Manning, Mr. G. Edward Pendray, Mr. John Shesta, and Mr. Peter van Dresser. At the conclusion of business a motion picture of the recent proving stand tests was shown.

New Apparatus Eliminates Guesswork

These proving stand tests constitute the real nucleus of the season's work, and in a sense they represent one of the most constructive moves so far. For some time the conviction has been growing amongst the Society's engineers and experimenters that we could learn much more about rockets —not by building and flying them— but by building rocket motors and putting them through exhaustive ground tests. Causes for failure or inefficiency could then be carefully observed and analyzed, in striking contrast to the difficulty of determining the causes of failure or success of a rocket in flight. From this reasoning was born action, which culminated in the new proving stand, designed and built by John Shesta and described elsewhere in this issue.

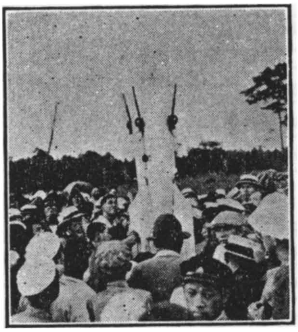
The first series of tests were run on April 21st. Five motors, with varying nozzles and pressures, were tested to failure. Accurate photographic records were taken of thrust, fuel pressures, and blast chamber pressure, this latter probably for the first time in history. (Mr. Shesta's detailed report may be found elsewhere in this issue.) Far more was learned in these trials than if each motor had been attached to a complete rocket and shot into the air, where its behavior would have been a matter of conjecture.

Another Series of Tests Ready

So successful and valuable is this technique that an intensive program of tests was immediately put under way. Six motors embodying new ideas are at the time of printing practically completed, and several more are under construction. By the time this new series is thoroughly tested it will probably be possible to build a motor sufficiently reliable and efficient to make the construction of one or two small rockets for trial flights worth while. This phase of the experimental program, which is scheduled for the summer months, will be preceded by stability tests on models powered by dry-fuel rockets. A later number of *Astronautics* will report these experiments in detail.

The kind cooperation of the Aluminum Company of America and the Air Reduction Company has been continued and is of great help. Members will also be gratified by the new appearance of *Astronautics*. Our publication will probably be issued for a while as a quarterly, as the three-month interval seems to allow time for the completion of a cycle of experiments. As progress accelerates and membership increases, the interval of publication will be shortened. To the best of our knowledge *Astronautics* is now the only regularly issued, technical rocket journal.

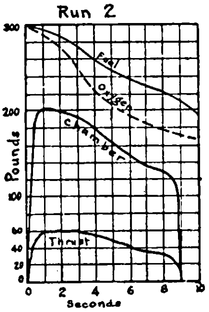
Probably at no time since its founding has the Society been progressing more soundly and surely towards the mastery of the latent power of the rocket. The understanding, appreciation and help of all members have been and will be of tremendous value to its work.

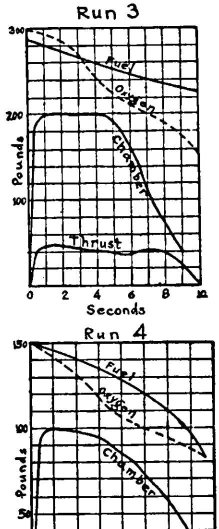


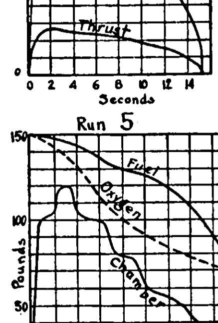
From Tokyo, Japan, comes this interesting photograph supplied through the courtesy of Acme Newspictures, Inc. The rocket model on exhibition was designed by Mr. Tsunendo Obara, and aroused great interest when exhibited last October.

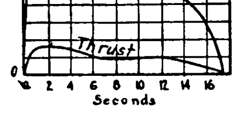
Report on Rocket Tests

by John Shesta









The first of the series of rocket motor tests proposed by the American Rocket Society was made on the proving grounds at Crestwood on the 21st of April, this year.

