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Number 61 **March, 1945**

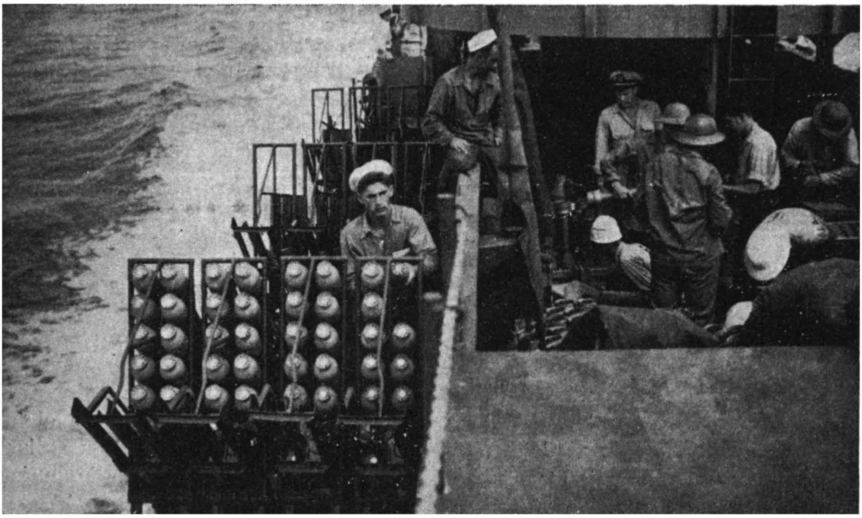
Navy Rocket-Firing Craft

Rocket Ships Add To Fleet's Firepower

Developed in great secrecy by British and American specialists rocket-firing ships are in general use by the Navy for attacking enemy vessels and in support of assault troops landing on hostile shores. The early rocket-equipped ships, designed as LCT (R), landing craft, tank, rockets, launched rockets in overlapping salvos from fixed multiple deck tubes with an estimated two and a half times the firepower of the largest battleship. These jet-driven missiles were of great assistance in neutralizing shore defenses in the Normandy invasion of June 6th last year.

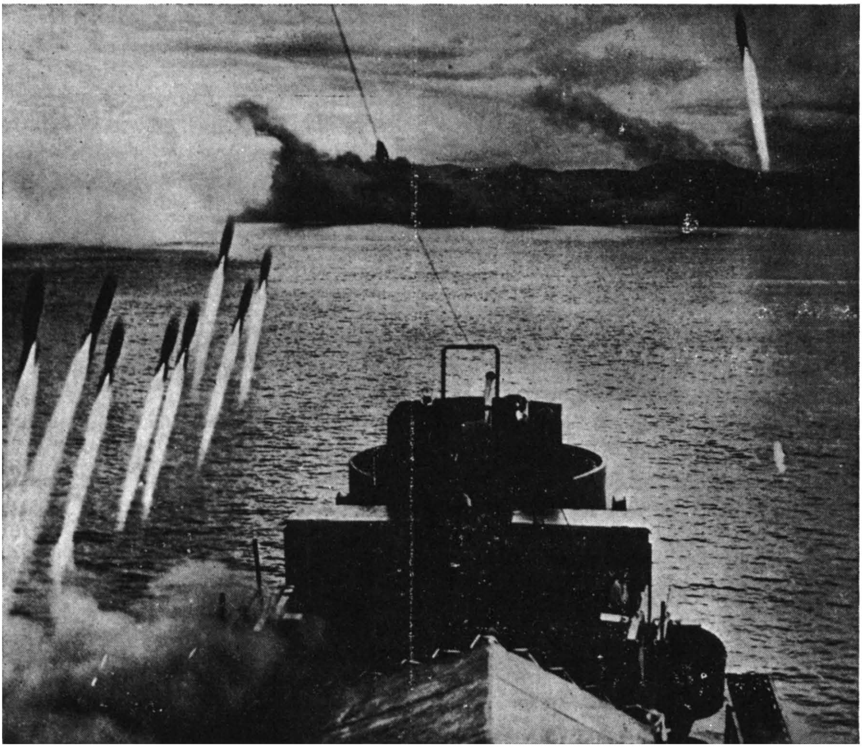
New type rocket ships of the task forces, now being used effectively in the Pacific war theatre, are the specially equipped Navy LCI, landing craft, infantry and the smaller LCVP, landing craft, vehicle, personnel. Due to the lack of recoil, rocket-firing installations can be mounted on such small landing craft to give them greater firepower. Carrying portable launching racks, the short range salvos from these rocket ships are reported to hit like 105 mm. shells.

Larger craft carry hundreds of three types of rockets: the high explosive beach rocket, the incendiary composition-filled rocket for determining range,



—U. S. Navy

Loading portable rocket-firing racks set up on an LCI.



—U. S. Navy

A rocket-firing LCI lets go a powerful barrage of deadly projectiles in the assault on Mindoro, P. I.

and the smoke-producing rocket for screening troops. Other than the more common 4.5 inch in diameter beach barrage rocket are the 2.5 inch SCAR, sub-caliber aircraft rocket, a 5 inch size, and several larger ones under development.

The rockets are usually placed in tilted launching crates, light of weight and easily set up. Installed in banks of ten the electrically ignited rockets are discharged separately or in groups. As the lower placed rockets are fired, the higher rockets slide down in the rack to take their place. For protection against the flaming gases emitted from the rockets, the rocket "gunners" wear asbestos suits and gas masks.

