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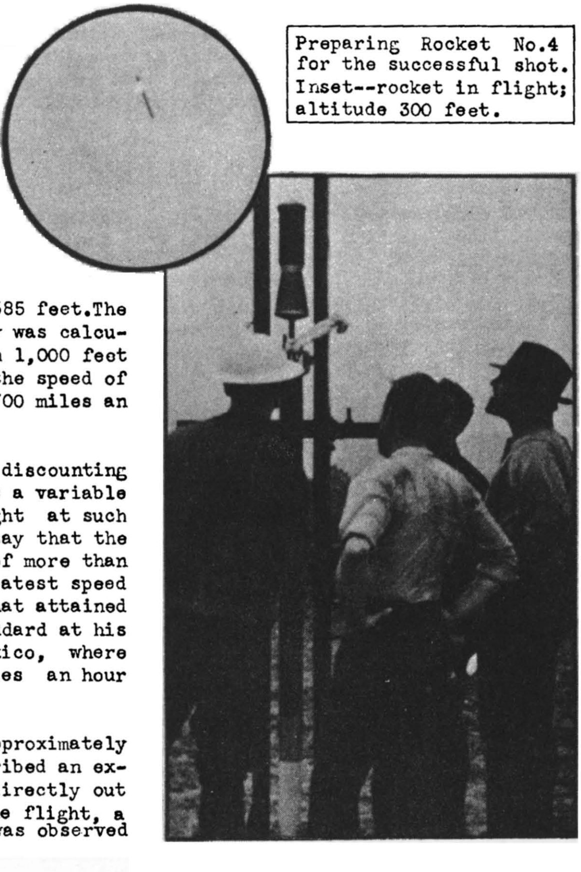
THE FLIGHT OF ROCKET NO. 4

600 MILE AN HOUR SPEED ATTAINED BY MULTI-NOZZLE TANDEM TANK ROCKET

Experimental Rocket No. 4, a four-nozzle single motor rocket with tandem fuel tanks was shot at 8:31 A.M. on Sunday morning, September 9th. It was one of the most successful and spectacular shots ever obtained with a liquid fuel rocket.



Preparing Rocket No.4 for the successful shot. Inset--rocket in flight; altitude 300 feet.

Careful calculations, based on a special triangulation system, indicate that the rocket reached an altitude of 382 feet at the highest point in its trajectory, landed 1,338 feet from the base of the launching rack and covered a total distance of 1,585 feet.The rocket's greatest velocity was calculated to have been more than 1,000 feet a second --- approximately the speed of sound, and equal to about 700 miles an hour.

Allowing for errors in discounting for air resistance, always a variable factor in accelerated flight at such speeds, it seems safe to say that the rocket attained a velocity of more than 600 miles an hour. The greatest speed previously reported was that attained in 1932 by Dr. Robert H. Goddard at his proving ground in New Mexico, where flight speeds up to 500 miles an hour were obtained.

The rocket fired approximately fifteen seconds, and described an excellent trajectory, going directly out to sea. After about half the flight, a weaving or"hunting" motion was observed which may be attributed to air resistance or to the fact that one nozzle burned out, or possibly to both bauses. The length of the trajectory, and the low altitude for the long base of the curve, is attributed to the burning out of the nozzle, which changed the direction of the flight radically. This apparently occurred at an altitude of about 350 feet.

Description of the Rocket

The general design of Rocket No.4 is familiar to readers of Astronautics. Some details of the rocket as rebuilt after the unsuccessful test of last summer are contained in the special engineering report on the shot, which appears on Page 3.

The chief new features of the rocket consisted of the four-nozzle arrangement of the single motor, the instantaneous valves, and the method by which the parachute was opened. The later, unfortunately, had no opportunity to demonstrate its usefulness in this test,because the rocket took such a trajectory as to preclude the opening of the 'chute.

