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EXPERIMENTAL ROCKETRY

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RRS BETA MODIFICATIONS

by
Richard Butterfield

In the beginning......the nozzle of the "T & B", (Teebken & Butterfield), Beta was smooth and shiny and had a throat turned to the 0.932 inch diameter as prescribed in the drawings. But, after a firing or two, the nozzle was eroded so badly that it was junk. (See Figure 1.)

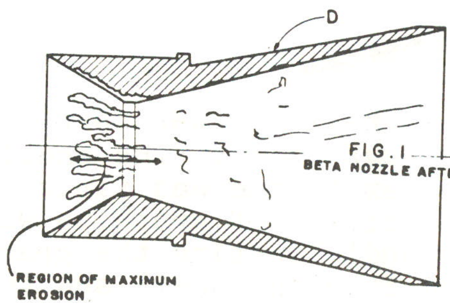


FIG. 1
BETA NOZZLE AFTER FIRING

We salvaged it by adding an insert of graphite.[1] We planned to epoxy the insert in place. To make the insert as secure as possible, we decided to taper the mating surfaces between the nozzle shell (D) and the insert so that, during the burn, chamber pressure would tend to force the conical insert further into the mating socket in the shell. (This design has a convenient feature regarding its construction: the only critical dimensions that must be held, when fitting the insert, are the mating angles. To match the angles is easy; simply do not change the angle on the lathe compound between the time the shell is bored out and the time the graphite plug is cut.) We fitted a solid graphite plug to the bored-out shell, smeared it with epoxy and clamped the assembly in a vise, (forcing the plug into the shell naturally), overnight. The assembly was chucked-up in a lathe, trued, and the graphite was turned to the original beta dimensions. This nozzle has been fired 5 times with absolutely no erosion on the graphite. (See Figure 2.)

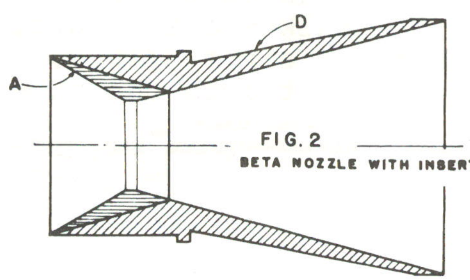


FIG. 2
BETA NOZZLE WITH INSERT (A)

[1] See article by Larry Teebken, RRS News No. 103, page 22.

Reviewing the nozzle's performance, we were quite satisfied except for one point; there was a great deal of erosion in the exit cone just downstream of the insert.

With this point in mind, a nozzle having a full liner was designed (Figure 3). The fully lined nozzle would permit the use of aluminum which not only reduces the nozzle's weight, but is much easier to machine than steel.

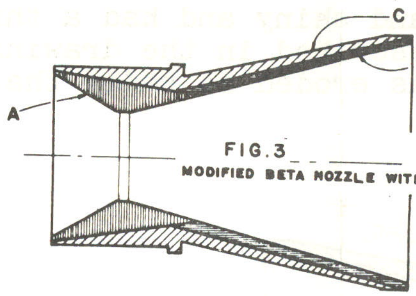


FIG. 3
MODIFIED BETA NOZZLE WITH FULL LINER (A&B)

The outside of the aluminum shell (c) was turned to final size. The inlet of the shell was rough-cut to 4°. The shell was then chucked on the inlet end and the exit cone was finish-cut. The shell was removed from the lathe and a billet of graphite was chucked up. Without changing the lathe compound's setting the graphite exit cone plug was turned. It was epoxied into the shell and then bored out to the finish dimension. The assembly was reversed in the lathe and the previously made 4° rough-cut was finished. A graphite plug was made for the inlet. It was finished in the same manner that the exit was. Note that the inlet liner overlaps the exit liner so that the exhaust gases flow over the junction, and do not tend to tear at it.

The method of attachment of the nozzle was next considered.

The process of drilling and tapping the nozzle is time consuming, and if one is not careful it is very easy to break off a tap in in the nozzle. In regard to these two factors we decided to retain the nozzle with hardened ground dowel pins. Eight holes were drilled through the motor tube and into the nozzle. The holes were drilled undersize and then carefully reamed out to full size (0.312). Half-inch long dowels were chosen to assure that enough of the pin would protrude far enough that the pins could be removed after the test. (Figure 4-A)

With regard to weight the best method of bulkhead attachment is to weld a thin disc in place. But: neither of us can weld-and we think that the failure of some of our previous engine casings was due to 'stress-points' induced by welds at the bulkhead or at fin attach points. We decided to pin the bulkhead in place. A cup shape was turned which was held in place by eight 5/16 D. x ½" dowels.(Fig.4-B) Note: Bulkhead and nozzle must fit into the tube tightly.