The 4.5 inch beach rocket has a high-explosive head and weighs about 15 pounds. The rocket motor consists of a long tube of slow-burning propellent powder in the rear of the rocket. Current from the electrical system of the ship flows from the launching rack to a wire pigtail attached to the rocket. On ignition the propellent powder generates flaming gases which escape through a nozzle giving a forward thrust until the fuel is exhausted.

New U. S. Jet Plane

SHOOTING STAR IS FASTER THAN SOUND

Announcement by the Army Air Force reveals its latest jet-propelled combat plane, the P-80 Shooting Star, being produced by Lockheed Aircraft Corp. and North American Aviation, Inc., is the fastest fighter in existence today. The first jet plane, the twin-jet Bell P-59A Airacomet, built in 1942, is now classified as a trainer.

In July 1943, Lockheed was requested to build a suitable airframe around a British De Havilland Aircraft Co. jet engine. Clarence L. Johnson, chief research engineer, designed the airframe and the P-80 prototype was built and flown in 143 days. Subsequently, a single General Electric turbo-jet engine which provided greater power than earlier jet engines was installed in the tail of the plane.

Air flowing into the forward streamline intake ducts on either side of the fuselage is compressed by a rotary impeller and on passing to the combustion chamber is expanded and increases its velocity by the burning fuel. The hot gases pass through a turbine wheel, which turns the compressor, and expell via a rear large nozzle propelling the plane. Fuel consists of gasoline, kerosene or low fire hazard bunker oil.

Knife-like leading edge wings and other aerodynamic innovations permit the P-80 to surpass the speed of sound (about 700 m.p.h.). The plane has a high rate and speed of climb, outstanding maneuverability and a ceiling well above that of conventional engined planes. Due to the light-weight engine and airframe, greater quantities of fuel can be carried providing a comparative range with conventional pursuit planes. Other features include a pressurized cabin equipped for pilot "G" suits to relieve the strain of pull-outs, a cockpit bubble canopy for better visibility, various combinations of nose armament, and provision for stowing heavy loads of ammunition, photographic equipment, bombs and fuel.

Maneuverability of the plane is aided by a hydraulic aileron boost and electrically operated flaps. The jet engine needs less than a minute warm-up, gives quick takeoff and develops about 4,000 h.p. Controls and instrument panel are simplified. The P-80 engine, besides having a lack of noise and vibration, due to its simplicity can be replaced in about a half hour compared with the required eight hours for standard fighters.

THE GLOSTER METEOR

London has announced that the RAF jet-driven fighter, the Gloster Meteor, product of the Gloster Aircraft Co., has been in action against robot bombs since Aug. 4, 1944. Powered with Rolls-Royce jet engines the plane does over 500 miles an hour enabling it to overtake flying bombs and has downed a considerable number.

Easiness of control, smoothness of flight and excellent maneuverability at high speeds enhance the high point efficiency of the plane. Gaining speed with height, the Meteor emits little or no flame or smoke trail and flies without excessive noise. A second British jet fighter is now in an advanced state of development.

Notes On Rocket Fuels

A Comparison Of The Relative Values of Fuels

By ALDO VIEIRA DA ROSA

Lt. Brazilian Air Force

We shall define as fuel any two substances that, under propitious circumstances, will produce an exothermic reaction. When this is the case, there is a potential energy between the two substances that is released under the form of radiant energy—heat or light—when combustion takes place. The "power" of the fuel is judged by the rocket engineer as the amount of stored energy per unit mass of mixture, in contrast with the rating of fuels for terrestial operations, when the number of calories per unit weight of combustible alone is taken in account. This is a natural consequence of the fact that in the case of a space ship, one has to lift and accelerate the mass of both components entering the reaction, while on earth one component is always available at no expense at all.

The value of the fuel as far as its energy content goes, can be rated by a figure of merit—which we, borrowing the symbol from radio engineering call Q—expressing the number of kilocalories per gram of **mixture**.

This figure of merit will deviate considerably from the usual ranking of fuels, because in a mixture of correct proportions the weight of oxygen is by far the predominant part. Thus, the mass ratio of this gas to combustible goes from 8/1 for hydrogen to 2.67/1 for carbon.

Energy Equations

To determine the Q of a mixture, it is necessary to know the heat of formation of the end product or the heat of combustion of the mixture, as the case may be. These heats are given usually in kilocalories per gram molecule. After writing out the equation describing the reaction that takes place, the atomic weights of all atoms on one side of the equation are added up, and the total is divided into the heat figure, the result being the Q.

The kinetic energy of a mass m of gas is one half the mass times velocity squared and therefore the kinetic energy of a gas in movement per unit mass is one half the velocity squared and can be equated directly to the corresponding potential energy Q, assuming no losses.* By introducing the mechanical equivalent of heat (427) we obtain the formula

$$v = 2930\sqrt{Q}$$

for the maximum theoretical exhaust velocity of the rocket gases.

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*Losses are due to lateral expansion of gases, heat transmission and radiation through walls, friction on walls, uneven mixture, etc. They are reduced by proper design of the dimensions and taper of the exhaust nozzle which decreases lateral expansion. By doubling the linear dimensions of a combustion chamber, its fuel capacity is increased eight-fold while the increase of wall area is only four-fold with a net result of a lower percent loss. The friction can be minimized by polishing the exhaust nozzle. The inhomogeneity of the burning mass is corrected by allowing the fuel to well mix before ignition.

As an example: Benzene burns according to the equation

$$2C_6H_6 + 15O_2 = 12CO_2 + 6H_2O$$

We have twelve atoms of carbon at an atomic weight of 12 each, twelve of hydrogen at 1 each and thirty of oxygen at 16 each, adding up to a mixture weight of 636, which when divided into twice the heat of combustion 782.3 kilogram calories, or 1565, yields the figure of 2.46 for the Q and 4.53 km/sec for the maximum theoretical exhaust velocity

Table I gives the figure of merit for a few fluid organic fuels. The products of combustion are gaseous carbon dioxide and nitrogen and liquid water. The table is strictly correct only for combustions taking place at 20°C under atmospheric pressure, but it serves to show the relative values of the different substances.

