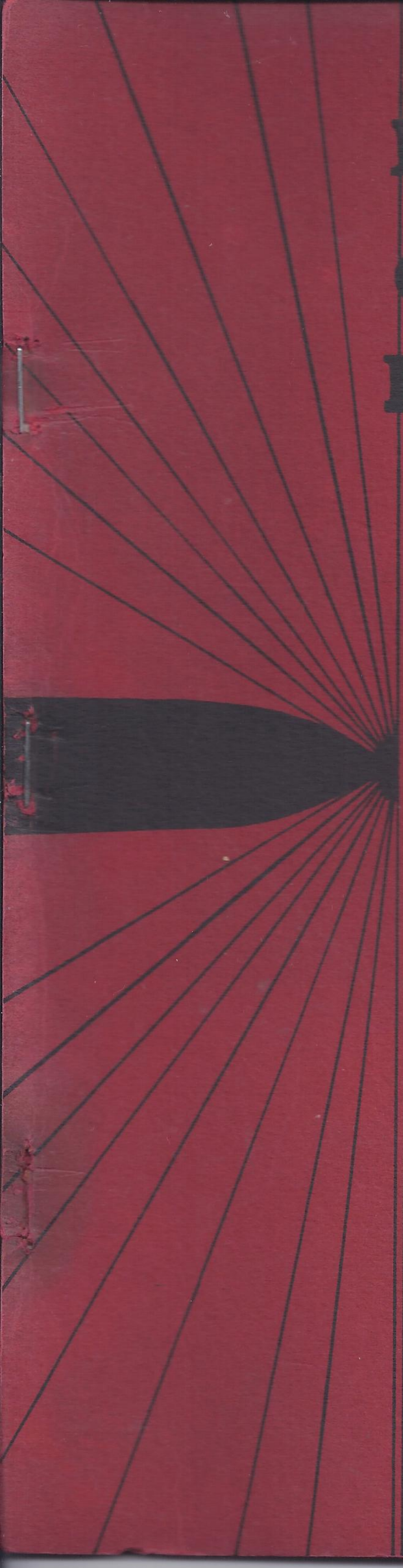


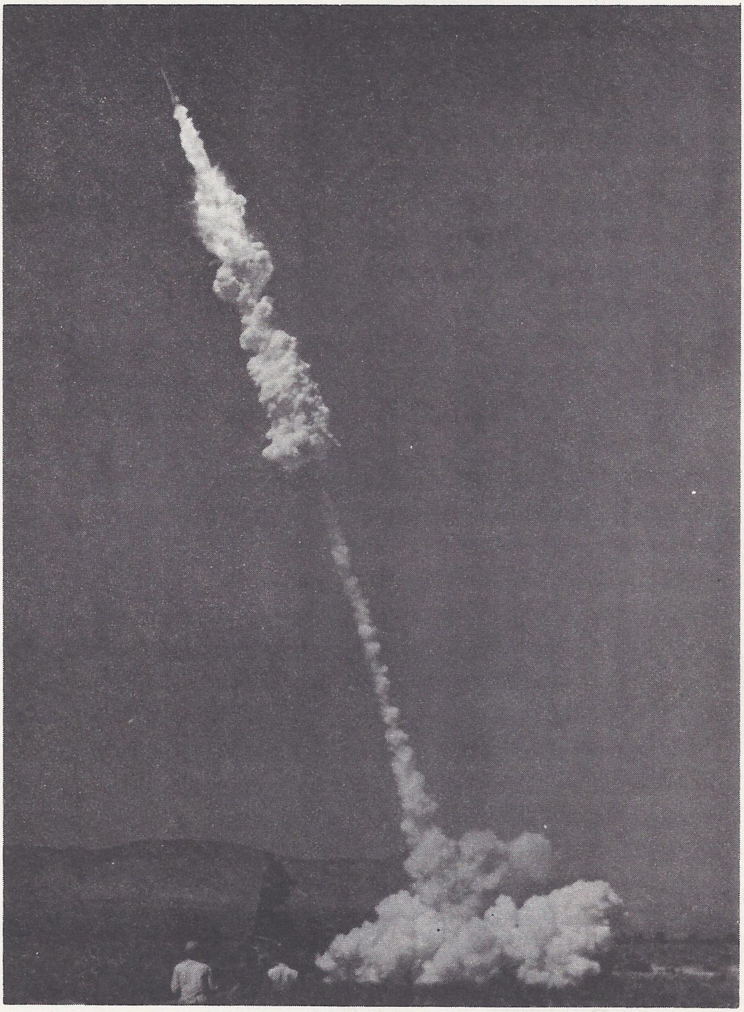
MICRO GRAIN ROCKETS

B. J. HUMPHREYS JR.

COX

The Micrograin Rocket

By
B. J. Humphreys Jr.



Two Stage Rocket built by;
Carroll Evans and Robert De Voe
Sept 20, 1953

Published by B. J. Humphreys Jr.
P. O. Box 45391, Airport Station
Los Angeles 45, California

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My appreciation is also expressed to Marie Cable; who spent many hours typing the manuscript for this book.

B. J. H.

B. J. Humphreys Jr.
Reaction Research Society
Pacific Rocket Society

DEDICATED TO THOSE INTRESTED IN ROCKETRY

The following pages will consider all phases of rockets of this type and in some cases go into theories used in other sciences when necessary in order to give a complete and accurate picture of the problems which you will meet.

The reader should bear in mind at all times that the building and flying of rockets of any kind is a Dangerous business and should not at any time be considered a toy or a plaything. In the experience of the writer and his association with both the Reaction Research Society and the Pacific Rocket Society there have never been any accidents where persons were injured, due primarily to one fact, and that is because of strict supervision by those who have much more experience in this field and are wise in the ways of rockets and the dangers which are involved.

If you need further advice or assistance it is suggested that you contact one of the societies or groups of rocket enthuasists which appears in the back of this book.

If there are no people in your area, the writer will be more than glad to assist you. If you send a self addressed stamped envelope to B. J. Humphreys Jr., P.O. Box 45391, Airport Station, Los Angeles 45, Calif.

John Parker with single stage rocket; on a "T" rail launcher Sept 20, 1953

The primary experience of the writer has been ten years association both with the Reaction Research Society Inc. and the Pacific Rocket Society Inc. both recognized active rocket societies in Southern California and they are known internationally for their study of rocketry.

Presently the writer is a member of the R.R.S. as a member of the executive council and testing director for them as well as techinal consultant to and active member of the P.R.S.