The efficacy of multiple nozzles on a single motor was well demonstrated, despite the fact that the motor itself had been designed as a single nozzle chamber, and has been made over into a multiple-nozzle. The indications are that much greater efficiency and better resistance to heat will be obtained in multi-nozzle rockets when the motor is especially designed with this feature in mind. Calculations are now being made to determine the proper theoretical shape for such a motor, and probably multi-nozzle motors will be cast for next year's experiments.

The Firing

The shot was made at the Society's proving ground near Great Kills,Staten Island, the launching taking place from the Society's new adjustable steel launching rack.

It has been decided to shoot two rockets during the week-end of September 8th to 9th. Both rockets were on hand, ready to be fired--Experimental Rocket Nos. 3 and 4. No. 4 was fired first because the rack had previously been adjust for it.

Triangulation stations had been established shortly after sunrise under the direction of Mr. Alfred Africano (who made the flight calculations),assisted by Mr. Stewart J. Rodger. The rocket was placed in the rack and fueled by Mr. John Shesta and Mr. G. Edward Pendray. A quart of gasoline and 300 pounds of nitrogen pressure were put in first, followed by approximately a quart of liquid oxygen,furnished for the experiment by the Air Reduction Sales Company.

Five minutes were allowed to elapse before firing, in order to build up oxygen pressure. Mr. Laurence Manning was timer; Mr. Pendray ignited the chlorate and sulfur fusees; Mr. Shesta was valveman.

Directly the valves were opened the rocket leaped from the launching rack. Almost vertical flight was maintained for nearly 300 feet, at which point the rocket turned rather sharply out to sea. It was at that point, observers assume, that the burned-out nozzle failed, shifting the direction of the propulsion forces acting on the rocket.

The rocket rapidly sloped over until it was headed (Continued on Page 12)

SHOT REPORT ON ROCKET NO. 4

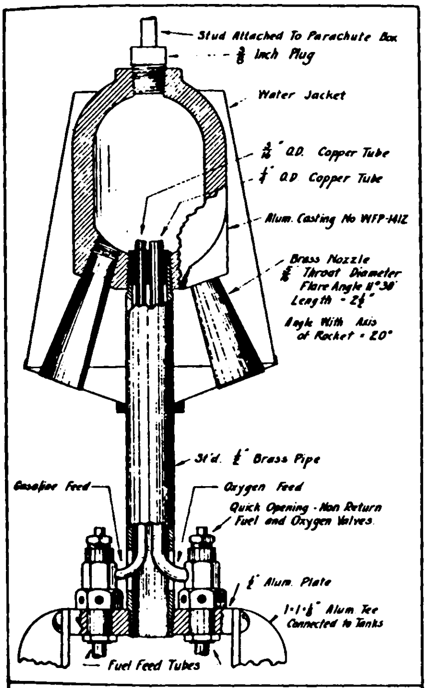
Rocket No. 4 had undergone various changes during the course of construction, and the final form adopted was quite different from that shown in the preliminary plans in the October 1933 issue of Astronautics.

In the first test of this rocket, which took place on June 10, 1934, the firing head described in the March issue of Astronautics was used. The test revealed faulty design. Fuel ports were too small to admit fuel at the rate necessary for proper reaction. The rocket failed to leave ground. The small exhaust nozzles melted or burned off during the test.

In the second test (September 9) the rocket. was provided with a new firing head which had larger fuel ports, larger exhaust nozzles, and a water jacket to cool the motor. The idea of the rotor wings for safe descent was abandoned as impractical for a rocket of such small cross-section, and a parachute used in its place. This was to be released by means of a special, spring operated, anti-gravity device. Dimensions and details of construction are shown in the accompanying diagram.