Rocket motors were attached to a special test stand, with means provided for measuring the pressures and reactions during the firing period. The charge consisted of one pint of fuel and two pints of oxygen. The method of loading the tanks and firing the rocket was substantially the same as previously used in rocket shoots. The rocket motor was of the same pattern as in the A.R.S. No. 3 Rocket. The only difference was in the length of the nozzle and in the method of fastening the parts together, which was done by means of a brass flange and external bolts.

The firing chamber of the original motor was elongated 2 inches by the introduction of an aluminum cylinder of the same diameter as the chamber, and assembled into a unit with the other two parts of the motor.

The joints were made up with sheet asbestos gaskets of the type used on steam lines. These gaskets stood up very well without any signs of leakage or failure.

Two types of nozzles were used in the tests. The short nozzle was 4 inches long, had a ½ inch throat diameter, and an expansion ratio of throat area to mouth area of five to one. The long nozzle was I2 inches long, and of the same throat diameter. Its expansion ratio was 25 to 1.

Two runs were made with each nozzle one at 300 pounds pressure and the other with 150 pounds pressure so as to compare the effect of pressure and nozzle length upon the performance of the motor.

Table I gives a summary of the results, which are also given in detail in the accompanying charts.

No figures are given for the first run, because the oxygen feed line blew out at the moment of firing. This was probably caused by a detonating wave set up by mixed fuels which backfired into the tubes.

A new aluminum casting had to be used for each run because of the burning out of the nozzles. In runs 2 and 3 the nozzles burned out at the end of firing and a hole was burned in the cap piece.

In runs 4 and 5 the burning out was less severe due to weaker combustion, but there was evidence of incipient fusion and sweating out of metal in the thin portions of the castings. Where metal walls were ¾ inch or more, no melting or scoring took place, showing that one way, at least, to prevent motors from burning out is to make them massive enough. This solution is only practical for ground test work because of the great weight of such motors.

The results of these tests are not sufficient to warrant making any but tentative conclusions.

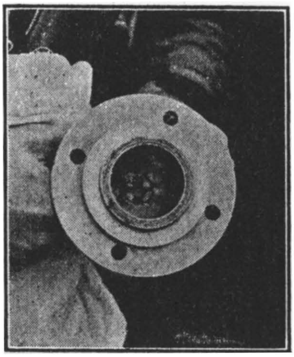
The tests do show, however, that long nozzles are of no value and that higher pressures are more effective.

Another point strikingly brought out is that the greatest obstacle at the present is the lack of a motor capable of withstanding the effects of firing for a sufficiently long time.

New tests are being planned in the near future with the object of developing more heat resistant motors. It is believed that cast aluminum motors are not practical for rocket use.

(A table of information covering flame characteristics during these runs will be found on the back page.)

A MOTOR HEAD



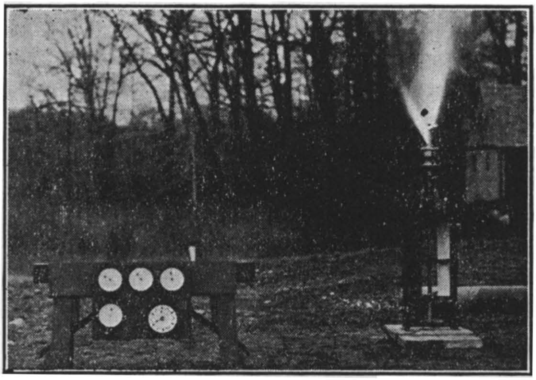
In the high pressure runs a small hole was usually burned through the head beside the fuel ports. This was probably caused by an irregularity in the jet of burning fuels which sprayed an oxidizing flame back towards the head.

The type of fuel port is clearly shown. It consists of two pairs of opposed orifices—the smaller pair for gasoline, the larger for oxygen. The fuels were forcibly driven against each other to cause mixing and complete combustion. In motors where the fuel is injected from the head this is a problem, as the fuels tend to be forced out of the blast chamber and burn partially in the nozzle. Some of the motors now in preparation for the next tests will have throat feed.