Note that all the Qs are smaller than that for the hydrogen-oxygen mixture listed at the end of the table for comparison. This is due to the fact that the heat of combustion of an organic compound is the average of the heats of separate burning of carbon and hydrogen atoms minus the heat of formation of the substance. The presence of carbon, with its low Q of 2.15, in all organic compounds will tend to make these compounds less efficient as rocket fuels than hydrogen alone.

TABLE I

Substance	Physical state	Q
Acetaldehyde	liquid	1.32
Acetonitrile	liquid	2.34
Acetylene	gas	2.94
Amylene	liquid	2.57
Benzaldehyde	liquid	2.32
Benzene	liquid	2.46
Benzonitrile	liquid	2.27
Borneol	liquid	2.48
Butyl alcohol	liquid	2.40
Butylamine	liquid	2.46
Caproic Acid	liquid	2.23
Carbon di-sulphide	liquid	1.55
Carvacrol	liquid	2.39
Citrene	liquid	2.52
Cyanogen	gas	2.23
Decane	liquid	2.53
Diamylene	liquid	2.55
Dihydrobenzene	liquid	2.42
Ethane	gas	2.59
Ethyl alcohol	liquid	2.30
Ethylene	gas	2.67
Formaldehyde	gas	2.16
Heptane	liquid	2.55
Hexane	liquid	2.53
Isobutane	gas	2.57
Isopentane	gas	2.57
Isopropyl alcohol	liquid	2.33
Methane	gas	2.63
Methyl alcohol	liquid	2.14
Octane	liquid	2.54
Propane	gas	2.58
Toluene	liquid	2.45
Xylene	liquid	2.41
Hydrogen	gas	3.21

Fuel Mixture Potentials

A fuel with a Q of the order of three is quite far from what a rocket engineer dreams of. One can safely state that the problem of finding a powerful mixture, is more than half the problem of space flight. There are many ways open to the investigator to attack the problem. The pet one with the fiction writers is that of completely abandoning molecular energies, and searching for a means to harness the formidable atomic forces. This may be the solution of the future, but until the physicists hand us the key to it, we have, per force, to stick to chemical energies.

There are ways in which the potential energy in store in a hydrogen-oxygen mixture can be increased many-fold. The normal molecules of both gases are diatomic, i.e., one finds that normally the atoms move around in pairs, bound together by considerable force. To disturb this disposition by either adding more atoms to the molecules or taking one away requires a certain amount of energy, which is kept in the gas and released when the molecules return to normal state. These modified molecules are all very unstable and difficult to produce in large quantities and with the required purity, this being the reason why they have not, as yet, been used. The list below shows the theoretical Qs.

TABLE II

Mixture	Q
Normal hydrogen and normal oxygen	3.21
Normal hydrogen and ozone (triatomic oxygen)	3.85
Normal hydrogen and mono-atomic oxygen	7.73
Mono-atomic hydrogen and normal oxygen	8.75
Mono-atomic hydrogen and ozone	9.45
Mono-atomic hydrogen and mono-atomic oxygen	13.35

Besides the three anomalous forms cited above, there are two others which however, are even more difficult to handle. They are hyzone, a triatomic hydrogen, stable for only one minute and only at concentrations of less than .02%, and oxozone, a tera-atomic form of oxygen.

High Heat Substances

Another approach to the problem is that of searching for substances having low molecular weight and picking out those with high heat of formation. The lightest possible end product of a combustion is normal hydrogen resulting from the combination of mono-atomic hydrogen with itself. Since the heat released per gram molecule of normal hydrogen is 50.4 kilocalories, the resultant Q reaches the enormous value of 25.2 Of course the question of stability is again the crucial one. A tank full of mono-atomic hydrogen is liable to explode at any moment, unless the right anti-catalyst is found. And here we are assuming that it is possible to get a tank full of this unreliable gas. Hyzone, when returning to normal hydrogen releases, also, a considerable amount of energy but like its mono-atomic brother, we have no means of controlling this fuel and of triggering it into action just at the right moment and in the right place.

Next in the line of increasing atomic weight we find helium, a gas that may have great uses in space flight as a safer substitute for nitrogen in the breathable air, but due to its utter chemical inactivity cannot be used as a fuel.

Lithium Analysis

Lithium, which follows helium up the scale, offers some interesting possibilities. Its small atomic weight assures the low weight of the compounds with the lighter gases, and its great chemical activity facilitates its use as a fuel. It combines directly with hydrogen, forming a hydride with a Q of 2.69. Also, combines directly with oxygen and fluorine with the appreciable Qs of 4.72 and 5.60, respectively. Although these merit figures are quite smaller than those for the abnormal forms of gases discussed above, they are quite promising on account of the stability of each of the components of the mix-

(Continued on Page 15)

German Jet Fighters

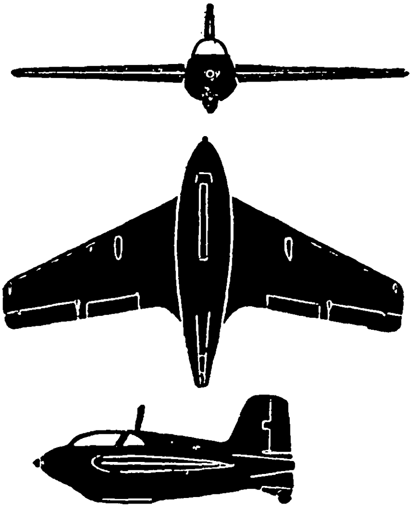
10-MILE-A-MINUTE AIRCRAFT IN OPERATION

After some years of experimental work, Germany has developed a number of high speed jet-propelled interceptor planes having a good rate of climb but extremely limited range and endurance. Early models were reported having poor maneuverability with need of wide areas for turns.