Please bear in mind when reading this text that the experience of both the R.R.S. and the P.R.S. are considered herein and their experiences are the source of information for this collection of facts.

B.J.H.

POLICY TO BE FOLLOWED AT PUBLIC LAUNCHINGS

The Executive Council of the Reaction Research Society has adopted the following policy to be followed at public launchings.

The following regulations will appear rather strict, however, they are for the protection and safety of the public as well as the participants in the firing. It is with this objective that the following policy will be strictly enforced.

1. No rocket will be fired unless everyone is behind shelter.

2. Only the recovery crew will be allowed in the impact area between firings to find and flag the rocket.

3. The public will be allowed to go into the impact area to observe and photograph the downed rockets only at specified times.

4. The public will not be allowed in the fenced area except at the discretion of those responsible for the firing.

5. No alcoholic beverages will be allowed inside the test area.

6. No firearms will be allowed inside the test area.

* PRS Reaction Research Society Inc.

* PRS Pacific Rocket Society Inc.

THE HISTORY OF MICROGRAIN ROCKETS

Micrograin's development should be credited to John Cipperley and George James. In 1943 they began to experiment with various propellants which included black powder.

The Micrograin as we know it today was developed from a combination of Potassium Nitrate (KNO_3) Sugar ($C_{12}H_{22}O_{11}$), Zinc dust (Zn) and Sulphur (S). It was found that Potassium Nitrate and Sugar would ignite and burn without the addition of the other chemicals.

The decision was then made to investigate the combination of Zinc and Sulphur when it was ignited. This led to the discovery that the mixture of these two chemicals burned much more rapidly than any other previous combination and as a result it was used in the early rockets as it is today in various proportions.

At one time the Micrograin rocket was not considered a rocket as it contained no Oxygen. This was an incorrect conclusion as we know it today.

The first Micrograin rockets were made of cast aluminum and soldered tin plate and for some strange reason the use of steel tube was not considered at first, but because of the higher melting point of tube made of steel and experience has taught us that this is best as long as the steel is seamless.

In the early part of 1946, the members of the Society decided that large semi-restricted rockets would be difficult to use as test vehicles due to the fact that the type of propellants necessary were very dangerous (Black Powder) and the Micrograin rocket was turned to in hopes that it would be suitable for the purpose.

The year 1946 saw the Micrograin rocket change from a curiosity to a useful research tool which the R.R.S. could use to carry on the study of rockets. At this time the largest Micrograin rocket was the Miler rocket which was 2½" in diameter and 15' in length, contained 26 pounds of propellant, weighed a total of 54 pounds; 10 pounds of this was payload.

On March 23, 1947, the Miler #1 was fired with a dummy payload to an altitude of 3500 feet. As a result of this, the Miler was used in the R.R.S. mail flight #1.

At the Public firing held September 20, 1953, a two step rocket built by Carroll Evans and Bob Devoe was launched. The booster (first stage) which was 67 inches long by 2½ inches in diameter, the fuel was 13.2 pounds of Micrograin which burned for .62 seconds and the second step which was 73.5 inches in length by 2½ inches in diameter containing 11.0 pounds of Micrograin burned for .55 seconds. The altitude reached was 3115 feet and distance traveled was 3000 feet from the launcher.

On September 4, 1955, a still larger Micrograin rocket was launched. This rocket was 3 inches in diameter and 13½ feet in length weighing close to 100 pounds. It included a 15 pound pay load which was separated from the rocket at the peak of the trajectory. It floated to earth by parachute and was recovered intact. This rocket was built by a group of R.R.S. members which included Don Waters and John Jennings of San Fernando, California. It was fired at the Mojave Desert Test Area.

Another more complicated rocket was built by Jim Humphreys, Edward Parker and James Medsker of the Inglewood Section of the R.R.S. It was a two stage with a recoverable second stage, which contained six parachutes, two in each fin.

This rocket was first fired on September 5, 1955, with the result being that the rocket crashed into the ground. After having risen only 20 feet and then going back down to about 4 feet, it continued to fly for about half a mile setting fire to the sage brush as it went, at a speed close to 350 miles an hour.

The next attempt took place on March 4, 1956. The booster unit consisted of three five foot long, 2½ inch diameter-4130 steel tubes arranged in a triangle. The second stage was ten feet in length and 2½ inches in diameter, also made of 4130 steel tube.

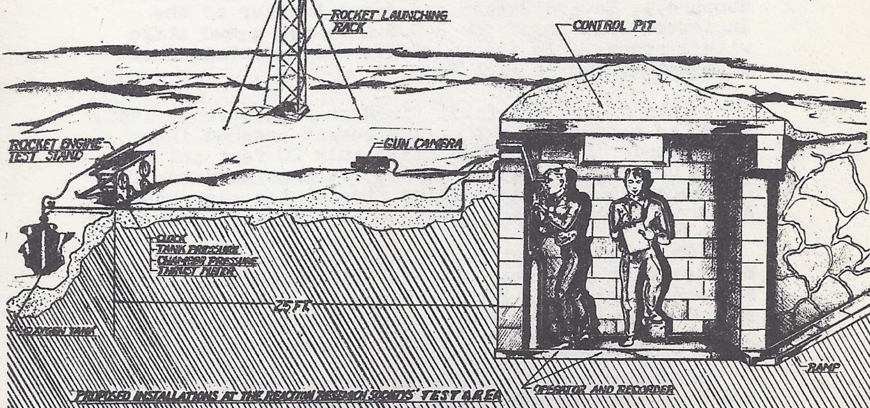
The instrument section was three feet in length and five and one half inches in diameter. The nose cone was 18 inches in length and was made of fiber glass with an aluminum pitot tube mounted on the fore end of the nose.

The design was modified from the original by having the fins of the second stage changed and the motor section decreased in weight and length.

A single large parachute was used instead of six small ones as in the first attempt.

The instrument section of the second stage contained an airspeed indicator with a 16 m.m. motion picture camera fixed to record data during flight. A de-acelleration switch was provided to ignite the second stage unit. This actuated about 500 feet from the ground and a complete separation was made thus enabling the second stage to reach an altitude of 3000 feet.

Due to the failure of the parachute, the instrument section crashed into the ground completely destroying it with all the instruments. This was the first effort to record the behaviour of a rocket by the use of camera which would take pictures of the instrumentation during flight by the R.R.S.



Early drawing showing safe firing procedure; by Nick Stasinas. 1948.