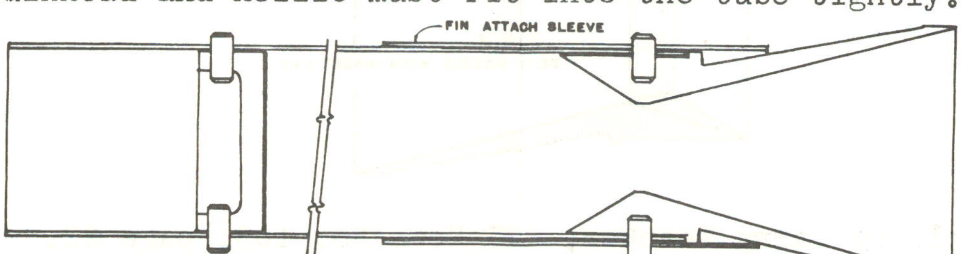


FIG. 4

The fins were riveted to brackets welded to a thinwall tube with a 2.007" inside diameter (Figure 5). The assembly is heavier than some other fin systems but is advantageous in that there is no welding on the motor casing and that the fins can be replaced in case of crash damage: or - the fins can be salvaged if the tube is ruined.

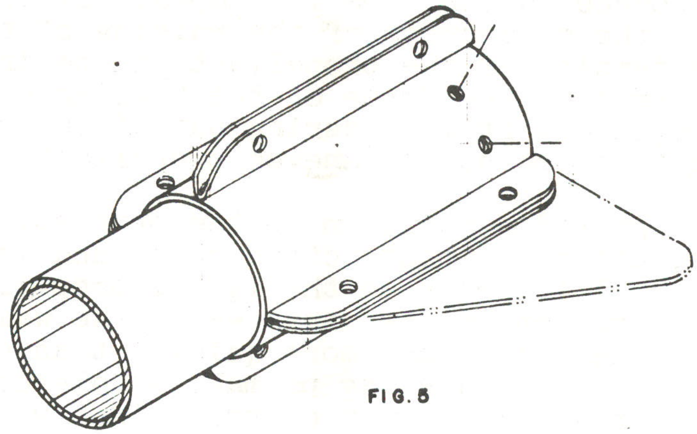


FIG. 5

The nosecone was turned from hardwood in the configuration shown in Figure 6. Dosa promptly dubbed it "Butterfield's Turk-head" nosecone. The enlarged section was made the same diameter as the exit of the nozzle to permit smooth guided travel through the launcher.

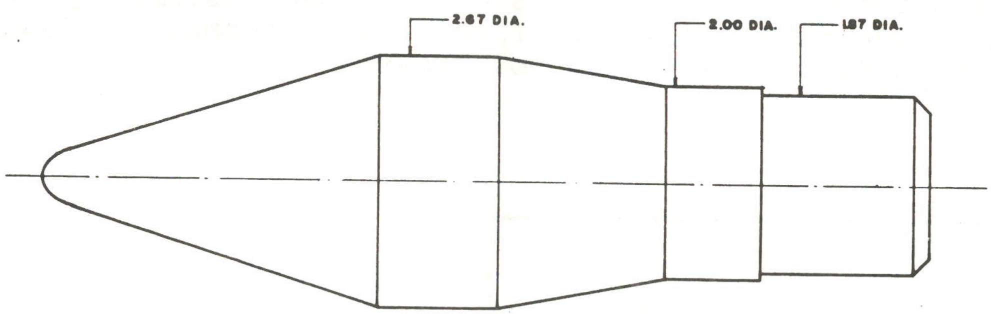


FIG. 6

To make it practical to replace the nozzle and or fin attach assembly, a drill jig was made. The jig has 8 holes, equally spaced, to drill pilot holes for 10-24 TAP.... (The holes are to be reamed out for the dowels.) The jig consists of 3 concentric pieces:
(1) A drill guide 3½" O.D. x 4" long bored out to 2.130".
(2) A piece of beta tubing 4" long and a piece of fin-sleeve also 4" long.
This combination permits the standardized drilling of any of the 4 rocket parts, (nozzle, tube, fin-sleeve and bulkhead).