Table I

Run	2	3	4	5
Nozzle	Short	Long	Short	Long
Pressure Lbs. per sq. in.	300	300	150	150
Duration of Firing Seconds	9	10	15	17
Max. Thrust pounds	59	46	25	17
Impulse pound secs.	430	380	280	180

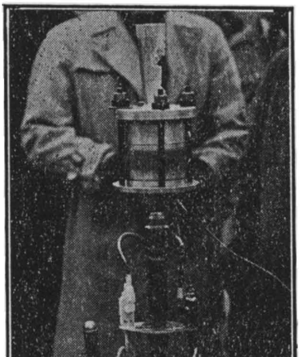
The Proving Stand in Action



This view shows a motor firing on the test stand, and the recording dials at the left. By the ingenious design of this apparatus unusual compactness, simplicity and portability was secured. Mounting the motor so as to fire upwards instead of downwards, as has always been done before, eliminated the necessity for bulky framework. The entire assembly of fuel tanks and motor is carried on a hydraulic plunger piped to a pressure gauge for recording thrust. This arrangement removes the need for flexible connections between the motor and fuel tanks. All gauges are mounted on one panel together with a timing dial, and the readings are recorded photographically during the firing.

The motor is shown at the instant when one side of the nozzle burned out.

A Motor After Firing



This close-up of the motor used in run number two shows how one side of the nozzle was cut away. It is believed that this is due to the fact that part of the combustion took place in the nozzle.

The assembly of the testing unit is shown clearly. At the left is the feed from the oxygen tank; also the safety valve. The oxygen and gasoline lines each pass through a combined check and quick-opening valve devised by Mr. Shesta. The chamber-pressure tube may be seen at the right.

The Experimental Committee will cooperate with any members who have motors they would like to test on the proving stand. To make this possible motors should be built with proper size feed lines so that they may be connected to the stand. This information will be given on consultation with the Experimental Committee.

Two Recent Books of Rocketry Reviewed

Raketen-Flugtechnik, by Dr. Eng. Eugen Sanger (Technical Highschool of Vienna) (Munich, Ed. R. Oldenbourg, 1934).

The book by Dr. Sanger, who is a teacher of aerodynamics and who is also a licensed pilot, is the only book about rockets so far that deals with the problems from the viewpoint of the constructing engineer. It is also the first book so far that has been written after a long series of experiments conducted by its author. These took place at the Technical Highschool of Vienna in the last few years. Being a flyer, its author tries to adapt the principle of rocket propulsion for stratopheric flying. The book has three parts; the first deals with rocket-propulsion, the second one with aerodynamical questions and the third one with the trajectories of rockets in general and with those of rocket-planes in particular. Though Dr. Sanger compiles much valuable material in the last two parts and develops proper shapes for wings and fuselage of planes that are to fly with speeds greater than sound the first chapter is the most interesting. Dr. Sanger gives tables of all possible fuels and oxygen-suppliers and arrives at definite conclusions as to which of them cannot be used. He limits successful experimentation to the hydrocarbons, and a few liquid gases, like marsh-gas and liquid hydrogen. He calls the attention of the experimenters to the use of Ozone instead of oxygen, showing that liquid Ozone has many advantages over liquid oxygen. Not only is its boiling point not so low, but it also develops power when its O_3 molecules are rearranged to O_2 molecules before combustion. A special feature of his rocket-motors is the extremely long nozzle, at least five times as long as the blast-chamber.

The second important book that has been published recently is a supplement to "L'Astronautique" by Robert Esnault-Peterie, the famous French rocket authority. It is essentially a lecture, delivered by Mr. Pelterie before the Societe des Ingenieurs Civils ds France. It deals with the following questions: "the movements of gases in a gravitational field"; "interplanetary trajecories"; "variations of movement"; "movement of rockets in air"; "combustion in a closed chamber"; and finally the "possible applications of rockets". In the last chapter the author restricts himself to the ultimate goal of space exploring and space travelling.