THE CONSTRUCTION OF MICROGRAIN ROCKETS

When building a Micrograin Rocket, the author has found it most important to use the proper material, namely Seamless Steel Tubing. Many rockets have been built of Shelby Tubing, which is used mostly in the aircraft industry as well as 4130 seamless steel tubing which is called Chrome-Molybdenum. These two are the best for the purpose. For smaller rockets "Thinwall electrical conduit" or E. M. T. which is electrical metallic tubing. This is good for rockets up to 2" in diameter, although this material is quite a bit heavier than the above mentioned tubing.

The wall thickness of the tubing used should never be less than 1/16" in wall thickness for rockets up to 2 1/2" in diameter for 3" diameter. 3/32" wall thickness, 4" diameter, 1/8" wall thickness, 5" diameter, 1/4" wall thickness.

Micrograin rockets should not be made in larger diameter than 5" above 3", they become costly, heavy, and are able to do great damage if they hit anything and generally require more money and heavier equipment which will use much more material and cost more than you can afford, besides being more dangerous than you are aware of.

CAUTION: Do not under any circumstances use Stainless Steel, Copper, Brass, Tin, Lead or Aluminum or any material other than Seamless Steel or Shelby Tubing.

NOTE: By building rockets of large diameter you will not gain an altitude much in excess to that of a good 2" diameter rocket of comparable length.

The writer, in this book is informing you of his actual experiences in building the rockets and parts disclosed herein. This in no way is to be considered a guarantee that the rockets herein described will fly or not explode as their are unknown mechanical and chemical behaviours which can occur and cannot be controlled precisely.

HARDWARE

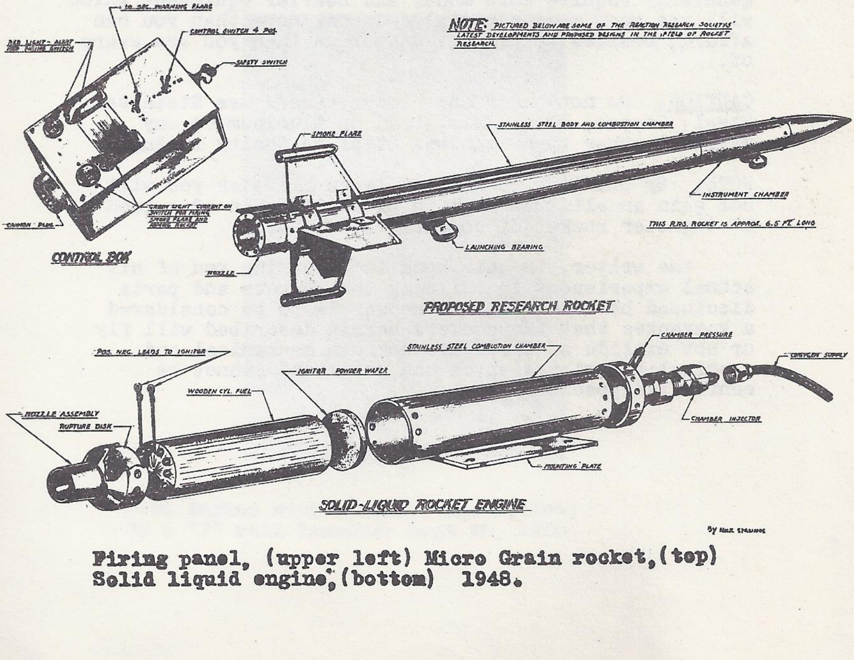
In building a rocket the quality of workmanship is as important as the material used in making it. If either one are of inferior quality, the chance of your rocket being a success are greatly decreased. If you want your rocket to perform in a good manner and reach maximum altitude it is necessary to be aware of the above at all times.

In the following pages there will be detailed information on how to build several rockets which have been flown successfully.

The nose cone can be made of wood, formed metal, fiber glass, plaster of paris or plastic.

Make sure that bulkheads and nozzles are fastened in securely.

Screws, nuts and washers should be made of steel. Have the National Fine Thread (N.F.) 6/32, 8/32, or 10/32 machine screws. Usually these three sizes will be suitable for all of your rocket building, and seldom need to be longer than 3/4 of an inch in length. These screws can be used for fin, bulkhead and nozzle as well as guide clips if you use them.



Firing panel, (upper left) Micro Grain rocket, (top) Solid liquid engine, (bottom) 1948.

FINS

The fins for the Micrograin rocket may be made of any avaliable metal as long as it is not thinner than 1/32 of an inch .0625 or 1/16" is recommended as it is not to flexible but is not so ridged as to fracture during take off. See Drawing #5

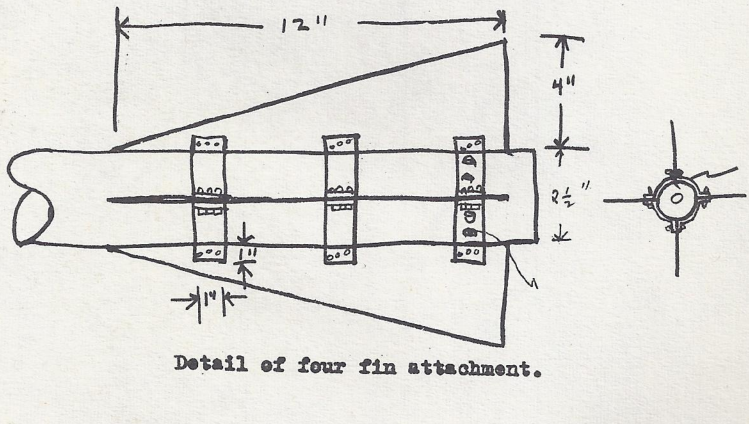
By using four fins on your rockets, you will get a better flight pattern as this results in both "Verticle" and "Horizontal" stability.

The fins are attached to the clips with three 6/32" round head machine screws at each clip. Be sure to use the same screws which hold the nozzle into the motor to fasten the rear clips to the rocket, otherwise the fins will come off on take off.