Fueling micrograin rockets is usually inconsistent, and often messy (especially when the engine casing is nearly full). After one has fueled a few micrograin rockets a "feel" for it is acquired and techniques are developed. The usual RRS method for loading micrograin is as follows:

The rocket is held vertically, bulkhead end down, and nozzle removed. A funnel is inserted into the tube and, in the case of the Beta, approximately $1\frac{1}{2}$ lbs. of propellant is poured into the tube. The funnel is removed and the motor, still held vertically, is "bumped" into a piece of timber set into the ground. The entire rocket is filled in this fashion. The person fueling the tube can feel the propellant settle, compress, and bounce as the tube is bumped. By regulating the force of the bump and the suddenness of the raising of the tube for the next bump, the density of the propellant can be increased. As the tube reaches capacity, the force of the bumping must be reduced to prevent the propellant from geysering out of the tube's end. This uneven bumping force causes an uneven propellant density.

Teebken suggested a solution to the problem: Fill a cloth bag with lead shot, attach a stout cotton cord, and lower the shot-bag down the tube until it rests on the $1\frac{1}{2}$ lb. propellant increment. Then, "bump" the rocket in the usual way. The weight of the shot should compress the propellant more quickly than other methods. The shot-bag would be self-adjusting to make a tolerable seal to the tube so that a very small amount of propellant would bypass it. (Any micrograin bypassing the bag would be able to re-bypass it as the bag is withdrawn. The diameter should reduce when the shot shifts as the bag is lifted.) The shot-bag was made and has been tested several times. Always, the fueling is quicker, and with less spillage than other methods. The propellant density is always increased. In one instance, a rocket was fueled to a very high density and did not burn well - combustion was very slow. In two instances, rockets fueled in this fashion have burst when fired. This technique shows a great deal of promise, but as yet is not proven.

April 21, 1969
457 Morse Ave.
Liberty, Mo. 64068

Don Girard, Managing Editor
RRS NEWS
Glendale, Calif.

Dear Sir:

As former Associate Editor of ROCKET EXCHANGE I feel I must comment on your review of our magazine in issue No. 103 of the RRS NEWS.

I have not read such an absolutely worthless piece of 'journalistic commentary' in a long while. As a 'book review' it doesn't match any standards of criticism that I know of. You launch into a vituperative critique of ROCKET EXCHANGE without even bothering to examine the reasons for its loss of popularity and progressive decline. Your review completely (deliberately?) misses the point; looking down from your ivory tower you seemingly fear any encroachment of what you feel is your private province.

ROCKET EXCHANGE failed, not because of its goals and aspirations, but because of a lack of support from groups like your own. ROCKET EXCHANGE had great potential but because of attitudes like your own it was never given a fair chance to realize that potential. No, our dream was not at fault; it was the 'clannishness' and reclusiveness of groups like yours. So long as your clique functions you are happy and you couldn't give a damn about anyone else. THAT, and THAT alone doomed ROCKET EXCHANGE from the beginning. ROCKET EXCHANGE WAS capable of improvement and expansion; it was capable of becoming a respected and top-notch technical journal of experimental rocketry. And why didn't it achieve those goals? The members of groups like the RRS simply didn't care enough to spend the extra amount of time and effort to support it.

If groups like yours had only joined us instead of opposing us at every turn we might have survived long enough to make something out of our magazine. But we were consigned to oblivion even before the first issue came out. The prejudice and complancency was just too much to overcome.

Experimental student rocketry continues to be a play-time hobby only because organizations like yours confine it to that category and do not attempt to make anything more out of it. As a hobby it is static, unprogressive and unsuited. To make a hobby of student rocketry is like trying to make a game out of war. Only pyromaniacs could enjoy lighting up a rocket simply to see it careen out of control or smash a mouse to hell. The hobbyist will never replace the idealist - the idealist has an aim and a goal, the hobbyist merely has alot of guts and a few loose screws.

Respectfully yours,

Erich A. Aggen, Jr.
Former Associate Editor
Rocket Exchange Magazine

THE TEST LAUNCHING OF A HIGH ENERGY SOLID PROPELLANT ROCKET

by

Fred Wagner

This report describes the details of a high energy solid propellant rocket that was successfully launched at the Mojave Test Area, about 9:10 A.M., on March 30, 1969, from an Estes type launcher.