Flight Behavior

The behavior of the rocket during its flight, as well as subsequent examination of its mechanism, showed that everything worked as planned with the following exceptions:



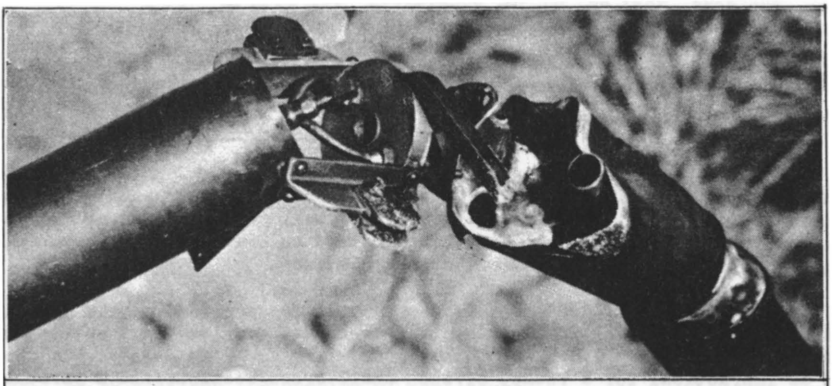
Design of four-nozzle motor of Experimental Rocket No. 4.

1. Water jacket failed to cool the motor.

The heat generated by the combustion was so great that a film of steam immediately formed on the heated surfaces, thus separating the metal from the water, and preventing further heat transfer. This condition was anticipated, of course, but it was hoped that the presence of water would nevertheless delay the heating of motor for the few seconds necessary for the flight. Experience has shown that this hope was not justified.

2. The firing head was faulty.

The aluminium casting for the firing head was designed originally as a single-nozzle motor, as used in one of the Society's early experiments. In converting it into a multi-nozzle motor, a great deal of metal had to be cut away in the various boring and tapping operations. This left the metal wall of the casting rather thin in certain places, particularly at the points where the brass nozzles were screwed in. As where was no way to avoid this difficulty, short of making a new casting, and since the precise nature of result was not known, the condition was allowed to remain.



Appearance of the motor end of Rocket No. 4 after the shot.
The bending evidently was caused by impact with the water.

At the end of about three to four seconds of firing, a hole was burned in the base of the aluminium casting, near the throat of one of the nozzles. Exhaust gases issuing from this hole, and playing on both sides of the nozzle, promptly melted it, blew the water out of the jacket, and so distorted the bottom plate of the latter that it got in the way of the blast from the other nozzles and deflected the stream of the exhaust to one side, making the rocket unstable in flight thereafter.

3.Place of burning.

An examination of the interior of the firing head shows that the burning must have taken place in a fan-like sheet at the point where the two streams of liquid fuel impinged on each other. There is a band of discolored and oxidized metal where the flame played on the wall of the chamber, but no traces of erosion or incipient melting anywhere but on the bottom surface, where the erosion is quite serious, especially near the nozzle throats. Probably this is not real erosion in the full sense of the term, but rather the result of melting off of successive thin layers of metal, the heat not having time to diffuse through its whole thickness. That this should take place near the nozzles, where the gas velocity is the greatest, is only natural, since the rate of heat transfer depends upon the speed with which insulating layers of gas are swept away from the metal surface, allowing new gas to flow past it.

Special heat and oxygen resisting, alloys, such as nichrome, etc. should be used in future tests, to make nozzles or liners for nozzles and possibly parts of the firing head. These may prevent burning out of rocket motors.

4.The parachute failed to open.

The parachute opening device did not get a fair test, because the horizontal flight of the rocket made it impossible for the parachute to open. The parachute was designed to open when the rocket acted as a freely-falling body, a condition which was not realized in this flight.

Sub-Committee on Rocket No. 4: John Shesta
Laurence Manning
Carl Ahrens
Alfred Best

TEST REPORT ON ROCKET NO. 3

This rocket was scheduled to be fired on Sunday, September 9, but lack of sufficient oxygen, after the shot of Rocket No. 4, precluded any but ground tests.

In this particular design, the fuel tanks are arranged concentrically,one about the other, around the rocket's motor; that is, built up from a series of duralumin tubes of increasing diameters. The gasoline container is innermost, encircling the motor. Next is the nitrogen tank, and outside of all the oxygen tank, each attached to the others by welding wherever possible. The outer tank wall of each tank constitutes the inner wall of the next.

The motor casting, of special aluminum alloy, consists of an egg-shaped blast chamber leading into a conical expansion nozzle. The blast chamber projects above the tanks and is surmounted by a removable cap held on with bolts. This arrangement permits easy inspection of the chamber and nozzle throat.