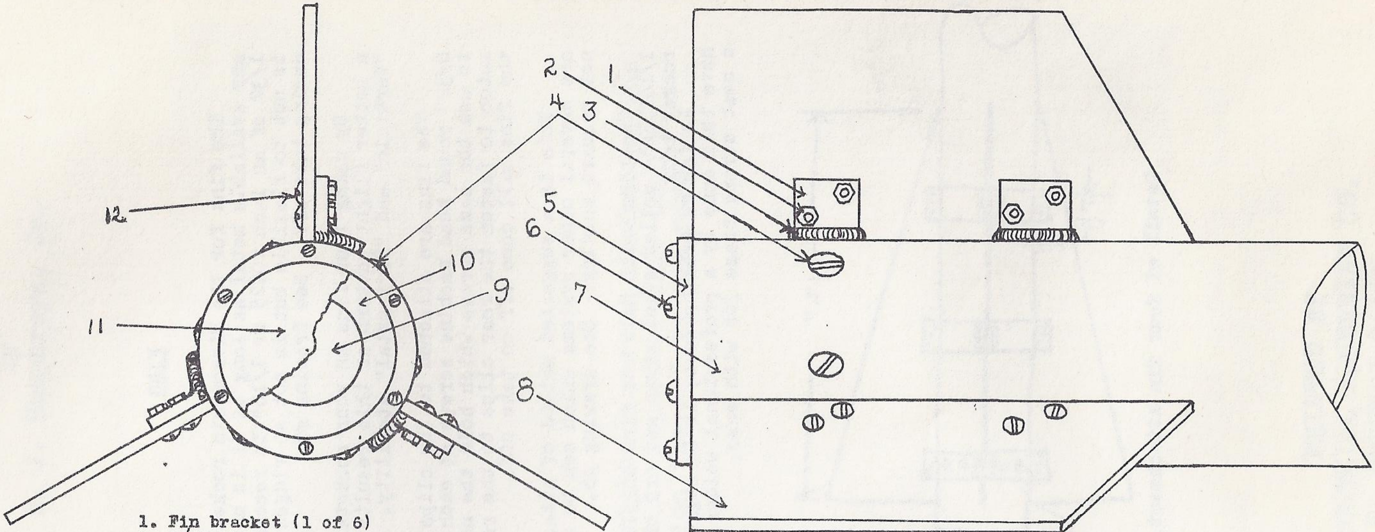
This is a suggested method of attachment. There are several other systems which can be used which do not require welding. See drawing #6.

The tabs which hold the fins in place are made of 1/16" cold rolled steel strip and are brazed to the rocket body.

As far as brazing goes, it is suggested that you have this done by a professional welder, as he can do a neat strong braze job with ease.



Detail of four fin attachment.



1. Fin bracket (1 of 6)
2. 6/32 nut
3. braze holding clip to rocket
4. 10/32 screw holding nozzle in rocket
5. burst disc retaining ring
6. burst disc retaining screws
7. rocket tube
8. fin
9. nozzle throat
10. diverging angle of throat
11. burst disc, .010 soft copper
12. 6/32 machine screw (oval head)

Fin Design

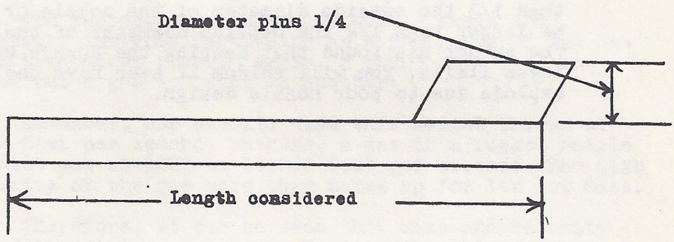
The tendancy to make fins to large is common and an effort will be made here to make it easier to calculate the fin size for any size rocket.

$\frac{d + .5 \times l}{6}$ equals area in square inchesof one side of the fin.

d Diameter of rocket in inches. (O.D.)
k Constant of .5.
l Length of rocket in inches.

The above considers the rocket from the base of the nose cone to the rear of the rocket but not the nose cone.

The fin should extend from the rocket at least the diameter of the rocket plus 1/4 the tube diameter.



See page 24, Drawing 1

Bulkheads

There are two types of bulkheads which both the R.R.S. and the P.R.S. have used with good results, the first to be described is the easiest to build and generaly does not require the use of a lathe.

This is merely a short length of cold rolled steel rod of suitable diameter which is cut to length, and if careful selection is made of available bar stock it is possible to find material which will fit snugly into the tubing which will be the rocket motor.

This bulkhead should not be shorter than one inch in length and be a snug fit or drive fit so as not to allow any of the pressurized gas to leak by and as a result, burning a hole in the rocket causing an erratic flight or an explosion as the heat and pressure are very high.

The second and more elaborate bulkhead requires the use of a lathe and is more difficult to make, This is used where it is desired to use an instrument section or a long nose cone. On the end of the bulkhead which goes intė the rocket the metal should not be shorter than one inch, see table, and be a drive or force fit.

It is not a good idea to make the bulkhead of aluminum as this type of bulkhead has a habit of blowing out and has caused many rockets to explode.

See page 25, Drawing 1 & 2

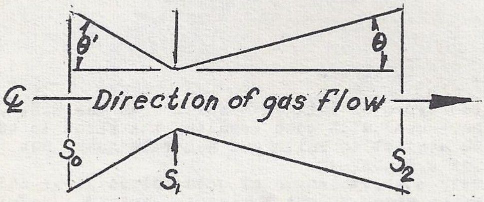
NOZZLES

Nozzle or Venturi design is of the utmost importance in the design and building of a rocket as a poor nozzle design will not give the desired flight performance to your rocket.

The Reaction Research Society has used the following method of nozzle construction: Cold rolled or mild steel is the easiest to procure and can be machined very readily if the lathe tools are sharp. Be sure to allow yourself enough time to be precise.

Usually the De Laval nozzle is the best design to follow, however, a simplified form of this can be made. The nozzle is a 60° convergent angle and a 30° divergent angle (full angle) the throat of the nozzle has a radius equal to the radius of the inside diameter of the rocket motors.

The throat of the nozzle should never be smaller than 1/3 the outside diameter of the nozzle or should it be larger than 1/2 the outside diameter of the nozzle. The author has found that keeping the nozzle with-in these limits, you will seldom if ever have one of them explode due to poor nozzle design.



	NOTE—
S_0	Nozzle Inlet Area
S_1	Throat Area
S_2	Exit Area
θ	Excluded 15°
θ'	Excluded 30°

See page 25, Drawing 3

Buttner

ON THE DESIGN OF SOLID PROPELLENT ROCKET NOZZLES

A method of converting available chemical energy into propulsive force is needed. The nozzle meets this need rather well for our use in rocket motors.

In principle, the nozzle accelerates mass in one direction and the net result is an equal force in the opposite direction. For example, a one pound weight acceleration at one "G" or 32.2 feet per second would provide one pound force in the direction opposite the motion of the traveling weight. In the case of the rocket, the weight is the mass of the combustion products created by the burning propellent and the acceleration is the velocity of the gas in feet per second issuing from the exhaust or nozzle divided by 32.2 feet per second, which is the acceleration constant.