The Messerschmitt Me 163, known as the "jetty", is a rocket-propelled single-seat home defense fighter which carries oxygen and liquid fuel aboard the plane. With semblance to a flying wing, the plane has wide extreme back-swept 30 ft. span wings in mid-position and double ailerons. The tailplane consists of a single fin and rudder but no horizontal tail surfaces. Identified by half-mile smoke trails, the Me 163 has a single jet orifice located at the rear end of the fuselage which provides a high g rate of climb and bursts of speeds up to 600 m.p.h. The short 10 minutes of power flight performance can be extended by intermittent gliding periods. After takeoff the undercarriage is usually jettisoned and the landing executed on an underskid and tail wheel. In the Me 163 series is the trainer version, 163A, and the operational fighter, 163B.

Thermal Jet Aircraft

The Me 262 is a jet-propelled single seat all metal fighter-bomber with twin Junkers Juno 004 axial-flow turbo-jet units mounted one under each wing. Span of the swept-back wings is slightly over 40 ft. Able to attain speeds of 500 m.p.h. with high rate of climb to great heights, the plane utilizes the oxygen from the air for combustion of the liquid fuel.



The Me 163 is a rocket-powered fighter.

Newer but not as fast is the Heinkel He 280, with mid-position pointed tip elliptical shaped wings having a 40 ft span and a dihedral compound tailplane with angular fins and rudders. The plane is powered with similar appearing jet units as the Me 262 but of a different design. These two planes have tricycle undercarriages, and a unique pilot-ejector device which throws open the cockpit cover and catapults the pilot clear of the plane in an emergency.

A fourth jet aircraft, called the Arado Ar 234, has been reported in action on the Western Front. Details are lacking except that the plane is twin-engined with a speed in excess of 400 miles an hour.

FRICTIONLESS FLOW IN A ROCKET MOTOR

BY J.J. PESQUEIRA

The following is a summary of results from the simple theory of a frictionless flow of propellant gases through a rocket motor, conforming with a polytropic process of the form pV^n = constant, where n remains invariable throughout.

THE MOTOR. A rocket motor consists successively of a combustion chamber, C, Fig 1, a convergent passage, N', leading to a constriction or throat, T, and a divergent passage or nozzle, N, opening into the atmosphere. In the absence of a convergent passage per se, as is the case with the forward squared end of most combustion chambers, the flow pattern is such that the bulk of the flow restricts itself to a more or less gradually convergent stream, Fig. 2, thus forming by itself a virtual convergent passage.

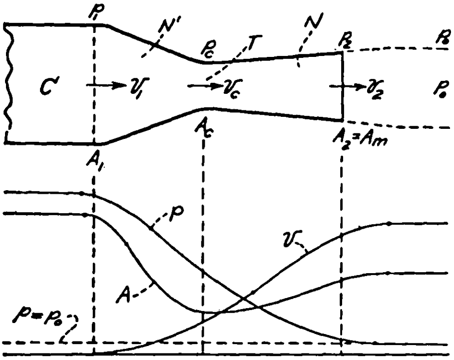


Fig. 1

The frictionless flow of gases through gradually convergent or divergent passages is identical to the flow in an elementary stream filament, in that the distribution of pressure and axial velocity on a transverse area is uniform. This kind of transverse distribution is, in fact, postulated by the simple theory of flow through large passages.

AXIAL DISTRIBUTION OF PRESSURES.– Initially with a value p_1 at the combustion chamber, the pressure gradually falls as the expanding gases advance through the diminishing transverse areas of the convergent passage, reaching a value p_c at the throat. This is the critical pressure. It is independent of the atmospheric pressure p_0, provided p_0 is below the value of p_c as calculated from the equation

$$p_c = p_1 \left(\frac{2}{n+1}\right)^{\frac{n}{n-1}}, \quad \text{---- (1)}$$

where p_1 is the combustion chamber pressure. The velocity of approach v_1 is assumed to be negligible

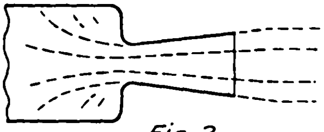


Fig. 2

Past the throat, the pressure continues to fall as the gases further expand in their forward motion through the increasing transverse areas of the divergent passage or nozzle, reaching a value p_2, – the exit pressure, at or near the mouth. In under-divergent nozzles (divergence = mouth area/throat area) p_2 is greater than p_0, and occurs at the mouth, as shown in Fig. 1, in which case the pressure reaches atmospheric value outside the nozzle. In over-divergent nozzles, however, the pressure becomes atmospheric within the nozzle, and the flow breaks away from the walls, as shown in Fig 3. This condition leads to pulsating flow. The value p_2 is the minimum pressure attained by the flow within the motor.

The axial distribution of pressures is related to the axial distribution of the transverse areas by the equation

$$\frac{A}{A_c} = \frac{1}{\left(\frac{p}{p_c}\right)^{\frac{1}{n}} \sqrt{\frac{2}{n+1}\left[1-\left(\frac{p}{p_c}\right)^{\frac{n-1}{n}}\right]+1}} \quad --- (2)$$

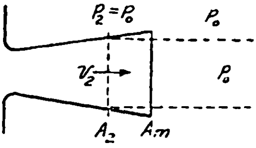


Fig. 3

where A_c is the throat area and p_c is the critical pressure [Eq. (1)]. The axial distribution of areas and corresponding distribution of pressures are shown diagrammatically in Fig. 1. In order to solve for values of p in Eq. (2) it is convenient to construct a graph of the equation, as suggested in the diagram of Fig. 4, giving values of A/A_c against p/p_c.