The rocket utilized a propellant with an actual specific impulse of 200 seconds that consists of 67% NH_4ClO_4, 17% $C_4N_2H_4O_2$ (Maleic Hydrazide), 13% PBAA (Polybutadiene Acrylic Acid), and 3% Al, by weight. After the ingredients are well mixed, the mixture is poured into the fiberboard combustion chamber into which the ceramic nozzle and the cardboard burst disc, have first been cast. This enables the ceramic material of the nozzle to cure at the same time that the propellant does. The mold for casting the nozzle and the propellant grain and the slight initial core in the grain was especially made for us by Caseco, of Riverdale, New Jersey. Next, the grain and nozzle are cured at 150° F for 48 hours. After this 48 hour curing time the oven is turned off and allowed to cool down to room temperature before the rocket motor is removed from the oven. Once it is removed it is ready for immediate use. The fiberboard combustion chamber rocket motor casings were purchased from United Pyrotechnics of Chicago, Illinois. Note also that it is not advisable to store finished propellant grains for more than one year from date of manufacture.

(EDITOR'S NOTE: In California it is illegal to store propellants except in a Fire Marshal approved powder magazine. All propellants must be made in the field under the supervision of a Licensed Pyrotechnic Operator.)

The rocket itself was 21.75 inches long and 1.220 inches in overall outside diameter. It had a plastic ogive shaped nose cone with a cardboard body and 4 balsa wood fins. The Center of Pressure Report, issued at the Goddard Space Flight Center in Maryland, was used to optimize the rocket so that it would have a good fineness ratio (length to diameter), minimum weight and drag, and minimum fin area for proper relationship between the center of gravity and the center of pressure for positive stability. Alan Wilson and Robert Hultz of the Pacific Rocket Society, wrote a computer program, based on this C of P Report, to determine the stability of rockets very quickly and accurately. I used their program in the Northrup Institute's computer in the design of my rocket.

Further data is included on the ROCKET TEST PROPOSAL FORM and on the one-half scale drawing of the rocket.

(EDITOR'S NOTE: Fred Wagner, now serving in the U.S. Army, has applied for a U.S. patent for the propellant formulation described in the above article.

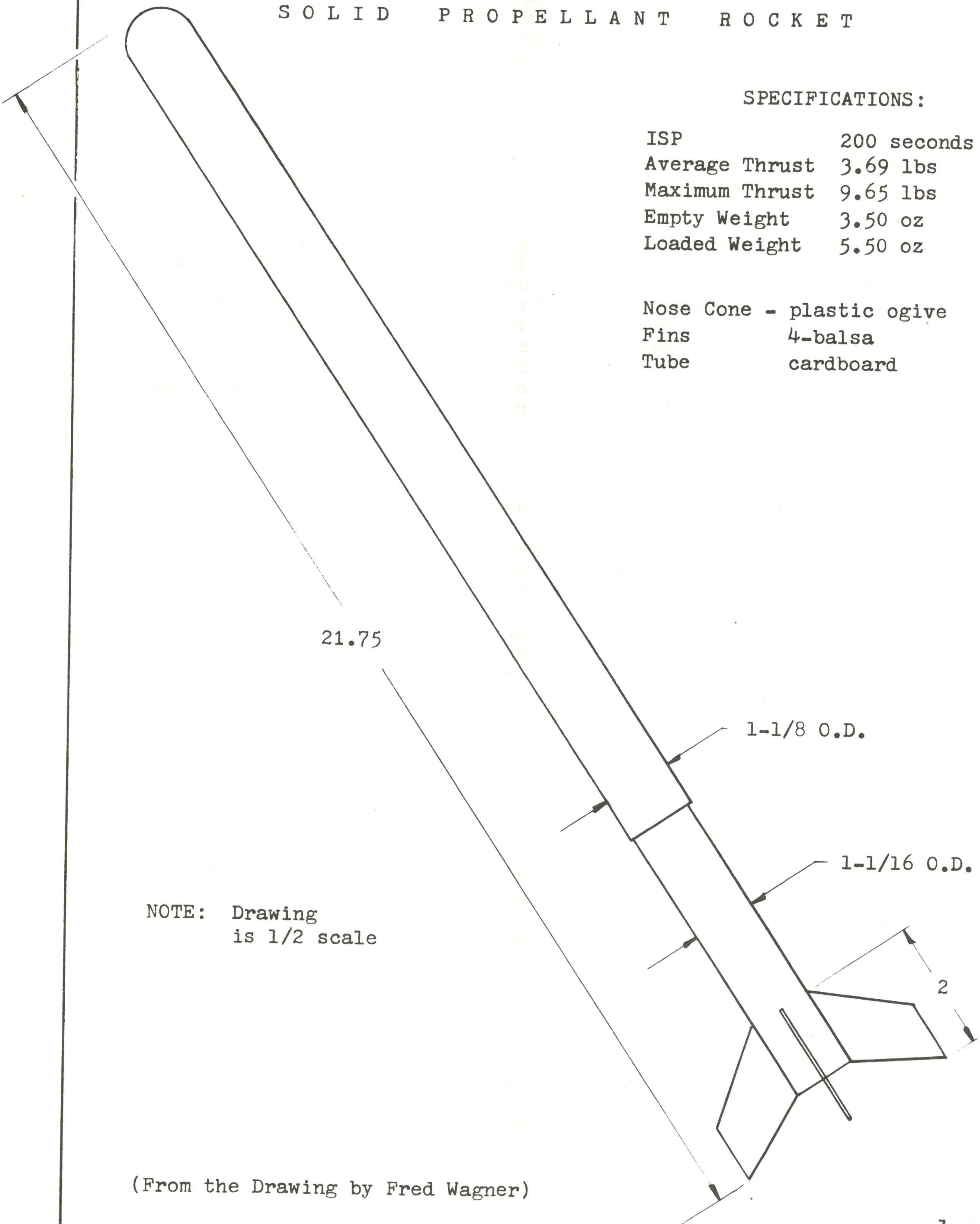
The rocket, in spite of its diminuitive size, was one of the most impressive solid propellant rockets that the Society has launched.)