Copper feed lines (intercepted by quick-release valves) lead from the fuel tanks to the combustion chamber. Pressure to force fuels into the chamber is supplied,in the case of gasoline, from the nitrogen gas tank, and in that of oxygen, by its own vapor pressure.

Object of Construction

Our object in constructing a rocket along these lines was:

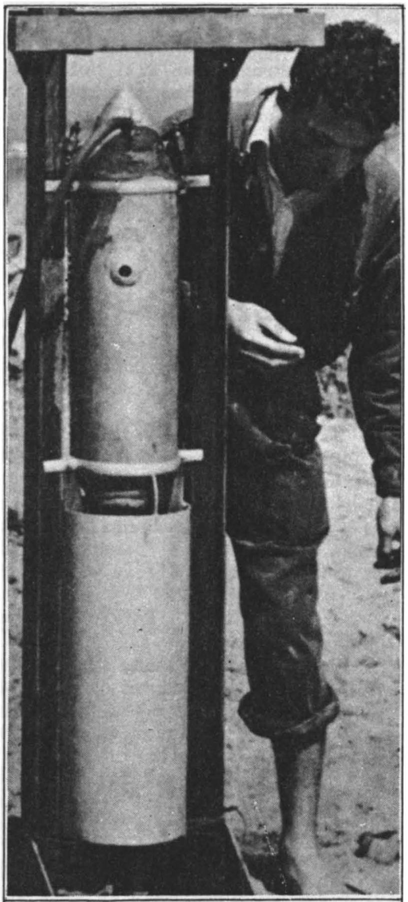
<u>First</u>, to keep the oxygen container away from the rocket's flame.

<u>Second</u>, to test the possibility of cooling the motor with one of the fuels (gasoline being in direct contact with the motor).

<u>Third</u>, to have the blast chamber and throat available for inspection after each firing.

<u>Fourth</u>, to see how much the use of a long nozzle would affect the stability and thrust of a rocket.

In the original design (Astronautics No. 27) a venturi or thrust augmentor was provided for, but due to the weight added in strengthening certain members of the rocket, this feature was abandoned and a simple circular fin, for stabilization purposes, was attached to the after end of the main section.



Bernard Smith preparing Rocket No. 3 for the proving stand test.

The dimensions over all when completed were; height 4 feet; greatest diameter, 8 inches; diameter along tanks, 6½ inches.

The landing devices on Rocket No. 4 were to be recovered and used for Rocket No. 3 but unfortunately parts were lost or damaged in its descent and new ones could not be supplied in time for the test.

The Rocket Test

The method of ignition decided upon was identical with the one used for Rocket No. 4 in its successful ascent.

No.3 was mounted in the launching rack and charged with 1¼ quarts of gasoline. Nitrogen gas to force-feed this gasoline was next pumped in to a pressure of 300 pounds per square inch.

We then attempted to fill the oxygen tank. Two quarts of liquid oxygen were fed through the fill hole,but to our observation most of it boiled off as soon as it struck the relatively warm inner tank. Further oxygen losses were sustained during the filling, when the out-rushing oxygen gas persisted in spurting the liquid from the funnel. Another two quarts were fed. This time, because the tanks seemed to be considerably precooled, the out-rushing of gas oxygen was not so pronounced. The frost line on the tank also rose considerably higher than at the attempted first filling.

From former experiences, inference was drawn at this time that at least one quart was in the container, whereupon it was closed.

We then proceeded to watch, from our dugout, for the safety valve's releas which would signify that sufficient pressure had been built up for the firing. After 1½ minutes the frost line began dropping rapidly on the oxygen tank. After another 2½ minutes no evidence of the valving off of oxygen was apparent.

At this time we decided to shoot. Mr. John Shesta fired the chlorate and sulphur flares and Mr. Bernard Smith released the valves. Immediately a succession of loud "chugs" were heard as if the oxygen and gasoline were feeding intermittently. These quickly ceased and were followed by an outflow of blazing gasoline from the nozzle. Assured by its character that this flame, which almost enveloped the rocket, was simply gasoline burning in air, we approached and extinguished the fire with sand.