Both books are highly scientific and very valuable but though Mr. Pelterie's book looks further into the future, Dr. Sanger's work is of greater immediate value. — *Willy Ley*

Russian Rocketors Reported Active

Dispatches from Moscow announce that a Soviet stratosphere committee has ordered the construction of a rocket capable of attaining a maximum velocity of 2,200 feet a second and a possible altitude of 34 miles. The rocket is to be equipped with automatic recording instruments and a parachute to return it to earth. It is also reported that plans are being studied for a larger rocket designed to ascend several hundred miles.

Materials for Rocket Construction - I

by Bernard Smith

The Society's Experimental Committee recently asked Mr. Smith to make a study of the properties of available metals and other materials for rocket construction. His report will be presented in two sections, of which this is the first. The second will appear in the next number of Astronautics. Ed.

The problems that face the rocket designer in choosing materials resolve themselves into two divisions:

(1) Selecting the materials for the blast chamber.

(2) Selecting the materials for the fuel tanks.

The ideal *blast chamber* materials should have these properties:

Good thermal conductivity

High melting point

High specific ten. strength at high temperatures

Good wearing qualities against the erosion of exhaust gases

Practical fabrication possibilities

As all the qualities desired cannot be found in one metal or alloy, some must be balanced out in favor of others.

For example the advantages lying in the greater strength and hardness of the alloyed metals may not be as desirable as the higher melting points and thermal conductivity found in the same ones unalloyed. Further, all heat treatable and age hardening alloys lose their superiorities in strength at the higher temperatures.

Even though the temperature of the ordinary rocket flame (oxy-gasoline) is 2000° C., it has been found preferable to use a blast chamber of moderate melting point like one made of Aluminum

TABLE I

Blast Chamber Metals

Metal	Sp. Gr.	M. P. °C	Cu 100 thermal conduct.	hardness	ten.strength lbs | in²	ten.str. at 1000° C	nature of oxide at High temp.
Aluminum	2.7	658	55	2.9	10,000	(Liquid)	refractory, hard
Duralumin	2.8	550	30	3.5	65,000	(Liquid)	refractory, hard
Copper	8.9	1083	100	3.5	30,000	Low	Powdery
Ber.copper	8.2	864	40	5.	193,000	(Liquid)	Powdery
Iron	7.9	1525	15	4.5	40,000	Low	Powdery
Stainless Steel	7.8	1250	5	5.5	175,000	6,000 lbs | in²	Partially Refractory
Stellite	8.6	1250	1.5	7.	256,000	24,000 lbs | in²	Partially Refractory
Molybdenum	10.2	2620	40	6.	300,000	50,000 lbs | in²	Oxidizes very slowly
Tungsten	19.3	3370	45	7.	560,000	15,000 lbs | in²	Oxidizes very slowly

Other Possibilities

Metal	Sp.Gr.	M.P.	Hardness	Thermal Conductivity	Nature of oxide at high temperatrue
Beryllium	1.84	1280	6.5	10	Refractory, but not protective
Titanium	4.8	1795	7.	40	Refractory, hard

rather than one of steel with a higher melting point but far inferior in thermal conductivity. This becomes obvious when it is realized that a material with a melting point below that of the flame temperature it comes in contact with cannot be expected to remain solid unless it can conduct this heat away quickly. For this reason copper can also serve well to form a blast chamber.

Aluminum blast chambers have superiorities in other ways that may appear obscure but which nevertheless are very real.

As aluminum is three times lighter than most commercial metals, motors of it can have about three times more volume to act as a heat reservoir, than would be possible with the others. Experience with rocket motors have shown this to be very important.

Also, the protection afforded by the oxide of aluminum is so good that it never allows oxidation to advance beyond a thin layer. (This feature has certain disadvantages, however, for a heavy layer of Alumina, which has almost the hardness of diamond and a high melting point would be highly useful in resisting the erosive flow of hot gases.) Titanium and to some extent Beryllium, have this same ability to form refractory, hard, tenacious oxides.

Copper, common steels and magnesium alloys, form powdery oxides with practically no structural strength or protective properties.