But suppose you wonder how such a small and seemingly insignificant thing as a few grams of gas has such tremendous power. Again, a pound weight is one thing but a gas so light is another.

Remember, our example used this weight thrown at 32.2 feet per second, whereas, a gas in a rocket nozzle is sent out at 6000 to 10,000 feet per second! The high velocity of the gas more than makes up for its low mass.

Therefore, it can be seen that mass and velocity are factors of each other. To describe this, we have a simple formula: F = ma. Where <u>f</u>orce or thrust is equal to the product of <u>m</u>ass times <u>v</u>elocity.

From our hypothetical examples, it is readily apparent that if we take advantage of the fact that low weight molecular gas products and high exhaust velocities are the keys to good performances, then a more efficient rocket vehicle will be the net result.

The reasoning behind the nozzles' ability to create thrust through velocity is that pressure is initially created through the combination and/ or decomposition of the propellents elements and radicals to produce heat. This heat in turn expands the gaseous products to produce pressure. This pressure is essentially potential energy and potential energy in this case, can be easily transformed into kinetic energy, which is energy dependent upon motion. The Law of the Conservation of Energy, which states: "Energy can be transformed, but in no process can energy be created nor destroyed."

The nozzle exit of the pressure vessel or rocket combustion chamber allows the potential energy of the gas to be transformed into kinetic energy by the very action of the gas pressure escaping into motion. How fast the gas travels through the nozzle depends largely upon the nozzles' shape. Not all nozzles are suitable for application to rocket motors.

Hence, we are concerned only with a specifically defined shape. We call this shape the De Laval nozzle so named after its inventor. This nozzle has an excluded angle of 30 degrees in the convergent section and an excluded angle of 15 degrees in the divergent section.

Thus, when a converging nozzle connects two chambers whose pressure ratio, that is, gas pressure/ stagnation pressure, is greater than that of the critical pressure ratio, the convergent section will produce shock free flow for all Mach numbers to the subsonic Mach number relevant to its corresponding area ratio. From this number to the supersonic Mach number corresponding to its area ratio, there will be shock waves in the divergent section of the nozzle.

Ideally, the gain in thrust obtained by making the gas flow uniform and parallel to the thrust line to complete expansion must be balanced against the friction involved with the greater nozzle length required. To exactly compute these arbitrary expansion ratios the reader is referred to a standard text on the subject. But suffice it to say, where zinc and sulphur mixtures are concerned, the throat to exit area underlines ratio approximately 15:1, assuming that the combustion chamber pressure is 600 pounds per square inch, and that the specific heat ratio (temperature @ constant volume/ temperature @ constant pressure) is 1:31:1.

There are enumerable other variables such as combustion instabilities, erosiom, etc., that cannot be comprehensively treated in this chapter. However, the most important facets of the design of nozzles, it is hoped have famaliarized the reader with their respectful problems.

Referances; Page 15 and 16
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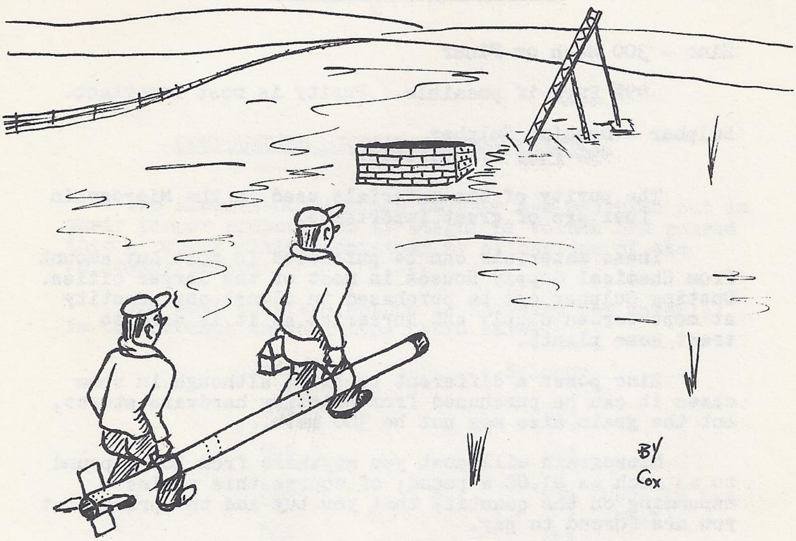
Degering
Kents Engineers Handbook 1954
Mc Graw Hill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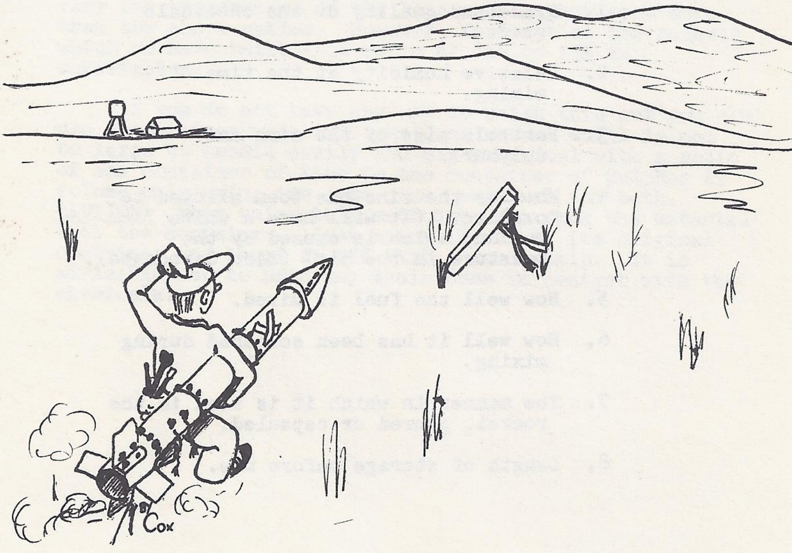
COX

MATERIALS FOR MICROGRAIN

Zinc - 300 Mesh or Finer

99% Pure if possible. Purity is most important.

Sulphur - Dusting Sulpher
99% Pure if possible.

The purity of the materials used in the Micrograin fuel are of great importance.

These materials can be purchased in most any amount from Chemical Supply Houses in most of the larger cities. Dusting Sulphur can be purchased in almost any quantity at most Garden Supply and Nurseries as it is used to treat some plants.

Zinc poses a different problem, although in some cases it can be purchased from paint or hardware stores, but the grain size may not be 300 mesh.

Micrograin will cost you anywhere from 30¢ a pound to as much as $1.00 a pound; of course this varies depending on the quantity that you buy and the price that you are forced to pay.