Results of Examination

Upon examination no fuels were found to remain in the tanks, nor was any part of the motor scored. From the preceeding facts, including the difficulties encountered when filling with oxygen, we were led to believe that only an extremely small amount of oxygen was present in the tank at the time of firing. This was further borne out by the existence of the preliminary "chugs" and their immediate cessation. The final conclusion therefore drawn was that this particular design will require at least twice as much liquid oxygen to cool its tanks as any previous type.

As no part of the rocket appeared to be damaged preparations were made for a second test. When we came to fill with oxygen, we found but three quarts left. As no more oxygen was available we proceeded to fill with what we had, and with a better method of filling we managed to install a larger quantity of oxygen than before.

Three minutes after closing the tank we observed the (Continued on Page 11)

THE THEORY OF ROCKET OPERATION

By John Shesta, C.E.
Member, American Rocket Society Experimental Committee

It is apparent from a perusal of rocket literature that the theory of rocket reaction is not generally understood by rocket experimenters. Various formulas and equations are given, which, however, lead to results not in agreement with each other. There is no reason why this should be so, for, while the serious study of rocket development is of comparatively recent origin, the underlying laws of physics and thermodynamics have been known for a long time.

Moreover, from the standpoint of practical design, the action of a rocket nozzle differs from that of the turbine nozzle only in so far as the pressure and temperature conditions of the ejected fluid are involved, while the principles of operation are identical.

In view of the above facts, as well as in anticipation of a series of tests of rocket motors planned by the American Rocket Society, the writer thought it desirable to elucidate the theory of rocket operation based on accepted thermodynamical laws, both in order to clarify the situation, and to furnish a standard of performance of an ideal rocket motor, whereby the performance of real rocket motors may be judged.

The Basic Formula

The action of a rocket depends upon a fundamental law of physics, namely the fact that every action has an equal and opposite reaction. ($M\,V \quad m\,v$).

Let us consider a rocket, not acted upon by a gravitational field.

Let: M represent the mass of the rocket
dm the differential mass of exit gas ejected during an infinitely short period of time (dt)
dV the increment in rocket velocity due to ejection of dm.
v the gas jet velocity.
a the acceleration of rocket.

Equating momenta:

$$M\,dV = v\,dm$$
$$M\,dV/dt = v\,dm/dt \qquad \text{(Dividing through by dt)}$$
$$M\,a = v\,dm/dt \qquad (dV/dt \quad \text{acceleration})$$
$$R = v\,dm/dt \qquad (\;M\,a \quad \text{Force} \quad \text{Reaction})$$

Since dm/dt is the mass of gas flow per second, we can write:

Reaction, lbs. (1/32.2) (Jet velocity, ft. per sec.)(Wt. of flow, lbs. per sec.) 1

This is the fundamental equation for all jet reactions.

An examination of equation [1] will show that the reaction may be increased by increasing the jet velocity, or the weight of flow, or both. Some attempts have been made to increase this reaction by introducing heavy inert materials into the jet, such as molten lead, mercury, or even solid projectiles. It will be shown later that such expedients are incapable of increasing the reaction.

Reaction of Liquid Jets

The equation [1]: $R = (v\,w)/g$ involves terms whose value we do not generally know, so we cannot apply it directly. Let us first consider liquid jets, under such conditions that the liquid is always below its boiling point. The theory of such jets is relatively simple; no thermal changes are involved.

Let:

v represent jet velocity (ft. per sec.)
w the wt. of flow (lbs. per sec.)
h the head in feet (an alternative measure for pressure)
d the density of liquid (lbs. per in.^{3})
A the nozzle area (square inch)
p the gage pressure (lbs. per square inch)
g the gravity (lbs. per square inch)

Then:

$$v = 2gh$$
$$h = p/12d$$
$$v = 2g\ (p/12d)$$
and $$w = 12\ A\ v\ d$$
in [1] $$R = 2g\ (p/12d)\ 12\ A\ d/g$$
$$R = 2\ pA \quad [2]$$

Equation [2] is for an ideal nozzle. Actually, the discharge coefficient, and the friction loss have to be considered, and they will somewhat decrease the reaction. It is possible, however, with proper design, to make these coefficients come very close to unity.