HIGH ENERGY SOLID PROPELLANT ROCKET

SPECIFICATIONS:

ISP	200 seconds
Average Thrust	3.69 lbs
Maximum Thrust	9.65 lbs
Empty Weight	3.50 oz
Loaded Weight	5.50 oz

Nose Cone -	plastic ogive
Fins	4-balsa
Tube	cardboard



NOTE: Drawing is 1/2 scale

(From the Drawing by Fred Wagner)

QUALITY ASSURANCE AND RELIABILITY CONTROL IN MICROGRAIN AND SIMILAR FUELS

Prepared for Ordnance Corps, Picatinny Arsenal, Dover, New Jersey — Att'n. Mr. J. B. Lishchiner

ORDBB-NRI-077
Prepared by Myron A. Lieberman for the Reaction Research Society, Inc.
September, 1961

Note: Due to local laws regulating the types of rockets flight-tested by the Reaction Research Society, Inc., the only reliability data that has been collected over a long enough period of time and varied conditions sufficient to draw noteworthy conditions has been with reference to micrograin fuels. The lack of any new developments in electronic gear on these rockets may limit the usefulness of our studies with respect to your project, but we are forwarding to you our reliability and quality findings regarding micrograin fuels in the hopes that we may be of some use to you in this respect.

PROBLEMS

There are three factors governing the performance of micrograin fuel. Micrograin is a mixture in granular form of ultrafine particles of elemental zinc and sulfur. These are mixed mechanically with a 5 to 10 percent excess of zinc. The size of the particles, degree of compression of the particles, and amount of water adsorbed onto the zinc are all factors which have a critical bearing upon the performance of the fuel.

Surface area plays a big part in any chemical reaction. Needless to say, if any zinc or sulfur exists in large granules or lumps after the fuel is mixed, this will lead to lack of homogeneity, reduced surface area, and consequently, slower uneven burning increasing the probability of explosion.

The normal burning rate for micrograin under ideal conditions is 10 ft. per second independent of cross sectional area. The rapid burning rate makes the use of shaped charges unnecessary. The normal micrograin rocket will, therefore, be of the "cigarette" burning type. If the fuel is just poured in, air pockets may develop which would serve as certain nuclei for detonation. If the fuel is tamped too much or placed in under too high a pressure, effective surface area would be diminished and ignition would be difficult, increasing the probability of a misfire.

Zinc, in the metallic state, is a moderately reactive metal, and a good dessicating agent. As soon as a can of zinc dust is exposed to the air, the metal will attract water molecules which will adsorb on the surface of the zinc. These will eventually react and form zinc oxides, hydroxides, hydrides, hydrates, and carbonates.