In practice, it is in most cases merely sufficient to determine the mouth area of a nozzle of correct divergence with respect to atmospheric pressure ($A_2 = A_m$ for $p_2 = p_0$) For this case, Eq. (2) gives

$$A_m = \frac{A_c}{\left(\frac{p_0}{p_c}\right)^{\frac{1}{n}} \sqrt{\frac{2}{n+1}\left[1-\left(\frac{p_0}{p_c}\right)^{\frac{n-1}{n}}\right]+1}} ,$$

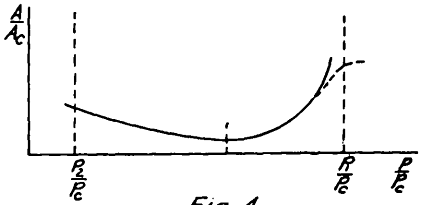


Fig 4

where A_m is the mouth area and p_0 is the atmospheric pressure.

AXIAL DISTRIBUTION OF VELOCITIES. From a negligible value of approach v_1 at the combustion chamber, the axial velocity of the advancing gases increases as the pressure falls, reaching a value v_c at the throat. Provided that $p_c > p_0$, the velocity v_c is found to be equal to that of propagation of sound in a gas mixture in the state existing at the throat, and is given by the equation

$$v_c = \sqrt{n g V_c p_c} , \quad ----------- (3)$$

where V_c is the specific volume of the gas mixture at the throat. In terms of conditions at the combustion chamber it is obtained

$$V_c = V_1 \left(\frac{n+1}{2}\right)^{\frac{1}{n-1}} \quad \text{and} \quad v_c = \sqrt{\frac{2ng}{n+1} p_1 V_1} . \quad ---------- (4)$$

The axial distribution of velocities is related to the axial distribution of pressures by the equation

$$\frac{v}{v_c} = \sqrt{\frac{2}{n+1}\left[1-\left(\frac{p}{p_c}\right)^{\frac{n-1}{n}}\right]+1} \quad ------------ (5)$$

Fig. 1 shows diagrammatically the axial distribution of velocities

In a theoretical nozzle of infinite divergence discharging into a vacuum ($p_0 = 0$), the maximum possible velocity is obtained:

$$v_{max} = v_c \sqrt{\frac{n+1}{n-1}} = \sqrt{\frac{2ng}{n-1} p_1 V_1}$$

The exit velocity in an orifice is $v = v_c$.

[A distribution of temperatures may be obtained from the equation

$$T = T_1 \left(\frac{p}{p_1}\right)^{\frac{n-1}{n}}$$]

WEIGHT OF FLOW. The flow, w, in units of weight per unit of time, is directly proportional to the transverse area of the throat. It is given by the equations

$$w = \frac{A_c v_c}{V_c} = A_c\sqrt{ng\,\frac{p_c}{V_c}} = A_c\sqrt{ng\frac{p_1}{V_1}\left(\frac{2}{n+1}\right)^{\frac{n+1}{n-1}}} \quad \text{--------} \quad (6)$$

This flow is independent of the presence of the nozzle, and exists for all values of atmospheric pressure up to $p_0 = p_c$.

REACTION FORCE. The integral of the axial components of the elementary forces pdS extended over the whole interior surface S of the motor, constitutes a resultant axial force R', which is the reaction force of the flow. On the other hand, the integral of the axial components of the elementary forces $p_0 dS'$, due to a uniform atmospheric pressure, extended over the entire exterior surface S' of the motor, constitutes a resultant axial force Q, opposing R'. The net useful reaction force is $R = R' - Q$. When the integrations are carried out in detail, they lead to the result

$$R = \frac{w v_2}{g} + A_2(p_2 - p_0) \quad \text{-----------} \quad (7)$$

For over-divergent nozzles as well as for those of correct divergence with respect to atmospheric pressure, then $p_2 = p_0$, and the equation becomes, simply,

$$R = \frac{w v_2}{g},$$

the familiar, but incomplete, formula for the reaction force.

Equation (7) may be put in the convenient form

$$R = KA_c p_1\sqrt{1 - \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}}} + A_2(p_2 - p_0) \quad \text{--------} \quad (7')$$

where $K = \sqrt{\left(\frac{2}{n+1}\right)^{\frac{2}{n-1}} \frac{4n^2}{n^2-1}}$, A_c is the throat area, and p_1 is the combustion chamber pressure. Eq. (7), or (7'), is obviously useful in the calculation of reaction forces in low-pressure atmospheres, where the use of correct divergence would result in nozzles of excessive length. When $p_2 = p_0$, Eq. (7') reduces to one derived by Shesta in ASTRONAUTICS, Oct.-Nov., 1934.

n	$\frac{n-1}{n}$	K
1.2	0.167	2.25
1.3	0.231	1.97
1.4	0.286	1.81
1.5	0.333	1.72
1.6	0.375	1.65