Reaction of Gas Jets

As all practical rockets use gas jets for their propulsion, except the powder rockets, where the jet may in some cases contain a small amount of solids as a by-product of combustion, it is the action of gas jets which is of primary interest to the rocket builder. Their theory will be discussed below. The writer wishes to point out in this connection that "Engineering Thermodynamics" by Lucke has been used as a reference book. Some equations have been directly reproduced from that volume, while others have been transformed and re-derived to make them applicable to rocket problems.

According to Boyle's Law the pressure - volume product of a gas is equal to a constant, to wit:

This law applies to isothermal conditions,i.e. those where heat is either added to or removed from the gas, so as to maintain it always at a constant temperature. In practice this is very seldom the case. Pressure - volume changes are always accompanied by thermal ones,which in turn affect the resultant pressure or volume, and thus introduce a complication. These changes follow the exponential law, which states: $P_1V_1^s \quad P_2V_2^s \quad K$

The value of the exponent "s" has been experimentally determined for a variety of gases and conditions. In a rocket nozzle the expansion takes place under substantially adiabatic conditions, or, in other words, at a constant entropy. Under such conditions the exponent s is equal to 1.4 for air, while for CO_2 and for superheated steam, it is 1.3. Since rocket exhaust, with common liquid fuels, consists chiefly of CO_2 and superheated steam, we may assume the value of s to be very close to 1.3.

The velocity of a gas jet expending from an initial pressure P_1 to a final pressure P_2, is given by Zeuner's Equation.

$$v = \sqrt{2g\frac{S}{S-1}\,P_1V_1\left[1-\left(\frac{P_2}{P_1}\right)^{\frac{S-1}{S}}\right]}$$

The weight of flow will be:

$$w = \frac{A}{V_1}\left(\frac{P_2}{P_1}\right)^{\frac{1}{s}} \sqrt{2g\,\frac{s}{s-1}\,P_1 V_1 \left[1-\left(\frac{P_2}{P_1}\right)^{\frac{s-1}{s}}\right]} \text{ lbs. per sec.}$$

where: P_1 represents absolute initial pressure, lbs. per square foot.
P_2 the absolute final pressure, lbs. per square foot.
V_1 the initial specific volume of gas, cubic ft. per lb.
V_2 the final
A nozzle area, square feet

Maximum Weight of Flow

Now it is a curious fact that at a certain pressure ratio of P_2 to P_1 a critical condition is reached where the maximum weight of flow occurs. This takes place when:

$$\left(\frac{P_2}{P_1}\right) = \left(\frac{2}{S+1}\right)^{\frac{s}{s-1}}$$

To quote Lucke:..."This result is quite remarkable and is verified by experiment reasonably closely. It shows that, contrary to expectation, the weight of efflux from nozzles will not continuously and regularly increase with increasing differences in pressure, but for a given initial pressure the weight discharged per second will have reached its limit when the final pressure has been diminished to a certain fraction of the initial, and any further decrease of the discharge pressure will not increase the flow through an orifice of a given area."

For most common values of s this maximum flow occurs when (P_2/P_1) is between .5 and .6.

It is also interesting to note that in every orifice, or nozzle there is a point where the pressure falls to this critical value of itself,and that the gas acquires a certain fixed velocity at that point which is the velocity of sound in that medium. In a properly designed nozle, further expansion, with an increase in velocity, takes place beyond the critical point.