The formation of these compounds inhibit the reactivity of the zinc, and also throw off the stoichiometry of the reaction by contributing numerous side reactions to the system.

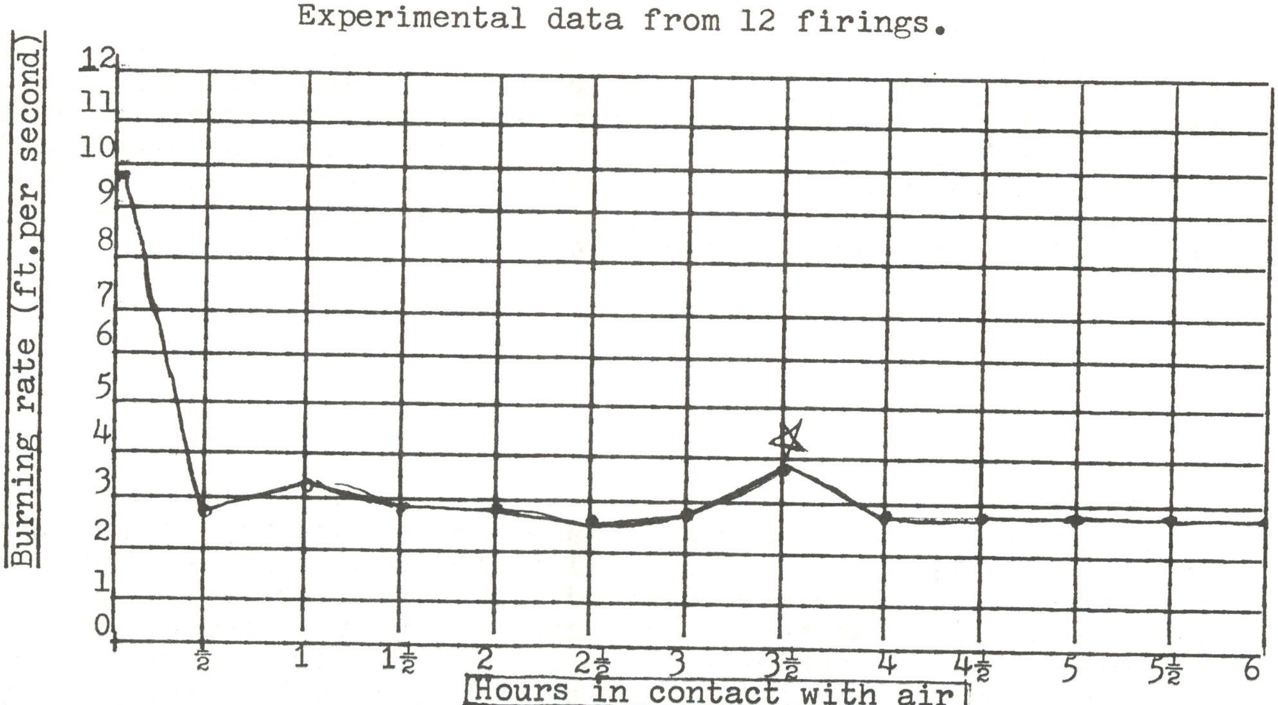
SOLUTIONS

Zinc dust and sulfur used in the preparation of micrograin should be fine enough to pass through a 400 mesh screen with ease. If need be, an anti-caking agent such as finely divided silica should be added to the fuel in trace amounts. This will help insure homogeneity and maximize surface area.

The prepared fuel should be lightly tamped into paper or cardboard capsules of approximately twice the lenghth of the diameter. These capsules should be placed in firm contact with each other and separated with extremely thin paper. Some loose micrograin should be placed between the burst diaphragm and the first capsule, and the igniting squib placed in this loose igniter fuel. This will minimize the eventuality of a misfire and greatly reduce, if not completely eliminate, the formation of air bubbles and the resultant detonations.

Ideally the chemicals should not be opened or mixed in the open atmosphere. The zinc especially should be thoroughly dessicated before, during, and after preparation of the fuel. This should prevent the adsorption of water on the zinc and minimize side reactions caused by the formation of zinc compounds from occluded, trapped, or adsorbed water.

Experimental data from 12 firings.



* This reading was questioned. It is assumed to be 2.86 by some of our members.

Chart prepared by David Sheldon.