In working with Micrograin (Zinc & Sulphur) you may find one or more of the following conditions will cause one batch of fuel to behave in a different manner than the other.

1. Grade and quality of the chemicals used.

2. Relative humidity at the time of mixing.

3. Particle size of the zinc and sulphur.

4. Whether the zinc has been allowed to "oxadize." (It will have a white residue which is caused by the moisture in the air) (Zinc Carbonate).

5. How well the fuel is mixed.

6. How well it has been screened during mixing.

7. The manner in which it is used in the rocket, poured or capsuled.

8. Length of storage before use.

COMPOUNDING MICROGRAIN PROPELLENT

The amounts of Zinc and Sulphur are measured out in their proper proportions by weight or volume and poured into a proper mixing container by either one of the following methods.

The most accurate method is to weigh the material in the amounts shown in the table below.

Zinc	Sulphur
83%	17%
84%	16%
85%	15% (Usually the best)
86%	14%
87%	13%

Due to the many variable conditions which may effect the behaviour of Micrograin it is sometimes necessary to vary the proportions of the Zinc and Sulphur even more than the above ratios. However, for most of the rockets which we have built this ratio of 85% to 15% is satisfactory.

If you do not have any way to weigh this out you can use a container which will hold an amount which is not to large to handle easily and mix your fuel with a ratio of one container of Zinc to one container of Sulphur by volume only using the same size container for both.
CAUTION: When using this method do not pack the material into the container. Just scoop it out of its original container and level it off with a wood strip. It is advisable not to have any tools come in contact with the chemicals.

IGNITER

From Right to Left

1. Paper match.
2. Paper match with holes for Nichrome wire.
3. 2" length of #28 Nichrome wire.
4. Nichrome wire strung through match. Be sure the wire is not shorting out.
5. Leads and Nichrome twisted and soldered. Be sure not to let the wires short out.
6. Short match to be put next to the match with the wire run through.
7. 1" of soda straw.
8. Igniter assembly ready to be covered by straw.
9. Completed igniter cemented in place with Duco cement.

See page 21, photo 6

FIRING PROCEDURE

1. PREPERATIONS: Signals, Green flag. Spectators may witness and take pictures of activities but must stay clear of fenced areas.
2. COMMENCE LOADING: Signals, Yellow flag, one blast of siren. All Persons not engaged in the test must return to the sheltered area.
3. ARMING: Signals, Red flag, two blasts of siren. All personnel must be in protected areas. The rocket is ready to be fired.
4. X-MINUS 1 MINUTE: Start of count down.
5. 15 SECOND WARNING: Siren and flashing red light. All persons must be behind protective cover during flight.
6. FIRE: All persons must remain behind protective cover during firing and be prepared to move to better cover incase of erratic flight.
7. In case of misfire of delay there will be an intermittent blast of the siren. All persons are to remain where they are and instructions will be given over the public address system.

We demand the cooperation of all visitors in observing these regulations and reserve the right to remove any individual from the area if they do not abide by all rules and regulations and the decisions made by the persons delegated to the responsibility of the firing.

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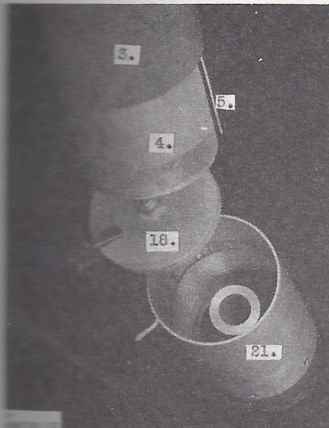

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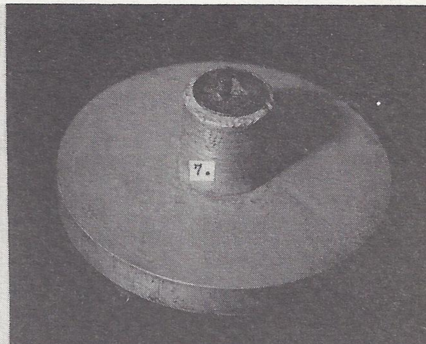

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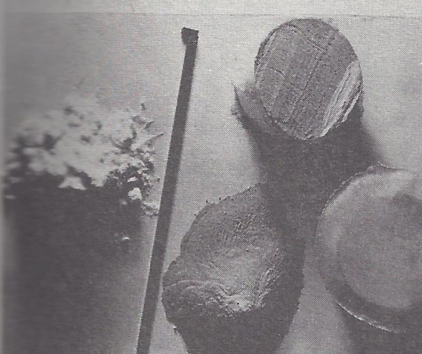

see page 28

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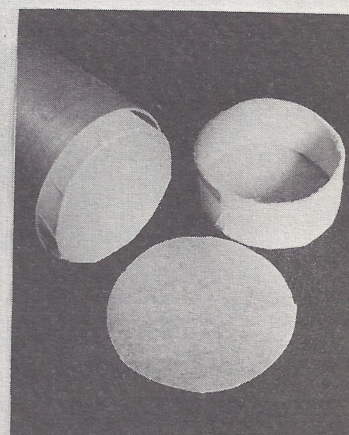
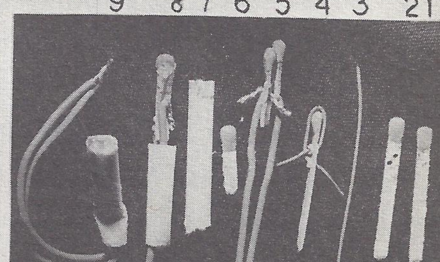