For any pressure drop greater than the critical one, the weight of flow will be as follows:

$$w = \frac{A}{V_1}\left(\frac{2}{S+1}\right)^{\frac{1}{s-1}} \sqrt{2g\,\frac{S}{S-1}\,P_1 V_1\left(1-\frac{2}{S+1}\right)} \text{ pounds per sec.}$$

Calculation of Reaction

We can now combine the equation for velocity and for the weight of flow, and evaluate the reaction developed by the nozzle.

$$3 \quad R = 2AP_1\sqrt{1-\left(\frac{P_2}{P_1}\right)^{\frac{s-1}{s}}}\;\sqrt{\left(\frac{2}{S+1}\right)^{\frac{2}{s-1}}\frac{S^2}{S^2-1}} \text{ lbs.}$$

In this equation, we may express the pressures in pounds per square inch, while A is the throat area of the nozzle in square inches. The pressures are absolute pressures = (gage + 1 atmosphere).

This equation applies to an ideal case, where all combustion takes place in the firing chamber and only the products of combustion are ejected through-the nozzle, without frictional reheat or sidewise dissipation. Of course these conditions cannot be fully realized in practice. Still, it is possible to make very nearly perfect nozzles. Certain steam turbine nozzles have developed a Rankine Cycle efficiency of 97 to over 98 per cent, when working against a very low back pressure.

Nozzle Design

If instead of a conventional flared nozzle,we should use a plain orifice, or hole in the wall of the rocket motor, we would still obtain some reaction from it.

The jet, however, would build up a back pressure on the outside of the orifice, limiting the velocity, as already explained, due to the critical condition, with the result that a large fraction of the potential energy of the gas would be uselessly dissipated. Furthermore, if sharp corners exist, the net area available for gas passage may be as low as 60 per cent of the gross area.

Ideally, a nozzle should be so designed that it will discharge the gas axially and at the pressure of the surrounding medium, without frictional reheat. If the mouth is too small, the full expansion is not realized; if, on the other hand, the mouth is too large, we have overexpansion with the result that recompression takes place, setting up waves, very detrimental to the successful operation of the nozzle. Too sudden an expansion of the nozzle causes the gas to bounce from side to side, producing frictional reheat, while too small an angle results in a long nozzle, which also causes increased friction.

For the determination of the expansion ratio, i.e., the ratio of the throat to the mouth of the nozzle, we can use Moyer's empirical equation.

$$\left(\frac{\text{Mouth Area}}{\text{Throat Area}}\right) \begin{array}{ll} = .172\left(\frac{P_1}{P_2}\right) + .7 & \left(\text{when } \frac{P_1}{P_2} < 25\right) \\ = .175\left(\frac{P_1}{P_2}\right)^{.94} + .7 & \left(\text{when } \frac{P_1}{P_2} > 25\right) \end{array}$$

The flare angle of the nozzle is not well established theoretically. Various angles are used, with not so much difference as might be expected. Angles between 10° and 20° are most commonly used in steam turbine practice. It should be borne in mind in this connection, that a rocket is subject to variable conditions. The tank pressure will gradually decrease as the fuel is used up, while the back pressure will vary from that of sea level to the prevailing at some high altitude, provided the rocket goes up that far.

In the design of rocket nozzles it is advisable to avoid hair-splitting and rather exercise some sound engineering judgement in selecting an average condition.

Example

Design a nozzle for a rocket working at 300 pounds chamber pressure, discharging to atmosphere at sea level, having a throat diameter of $\frac{1}{2}$ inch. If the weight is 20 pounds what will be the acceleration of the rocket?

$P_1/P_2 = 315/15 = 21$

Then mouth area/ throat area $= .172 \times 21 + .7 = 4.31$
Throat area (1/2ø) $= .196$ in^2.
Mouth area $= 4.31 \times .196 = .845$ in^2.
Mouth diameter $= 1.04$ in.
Difference in radii $= .27$ in.
Assuming 12° flare angle (included), length $= \cot 6^\circ \times .27 = 2.57$ in.
Nozzle reaction by equation (3) :
$= 2 \times .196 \times 315 \times .710 \times .950 = 83.4$ pounds
Acceleration $= (83.4-20)/20\text{xg} = 102$ ft. per sec. per sec.