DISCHARGE THROUGH AN ORIFICE. The net reaction force produced by the discharge of an orifice, Fig. 5, is sometimes thought erroneously to be

$$R = \frac{w v_c}{g}.$$

This value is in general too small, being correct only for $p_c = p_0$. By Eq. (7) the reaction force is

$$R = \frac{w v_c}{g} + A_c(p_c - p_0) = (1+n)A_c p_c - A_c p_0.$$

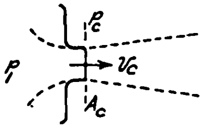


Fig. 5

or, in terms of the combustion chamber pressure,

$$R = 2\left(\frac{2}{n+1}\right)^{\frac{1}{n-1}} A_c p_1 - A_c p_0.$$

For $n = 1.4$, the term $w v_c/g$ amounts to only $0.74 A_c p_1$, whereas $w v_c/g + A_c p_c = 1.27 A_c p_1$. — With a theoretical nozzle of infinite divergence discharging in a vacuum, the maximum possible reaction force is obtained, with $p_2 = 0$, as $R_{max} = KA_c p_1$. This is equal to $1.81 A_c p_1$ for $n = 1.4$, the nozzle accounting for about $0.54 A_c p_1$, or nearly 30% of the total reaction force.

AMERICAN ROCKET PIONEERS

No. 3 — Dr. Darwin O. Lyon

As American rocket experimenter, physicist, surgeon and writer, Dr. Darwin Oliver Lyon traveled throughout Europe and Africa during the late 20's and early 30's lecturing and experimenting on high altitude rockets. Dr. Lyon received an M.A. degree from Columbia University in 1908 and a Ph. D. in Psychology in 1917. He went to Vienna for post-graduate study after receiving his medical degree from the College of Physicians and Surgeons, Columbia University, saw service as a surgeon with the French Army in the last war, and later represented the American Red Cross in Austria.

Following World War I, Dr. Lyon became interested in solving the problems of meteorology with rockets and sent many data-seeking projectiles into the upper air. A world's record was established on Jan. 29, 1929 at Mount Redorta, near Milan, Italy, when a rocket designed by him attained an altitude of nearly six miles. Instruments in the nose of the projectile recorded at the 5.9 mile culminating point, atmospheric density as 212 mm, temperature at 48°F. below zero, and air composition similar to that at sea level.

During 1930, a two-step 10 foot rocket was constructed of a special beryllium alloy which weighed, complete with scientific instruments and without fuel, 132 pounds. Propellants consisted of liquid oxygen and benzol, as well as a dry fuel similar to T.N.T. in the first step. The rocket was planned to reach a 70 to 90 mile height stabilized by a nose gyroscope and carry apparatus for measuring the strength of cosmic rays. On Feb. 2, 1931, at the start of the flight from the 10,000 foot Mount Redorta, the rocket exploded injuring the inventor and several assistants.

Plans were immediately made to build another rocket, this time under the auspices of the Royal Meteorological Observatory of Libya, to be fired just outside the city of Tripoli. This was to be a multiple-step rocket, carrying various meteorological instruments and cosmic ray detectors, for reaching altitudes in the stratosphere up to 100 miles. The rocket was to be guided through the denser atmosphere by fins and be later dependent on gyroscopes to hold it straight. Arrangements were made to bring the instruments to earth by parachute.

Dr. Lyon made numerous studies on the reactions of gravity and cosmic rays on small birds and mice sent aloft in rockets. In one experiment a canary and a mouse were sent to a one mile altitude at an acceleration of 55 meters per sec per sec, or five times gravity. Descending by parachute no ill effects were noticed from the high acceleration.

Dr. Lyon died on April 14, 1937 at Mount Vernon, N. Y., after a long illness. He was then 50 years of age.

In Vienna, on January 1, 1931, during an interview, Dr. Lyon said: "The ultimate goal of the rocket is, of course, interplanetary flight and the body to be visited will undoubtedly be the moon, but it is doubtful whether any attempt of that kind will be made for another fifteen years."

ASTRONAUTICS Nos. 9 and 21 contain reports of Society Biological Research Committees on the physiology of acceleration on white mice and guinea pigs subjected to high gravity forces.

A Vocabulary For Jet Propulsion

An Essential Astronautical Nomenclature

By G. EDWARD PENDRAY

New arts naturally demand new vocabularies. Nowhere is a clear systematization of words and phrases more needed than in the new art of jet propulsion

So fast has this field grown in the last half dozen years, that words and expressions have had to be coined rapidly to keep up with it. The growth has occurred principally in wartime, and much of it under necessary military restriction, so that free exchange of ideas among engineers and specialists has been impossible.

The purpose of this article is to present the beginnings of some sort of orderly vocabulary for the age of jet propulsion. It does not seem too difficult a task, since the underlying ideas themselves are simple and clear, and the principal problem is merely to choose the words and phrases that most clearly express the idea.

We can begin best at the beginning, with a definition of **jet propulsion:**

The basic principle upon which all reaction motors operate; production of **thrust** by the ejection of a directed stream or spurt of gas, liquid or other material through an orifice.

Jet propulsion is therefore seen to be the name of an operating principle, as compared with, say, the reciprocating principle, upon which gasoline engines, steam engines, diesels, etc., operate. Any type of motor or engine that produces thrust by ejecting matter at high velocity through an orifice is therefore a jet propulsion motor — or more simply, a **reaction motor.**

There are now discernible five general types of such reaction motors, divided into two principal groups: the **true rocket or chemical fuel motors,** and the **airstream engines.** The two groups are distinguished principally by the sources of the oxygen used for combustion. The true rocket motors obtain oxygen as a part of their fuels or propellants. The airstream engines obtain oxygen from the air.

These five motors and engines may be classified and named thus:

The True Rocket Motors

1. **The dry (or solid) fuel motor,** such as is used to power skyrockets, antiaircraft rockets, airborne rockets, barrage rockets, bazookas, projectiles, etc.
2. **The liquid fuel motor,** such as is used in some types of military apparatus, sounding rockets, and in the German V-2 rockets.