Stellite has been suggested as a good alloy for a rocket motor. It has a hardness of 7, and high tensile strength which it tends to hold at elevated temperatures, but it must be rejected on three points: poor thermal properties, melting point not high enough for its rate of conductivity, and the difficulty involved in manufacturing a motor from it.

Of the two remaining blast chamber metals, Molybdenum can be judged the better, in fact it can be called the best of all the metals for the job of making a rocket motor.

With a melting point exceeding even that of the Oxy-Hydrogen flame temperature (2400° C) and its good thermal conductivity, to which add great hardness, low chemical activity, high tensile strength at high temperatures and moderate specific gravity, it may well go to form a blast chamber able to withstand the Oxy-acetylene flame (4400° C).

Tungsten, although having a melting point 700 degrees higher, falls off very rapidly in tensile strength until at 1000° C it has only about ⅓ that of Molybdenum at the same temperature. So it can be seen that to design a motor to withstand a given pressure at this temperature, 6 times as much Tungsten would be required to give it the strength equal to one of Molybdenum. With advancing temperature the differences

(continued on back page)

Memorandum on the Mechanics of Rocket Flight

The reasoning behind calculations of rocket flights is comparatively simple, and can be explained, in essentials, in a few paragraphs. In this memorandum we will try to develop the subject logically, under a number of subheads.

1. What is a rocket?

It is essentially a contrivance for changing chemical energy into mechanical motion. This it does by converting the liquid fuels into gas under high pressure. The gas is formed in a compartment called the *blast chamber* and ejected through a properly shaped nozzle. Ejection of the gas causes the rocket to develop a thrust in the opposite direction, the thrust being equal to the mass of the ejected gas multiplied by its velocity.

This reaction is independent of the air or any surrounding medium, and depends upon a physical phenomenon expressed in Newton's famous Third Law of Motion: "Every action has an equal and opposite reaction." It is strictly analogous to the kick of a gun, except that in the rocket the ejection of gas, and hence the recoil, continues for a longer period.

The blast chamber and its nozzle are known as the *motor* of the rocket. The motor contains no moving parts, and is thus the simplest possible contrivance for converting chemical into mechanical energy. Its efficiency depends, however, upon high velocity, the greatest efficiency appearing at velocities of the order of the speed of the escaping gas (possibly two miles a second). At such speeds we may expect to develop thermal and mechanical efficiencies as high as 85 per cent. This may be compared with the efficiency of the gasoline engine, about 25 per cent, and of the steam engine, about 10 per cent.

2. How a rocket flies.

A rocket consists of its motor or motors, tanks for carrying its fuels, apparatus for controlling the flight, parachute or other gear for landing, and the pay-load, which may consist of instruments, cameras, etc.

Suppose that a rocket, completely loaded for flight, weighs twenty pounds, and the motor is capable of developing a thrust of twenty pounds. Such a rocket, if pointed directly upward, will not rise, because the motor is capable only of counterbalancing the pull of gravity. The rocket will merely hang in the launching rack.

If, however, the motor of such a rocket is capable of a thrust of forty pounds, the rocket will have a net upward thrust of twenty pounds. Since this is exactly equal to its weight, it will move upward with an acceleration of one gravity, or 32 feet per second per second. At the end of the first second it will be going at the rate of 32 feet per second; at the end of the second, 64 feet per second; at the end of the

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Members of the Society are constantly asked for explanations of just how a rocket works. This article, prepared by Mr. Pendray and Mr. Ley, is designed to answer this question in the simplest, clearest, and most authoritative fashion. It is suggested that the article be passed on to those not yet acquainted with the principles of rocketry, but who have expressed interest.

third, 96 feet, etc. Its speed at the end of any second of flight may be calculated by the formula:

$$v = gt$$

where v is velocity, g the acceleration, and t the time in seconds.

The distance traveled in a given time, at this rate, is expressed by the formula:

$$s = \frac{1}{2}t^2 g$$

where s is the distance, t the time in seconds, and g the acceleration. By this formula it may be shown that our hypothetical rocket, with an acceleration of 32 feet per second per second, will cover, in the first ten seconds of flight, 800 feet. By the end of its 20th second of flight, it will have covered 3200 feet, or three-fifths of a mile. By the end of its first minute of flight it will have gone 28,800 feet, or more than five miles. By this time, according to our first formula, it will be traveling at the rate of 1920 feet a second.