MIXTURE AND METHODS OF LOADING SOLID ROCKET PROPELLANTS

by
Tom Rust

In order for the propellant to deliver maximum performance, it must be prepared and loaded in the rocket chamber properly. This report deals with the mixing, heating, loading, and compaction of various rocket propellants.

POTASSIUM NITRATE	60%
SUGAR	40%
Type	B

The chemicals are first weighed out on a scale, crushed to a fine powder, then carefully mixed. During the crushing, care should be taken to prevent any metal scraping that may produce sparks. This should be remembered in the handling of all ingredients. The propellant is then carefully heated and melted down at approximately 300° F. Some method of controlling the heat is necessary to obtain proper propellant composition. The mixture should then be stirred until it is at the consistency of slightly thin syrup and loaded into the rocket chamber.

This propellant is most often cast in a tubular grain configuration or other short burning type grains. It is very sensitive to pressure changes in the rocket chamber. Small inaccuracies in the area of the nozzle throat can cause pressures to rise drastically, resulting in possible rocket failure. This fuel is also hygroscopic, so any water or water vapor (including that which is in the air) must be kept from prolonged contact with the propellant.

ZINC	67%
SULFUR	33%
Type	CA

After the chemicals have been weighed, ground and sifted, put them into a cardboard container and shake until a smooth, even powder is obtained. This is poured in small increments into the rocket chamber, then packed down with a wooden rod (having a diameter slightly less than the inside diameter of the rocket body) and tamped lightly with a hammer or wooden mallet to form an end-burning type grain. This propellant burns very slowly and erratically at low pressures but fairly evenly at high pressures. In order for the propellant to be brought up to this pressure (about 1000 psi) a metal or brittle plastic diaphragm must be placed between the nozzle and the fuel. This diaphragm bursts at this pressure, releasing the hot gases. The propellant continues to burn at an even rate, pressure remaining equalized.

ZINC	80%
SULFUR	20%
Type	CB

This propellant is loaded similarly to fuel type CA, but in the compaction the fuel is rammed into the chamber with a wooden mallet or hammer as hard as possible. This propellant needs a diaphragm as type CA, but has the advantage of being easier to ignite and also it delivers a higher specific impulse (50-70).

ZINC	67%
SULFUR	33%
SOLVENT	
Type	CC

This propellant contains a solvent of either acetone or alcohol which is added to the regular mixture type CA. The propellant is then placed in the chamber of the rocket and a wooden rod pushed down the center to form a tubular type grain. According to other researcher's reports, this propellant has high potential, but as yet I have been unable to obtain satisfactory results from it.

POTASSIUM PERCHLORATE	86%
ASPHALT-OIL MIXTURE	14%
Type	AA

This propellant is a very powerful type that is in a semi-powdered form after heating. When heated for a comparatively short time, the propellant is not completely formed into a molten state, and in such a form, burns very erratically. High pressures cause it to burn very unstably, resulting in an explosion even with end-burning grains.

POTASSIUM PERCHLORATE	75%
ASPHALT-OIL MIXTURE	25%
Type	AB

This is the propellant used in the JATO solid-fueled boosters. The asphalt must be melted completely into the molten state then the potassium perchlorate slowly added. The mixture is then poured into the chamber and formed usually into a tubular type grain. According to other reports, its specific impulse is 180-195 seconds.

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Included in this book is the work of the Reaction Research Society as well as the hybrid rocket work of the Pacific Rocket Society which was done in the early 40's. It is based on the activities of these societies, including the Reaction Research Institute and the National Rocket Safety Registry.

Eric Burgess, noted author and lecturer in the field of rocketry since 1940, intruduces this collection of valuable historical information written by Mr. Humphreys and edited by Mr. Porter. The reader will be brought up to date on the work of the Amateurs and Students.

Mr. Humphreys has been a member of the RRS and the PRS since 1951. Acting as Testing Director at one time for a six year period for the RRS. He has been actively engaged in Amateur Rocketry since 1947. At present he is Vice President of the Pacific Rocket Society and an Active Member of the Reaction Research Society.

Mr. Porter is a Professor of Electronic Engineering at the Northrop Institute of Technology in Inglewood California. He is past president of the Pacific Rocket Society a position he has held for five years.

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May we present THE REACTION RESEARCH SOCIETY NEWS, a journal of amateur rocketry published in Los Angeles and distributed internationally.