The Airstream Engines

3. **The thermal jet engines,** used to drive military aircraft. This type draws air through a forward opening, compresses it with the aid of a rotary compressor, burns it in a combustion chamber, and obtains thrust from the resulting jet. In most types some of the power of the jet is extracted by a turbine wheel, which operates the rotary compressor. When a turbine wheel is used, the device may be called a **turbo-jet.**
4. **The intermittent duct engine,** used to drive the German and American "buzz-bombs"—hence sometimes called the "buzz-bomb engine" or the "jitterbug stovepipe."

5. **The continuous duct engine,** also called the **athodyd,** in contraction of the more horrendous title: "**Aero Thermo Dynamic Duct.**"

Rockets, jet planes and jet gliders, of course, are only various types of vehicle driven by reaction motors.

A **rocket** is a **projectile** driven by jet propulsion. It makes no difference what type of reaction motor is used; so long as the object is a projectile, it is a rocket.

A **jet plane** or **jet glider** is an **airplane** driven by jet propulsion. **Jet plane** usually refers to a craft intended to carry a pilot and possibly passengers. A **jet glider** is usually robot-controlled and pilotless.

For its more general terms, jet propulsion engineering necessarily leans heavily on the vocabulary of aviation, dynamics and physics, slightly redefined or reoriented to fit the special meanings of the newer art. Other terms have either been newly coined for the service of jet propulsion, or adopted from entirely different fields.

Some of the words and phrases in common use or that could well be adopted are the following:*

A

Acceleration—The rate of increase of speed of a rocket during powered flight; usually measured in terms of **gravity (g)** or the rate of increase of velocity acquired by a body in free fall at the surface of the earth.

Airfoil—A thin, flat streamlined surface used for jet-glider or jet-plane wings, rudders, or flaps.

Airstream engine—A reaction motor that depends on the atmosphere to support combustion or increase the mass of the jet.

Area ratio—The ratio between the mouth area and throat area of a rocket nozzle.

Axial-flow compressor—A rotary air-compressor using propeller-like blades, through which the air flows parallel to the shaft.

Axis of thrust—An imaginary line, drawn through the center of the jet of a rocket motor, along which the thrust or reaction of the motor is directed.

B

Blast chamber—The chamber in which the propellant is burned in a rocket motor or jet engine. (Same as **combustion chamber).**

Booster rocket—An auxiliary rocket device with a large thrust and relatively brief firing time, used to bring a rocket or aircraft up to flying speed. (Same as **thrustor).**

C

Catapult—A device for launching a rocket or airplane with high initial speed.

Centrifugal compressor—A rotary air-compressor similar to a centrifugal pump, in which the air is thrown radially outward by vanes on a flat disk.

Center of gravity—The point at which all the mass of a flying body appears to be concentrated.

Ceramic liner—A porcelain-like heat resistant lining for a combustion chamber.

(To be continued)

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* This vocabulary is taken from a more extensive glossary of terms and phrases prepared by Mr. Pendray for his forthcoming book "The Coming Age of Rocket Power" to be published in May by Harpers.

The A. R. S. Journal

Name of the Official Organ is Changed

With this issue the name of the official publication of the Society is changed from ASTRONAUTICS to the JOURNAL OF THE AMERICAN ROCKET SOCIETY. This term appears more appropriate as the Directors have been contemplating the advisability of transforming the Society into a national engineering organization in the field of rocket and jet propulsion similar in form to the present great engineering societies. The prewar amateur status of the Society is fast becoming outmoded due to the vast change in the rocket-jet propulsion field from the war impetus and a reorganization seems imperative. The name ASTRONAUTICS is to be held in abeyance for possible future use.

THE BULLETIN

Following the organization on March 21, 1930 of the Society, then known as the American Interplanetary Society, an official publication called the BULLETIN appeared in June 1930. Edited by C. W. Van Devander, the BULLETIN was mimeographed in 8½ x 11 inch size, first with four pages and later with eight. Published usually monthly, the BULLETIN ended with its 18th issue of April 1932 which was printed in a 7¾ x 10 inch size. Numbers 8 to 18 inclusive were edited by Clyde Fitch.

These early publications of the Society stressed the interplanetary aspect and noted many details dealing with space flight. Surveys and tests pertaining to interplanetary travel were conducted and reported on in the BULLETIN.

ASTRONAUTICS

Beginning with No. 19 May 1932 issue, the name of the BULLETIN was changed to ASTRONAUTICS, meaning the science of extra-terrestial navigation or navigating above the air. The new editor David Lasser, founder and first president of the Society, continued the publication with a similar format of 8 pages until the 25th issue of Jan. 1933. Many of these issues contained information which formed the basis on which the early experimental rocket motors of the Society were planned.

Starting with the next edition on May 1933, under the editorship of Laurence Manning, ASTRONAUTICS appeared in printed form approximately 5½ x 8½ inches. This smaller size was considered to be more handy for reference use and easier to carry. ASTRONAUTICS came out irregularly three times yearly and varied from 8 to 20 pages for some years, finally arriving at a 16 page issue. During this time Peter Van Dresser, G. Edward Pendray and James H. Wyld succeeded as editors. Also in 1938 appeared two issues of a four page mimeographed BULLETIN, supplementing ASTRONAUTICS, supervised by Alfred Africano and edited by Fred Lorton.