TEST REPORT ON ROCKET NO. 3

(Continued from Page 6)

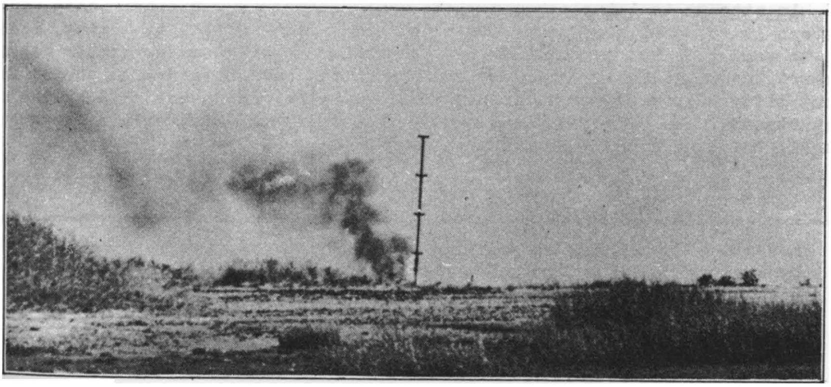
frost line again falling. Unable to hear the safety valve release even after $4\frac{1}{2}$ minutes, we fired. Results were identical with the previous experiment, excepting the "chugs", which were more powerful and longer sustained, indicating that a larger quantity of oxygen was present at this attempt.

All mechanical parts functioned perfectly and none showed sign of scaring or weakness during these tests. Another test has been arranged for and will take place shortly.

The technique needed for handling this type of rocket has now to some extent been developed. Future experiments with it will take place with greater speed and ease.

Sub-Committee on Rocket No. 3: **Bernard Smith, G. Edward Pendray, Alfred Africano**

CORRECTION: --Persons in the front page picture of Astronautics No.29 were mistakenly identified in the caption. Pendray is the figure at the left; Shesta is at the right.--Editor.



Scene at the Society's proving field during a ground test. The launching rack inclines toward the ocean.

THE FLIGHT OF ROCKET NO. 3

(Continued from Page 2)

directly toward the water. Shortly after the change of direction it began to "hunt". It struck the ocean with a terrific splash, the force of the impact bending the upper part as shown in the lower picture on Page 3. The rocket was recovered by Mr. Daniel DeV. Harned.

NEWS OF ROCKETS

Dr. Robert H. Goddard, head of the physics laboratory of Clark University and pioneer rocket experimenter, has returned to Roswell, New Mexico, to resume his interrupted experiments there under a grant from the Guggenheim Foundation. His announced intention is to develop altitude rockets for stratosphere research, with the idea of reaching heights of forty miles or more.

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A new series of motor proving stand tests will soon be commenced by the experimental committee of the American Rocket Society, with a light, portable proving stand of new design now under construction. The design and construction are due to Mr. John Shesta. Permanent records of the tests will be made photographically, with the aid of motion pictures.

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Rocket articles appearing recently in magazines of national circulation include "Developing Rocket to Explore Stratosphere", Literary Digest, September 29; "What's In the Rocket?", Scientific American, July 1934, and "Men of Space", New Outlook, October, 1934. All of these articles mention the work of the American Rocket Society. The New Outlook article is an interesting collection of thumbnail sketches of rocketors and astronauts.

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An attempt to establish a rocket mail between Harris and Scarp, in the Western Isles, Scotland, unfortunately ended in disaster last August, according to word received by the American Rocket Society. The experimenter was Herr Gerhard Zucker, a German engineer, and his rocket was charged with powder fuel. About fifty letters, one addressed to King George, were enclosed in the mail compartment. Upon ignition the rocket exploded with great violence, destroying itself, the letters and the launching rack.

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Associate Membership in the Society at $3 per year may be obtained by sending the first year's dues to the Secretary, Dr. Samuel Lichtenstein, 147 West 86th Street, New York City. Information on other classes of membership may be obtained by writing the Secretary. Meetings of the Society are held monthly, except in summer, at the American Museum of Natural History, 77th Street and Central Park West, New York City.