See page 34, #9

4

5

9 8 7 6 5 4 3 2 1

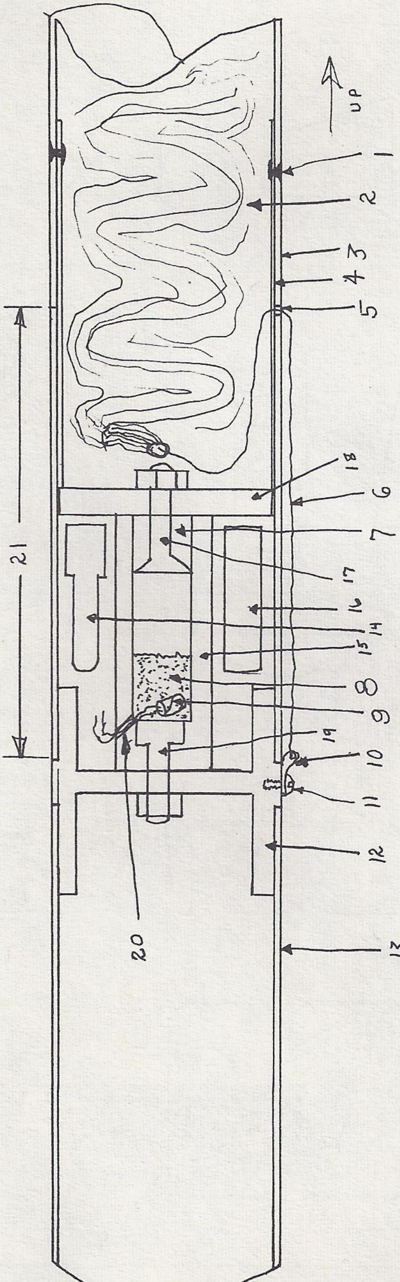


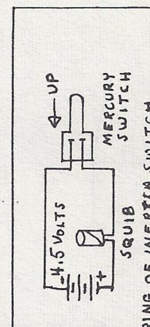
See page 20

6

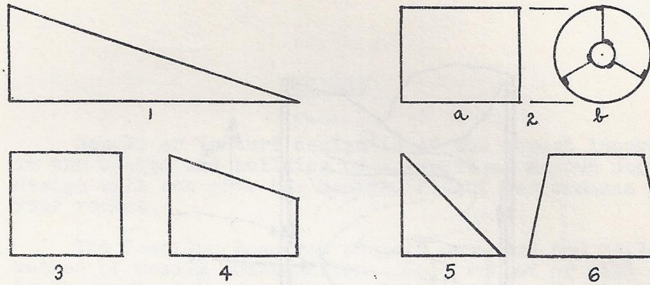
1. Flush Aluminum rivet
2. Parachute
3. Instrument section tube
4. Connector coupling *
5. Notch for pull thread **See page 21, Photo 1**
6. Linen pull thread attached to top of chute
7. Aluminum piston
8. **Jetex Fuel**
9. Squib
10. Lug for pull thread
11. 6/32 machine screw
12. Bulkhead
13. Rocket tube
14. Mercury switch (contacts in a position so as to be open when rocket is in a verticle position.)
15. Aluminum cylinder **See page 21, Photo 1**
16. One of three pen cells
17. Flat head piston attachment screw 1/4" 28
18. Thrust plate **See page 21, Photo 1 & 2**
19. Cylinder attachment bolt 1/4" 28
20. 1/8" hole for squib leads
21. Parachute ejection section

* 4. The coupling connection is to be a slip fit into 21, as if it is to loose it can drop off. This must be snug. See Photo #1 and note the split in the coupling; which is to allow a space for the pull thread as well as to make a flexible coupling for the instrument section and parachute.

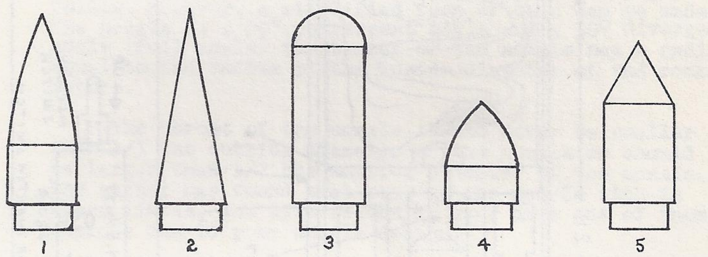




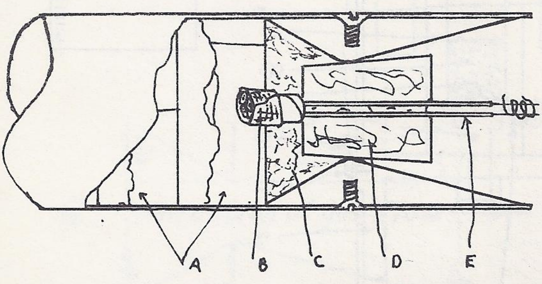
WIRING OF INERTIA SWITCH.



1

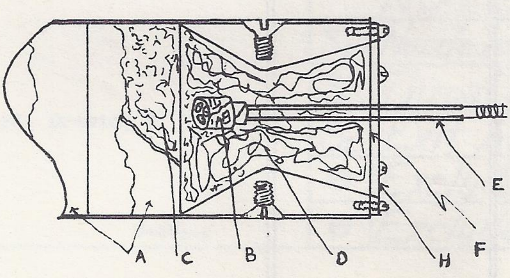


2



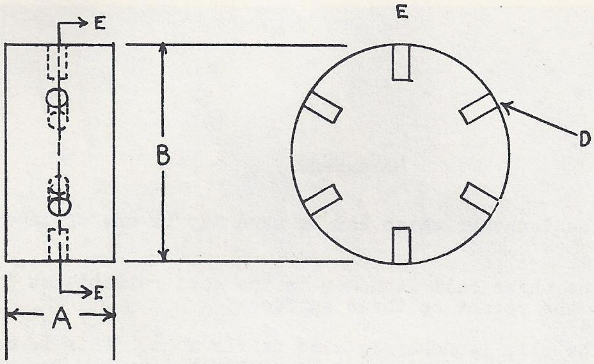
A Capsule
B Igniter
C Propellant
D Cork Plug
E Igniter Wires, Shorted Across

3

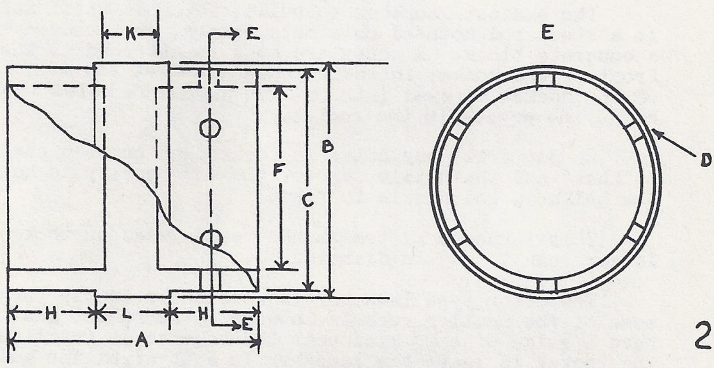


A Capsule
B Igniter
D Wadding, Paper
E Igniter Wires Shorted
F Burst Disc .010 Soft Brass
H Burst Disc Ring Retainer

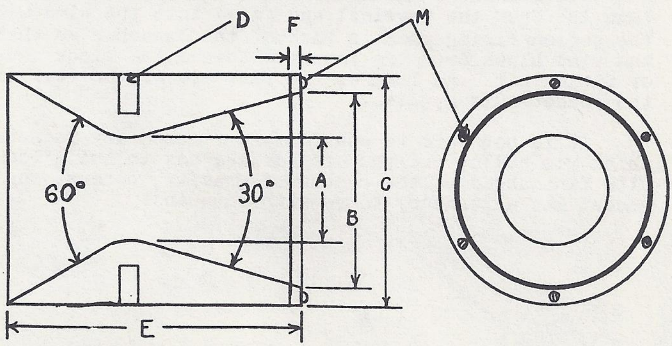
4



1



2



3

LAUNCHERS

The launcher which can be used may be one of several types:

The three rail launcher is the most reliable as it guides the rocket on three surfaces.