With the publication of the 43rd number of ASTRONAUTICS in Aug. 1939, Roy Healy became editor. Experiments of the Society and doings of other rocket societies were reported in detail and with the outbreak of war articles in ASTRONAUTICS reviewed the many types of rocket weapons and gave many references on similar subjects. With the 59th issue of Sept. 1944, Cedric Giles became editor of the publication which was being published quarterly

(Continued from Page 6)

ture and the ease with which combustion can be started. The main disadvantage is the fact that lithium is a solid metal up to the temperature of 186°C, which means that fuel tanks and lines have to be heated up, if one insists in liquid feed. I want to add here, parenthetically, that this is not too much of an obstacle, since the waste heat from the engines can be utilized for this melting process, and once outside of the protection of earth's atmosphere, the tanks, if painted a dark color, will heat up when exposed to the sunlight. A second objection to the use of lithium fluoride is the necessity of using specially protected tanks, lines and exhaust nozzles, to guard against the highly corrosive action of fluorine gas. Copper tanks and lines covered with rubber varnish, and platinum-plated combustion chamber nozzles would, perhaps, solve this problem.

Boron fluoride with a Q of 3.82, boron oxide, Q of 4.10, and, perhaps, beryllium fluoride are other possibilities from the Q standpoint.

Reference

Handbook of Chemistry and Physics.

The Rocket Society of Cincinnati, University of Cincinnati, Department of Physics, Cincinnati 21, Ohio, has announced that its officers are: Walter Friedlander, president and publicity manager; Irvin Oxlander, vice-president and treasurer; Frank Blatt, secretary; and Fred R. Armstrong, editor. This amateur group, which became affiliated with the American Rocket Society on May 17th, 1944, has actively participated in a number of science demonstrations having rocket exhibits.

LETTERS TO THE EDITOR

Mr. George D. Lewis, of Ansonia, Connecticut, has sent the Society an interesting account of his observations of the V-1 and V-2 rocket bombs and a clipping from a Belgian newspaper describing the V-2. He mentions that while overseas he had the opportunity of watching the effect of Hitler's V-weapons in action as he was "sitting on the target." In thirteen days approximately 450 missiles landed in the area at the rate of from five to fifty a day. Mr. Lewis comments as follows on the V-2:

> "The V-2 rockets come over from the north in Holland and the east in Germany. Unlike the buzz bombs, they cannot be detected approaching, but their direction of flight can be determined from the site of the explosions. The only indication I have seen of a rocket flight was a very erratic smoke or vapor trail leading to a rocket explosion. This trail was formed of small climbs and levels as though the power came in bursts. The V-2 hits without warning other than the first explosion. This gives the bystanders from 1 to 10 seconds to prepare for the explosion of the warhead.
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> "The first of the two explosions seems to occur in the air and produces a bright orange flash, a little smoke, and a shower of a light aluminum alloy metal, probably the rocket shell. This explosion seems to drive the warhead downward where it explodes on contact. It appears that unlike the V-1 which runs until the fuel is exhausted, the V-2 is fused to go off at a certain point, much like an anti-aircraft shell. The difference in time between the two explosions indicates that the rockets come in at various altitudes, possibly depending on the point of launching. The second explosion causes a greenish flash, a pillar of smoke and a loud noise.
>
> "At a range of over two miles the concussion opens doors, knocks over objects, and pushes one's pants tightly against one's legs. The rocket devastates from one-half to one city block with the main power to kill in the concussion, not in the shrapnel, as the warhead is made of light aluminum alloy."

Other amateur rocket interested groups which have been affiliated with the A.R.S., are: the Amateur Research Society of Clifton, N. J.; the California Rocket Society, Los Angeles; the Westchester Rocket Society, New York; and the Yale Rocket Club at Yale University.

BOOK REVIEWS

Rockets, Dynamotors, Jet Motors, by A. L. Murphy. Wetzel Publishing Co., Inc., Los Angeles, 1944; 169 pages, $2.50

Written in question and answer style, this manual was compiled to acquaint the uninformed with rockets and jet propulsion. The word "dynamotor" has been coined by the author to express arrangements or designs of a converter or applicator for applying jet force for purpose of control or propulsion. The sections explain the many kinds of jets, and their applications to vehicles in the air, on land and sea. Means of launching and landing various types of craft, and fuels and methods of supply are covered. Included are a number of illustrations, data on atmospheric conditions at different altitudes, and an index.

Rockets and Jets, by Herbert S. Zim. Harcourt, Brace and Company, New York, 1945; 326 pages, $3.00

Published under wartime regulations, this book contains the latest facts about rockets and jet devices now being used in the war. The early history of rockets and their development is reviewed. Basic rocket principles, construction details, types of fuels and methods of operation are explained in length. Chapters are devoted to early and modern battle rockets, the V-weapons and jet-propelled planes. Consideration is given to the problems of interplanetary flight and the future of rockets.

Information about the experimental programs and achievements of the American Rocket Society and other groups is presented. The book is well supplied with illustrations and is indexed.

Astro-Jet, Journal of the Glendale Rocket Society. No. 9, September 1944; 12 pages, $0.35.

This issue has a more pleasing format and is a great improvement over earlier bulletins. Two articles, accompanied by a number of rocket drawings, describe a series of powder rocket tests. Numerous short articles deal with society news and recent rocket weapons. The cover of the publication depicts an action shot of a rocket in flight.

Book Notes

The 1945 annual book of the air age "The Airman's Almanac," edited by Francis Walton and published by Farrar & Rinehart, contains facts on world aviation, rules, routes, records, etc, and analyzes jet propulsion.

The JOURNAL OF THE AMERICAN ROCKET SOCIETY (formerly ASTRONAUTICS) is devoted to the purpose of disseminating information on the development of the rocket and jet propulsion and their application to problems of research and technology

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Editor, Cedric Giles.