The Reaction Research Society is one of the oldest rocket societies in the U.S., and is in joint possession of the largest amateur testing area in America. The Society serves to promote experimental rocketry, and at the same time provide educational opportunities in rocket design for the student.

One facet of our work is the publication of THE RRS NEWS, a news magazine of about forty pages that attempts to describe the rocket activities of the Southern Californian area, to present articles of value in amateur work, and to report accurately developments in state and national legislation, the progress of other societies, and matters of public interest.

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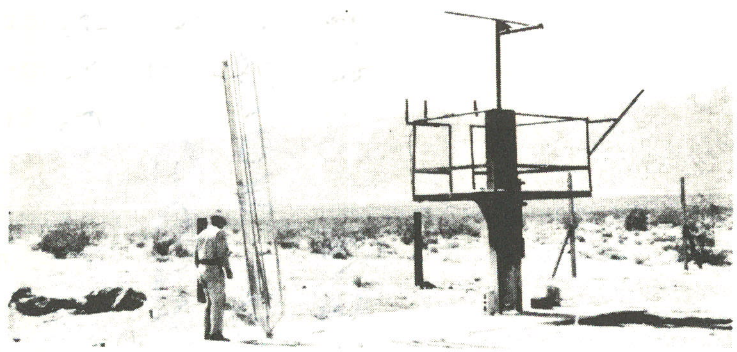

Static test structure at the Society's desert launch area.

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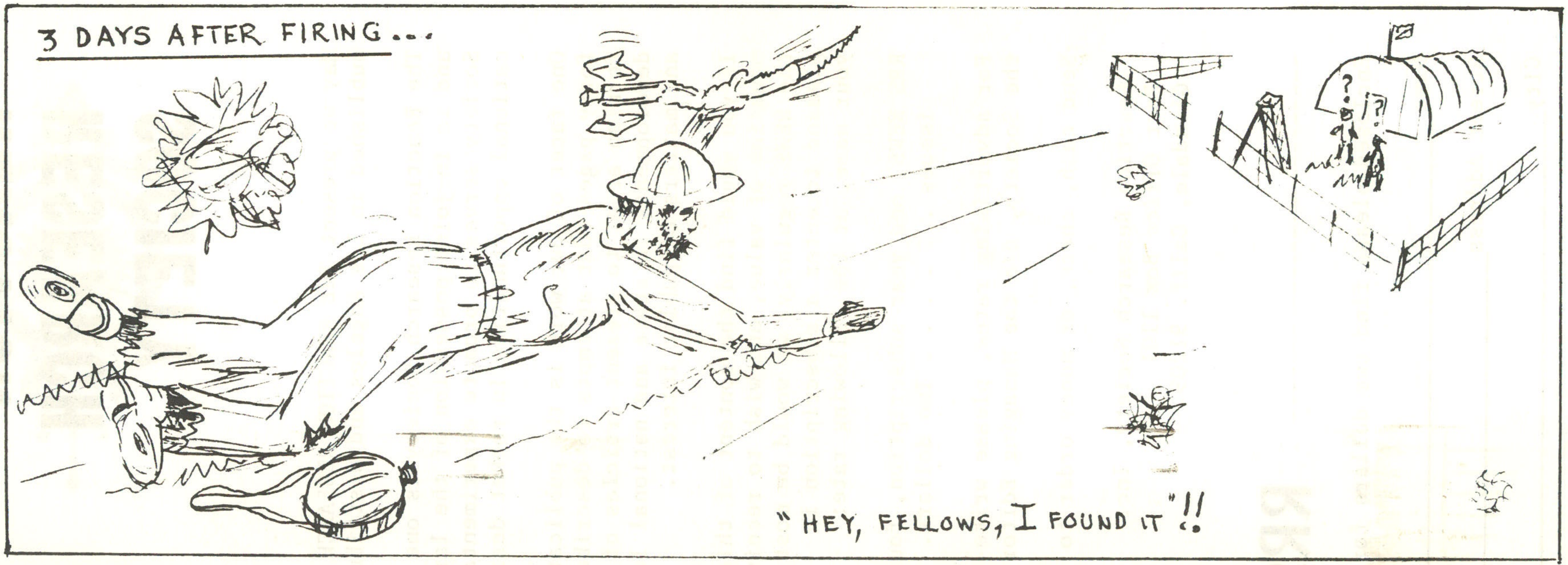

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