If, now, the power is shut off, the rocket will continue upward on momentum, to a distance expressed by the formula:

$$S = \frac{V^2}{2g}$$

where S is the distance, V is the velocity at the end of powered flight, and g the acceleration of gravity, or 32 feet per second per second. In the case of our hypothetical rocket, the additional, or "free" flight would be 57,600 feet, or more than ten miles. This, added to the distance covered by powered flight (five miles) would make a rocket shot of fifteen miles or more.

The above calculations have not taken into account the resistance of the atmosphere, which would probably reduce the altitude reached by about 25 per cent, leaving a total altitude of 10 or 12 miles for the shot of our hypothetical rocket.

The flight of a rocket may be likened to the flight of an arrow, which has a sharply accelerated portion (while it is in contact with the bowstring) and a long coasting flight on momentum.

The height theoretically attainable in a vertical direction may be calculated from the above formulas. Trajectory flight, which is not now under consideration, obeys similar laws, but the calculation of the trajectory is rather more complicated, and requires the use of mathematical formulae similar to those worked out in connection with ballistics.

3. The Energy Problem

In calculating the flight of our hypothetical rocket we have not taken into account the source of its power. This must come from the fuels carried in the tanks. These are fed into the chamber rapidly and continuously during the powered part of the flight, and are quickly used up in generating power for the rocket.

The rocket cannot get more power than is contained in the fuels—in fact it will get considerably less, because no machine has yet been devised that has an efficiency of 100 per cent. Moreover, the rocket, at slow speeds, is inefficient, and since it must start at zero velocity, a good portion of the powered flight of such a small rocket will take place during this inefficient phase.

The longer the rocket fires, at a given acceleration, the higher it will go. But the longer it fires, the more fuel it must burn, and the more fuel it burns, the more it must carry. More fuel means larger fuel tanks, more starting weight. This in turn complicates the calculation of acceleration.

All of these factors must be taken into account in designing the rocket, and the factors will vary for every intended altitude. This is the designer's problem, and is one that must be finally settled in practice, by actual field tests. The fuels commnonly used, gasoline and liquid oxygen, theoretically contain enough power to shoot themselves and a loaded rocket across the Atlantic, provided the initial fuel supply is big enough and the motor efficient. For altitude shots of ten, fifty, 100, or even 500 miles this combination should be sufficiently powerful, when burned in motors of efficient design, and when propelling a rocket of correct aerodynamic proportions.

Willy Ley and *G. Edward Pendray*

Materials for Rocket Construction

(continued)

become more marked.

Other metals with high melting points, like Tantalum and those of the Platinum group, do not offer the advantages that either of the aforementioned do.

Because Molybdenum and Tungsten cannot be cast, and become workable only at temperatures at which no other materials can be used to forge them, a method of sintering must be used to form them. The powdered metal is placed in the desired mold and then subjected to high temperatures and presssures. The intercrystalline friction created by this treatment causes a fusion of the powder, making the metal solid and homogeneous.

Flame Data for Test Runs

These observations were made by Mr. Nathan Carver.

		Length of Visible Flame during Run			Color of Flame during Run		
Test No.	Length of nozzle	Start	Middle	Finish	Start	Middle	Finish
2	5 "	11 "	33 "	35 "	Blue	Milky Yellow	Blue-white
3	12 "	11 "	17 "	47 "	Blue	milkyellow streaked Blue-white	Yellow
4	5 "	11 "	15 "	31 "	Blue-white	Very Light Yellow	Yellow
5	12 "	18 "	34 "	48 "	Blue-green	Light Yellow	Reddish Yellow

In all shots after the initial firing the flame lengthened, at first very quickly, then for the longest period very slowly, and at the end very rapidly.

In one or two cases there was a blue-white tinge at the end of the shot, due probably to aluminum combining with oxygen.

Measurements are accurate plus or minus ½ inch. Color observations are approximately accurate.