The clip launcher is also fairly good. This is made so that two clips which has been attached to the rocket fits over a "T" rail so that the only way the rocket can get off the launcher is to go off the upper end of it.

The easiest launcher to build, which is still safe, is a steel rod mounted on a metal plate, or imbedded in a concrete block. A screw eye must be attached to the front of the rocket in-the bulkhead, and at the rear of the rocket screwed into one of the screw holes that holds the nozzle in the rocket.

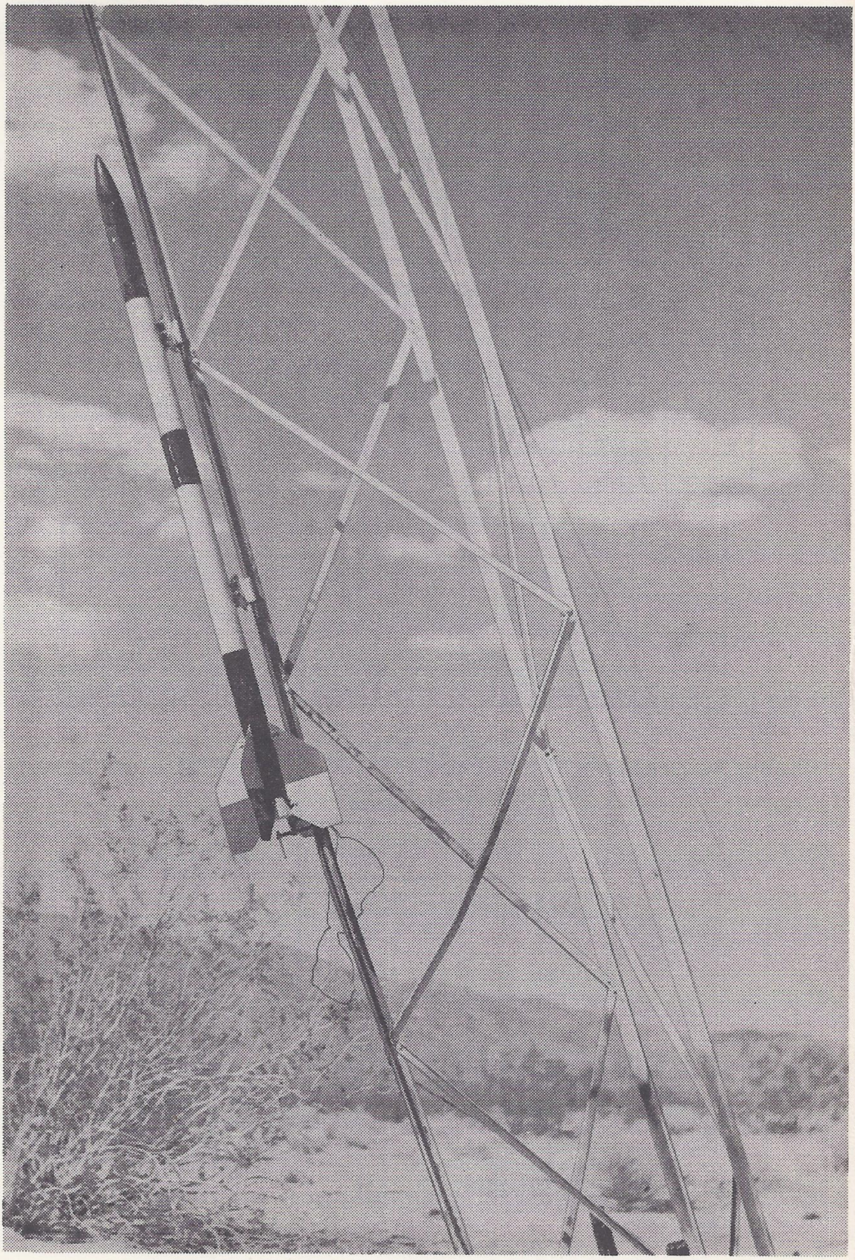
Do not drill any holes in the rocket between the bulkhead and the nozzle, except those necessary to hold the bulkhead and nozzle in place.

This launcher system should not be used on rockets larger than 1 1/2" in diameter.

The motor type launcher is acceptable to use for some of the smaller rockets, however, the rocket must have a guide of some kind near the nose so as to allow the rocket to leave the launcher in a straightline and not bind.

All launchers should be set at an angle of not less than 15° from the vertical and fired into the wind with the person firing them in back of the launcher so that the wind blows from the launcher toward the block house or firing pit. As long as the fins are at the rear of the rocket this applies.

It is not safe to use forward fins on any rockets which you build, and you are advised not to build rockets with fins ahead of the center of gravity, because the rocket has a tendency to go with the wind.



Rocket by Bob Johnson R.R.S. "T" Rail launcher R.R.S.

Table for page 25

Bulkhead

O.D.	A	B	D	Screw Size
1 1/4	3/4	1 1/8	29	8/32
1 1/2	1	1 3/8	29	8/32
2	1 3/8	1 7/8	21	10/32
2 1/2	1 1/2	2 3/8	21	10/32

Machined Bulkhead

O.D.	A	B	C	F	H	K	L	D
1 1/4	1 1/2	1 1/4	1 1/8	Solid	5/8	1/2	1/2	8/32
1 1/2	2	1 1/2	1 3/8	1 1/8	5/8	1/2	1/2	8/32
2	2 1/2	2	1 7/8	1 3/8	3/4	1/2	5/8	10/32
2 1/2	2 3/4	2 1/2	2 3/8	1 5/8	1	5/8	3/4	10/32

Nozzle

O.D.	A	B	C	D	E	F	M
1 1/4	9/16	See no VI	1 1/8	8/32	See Drawing VI		
1 1/2	11/16		1 3/8	8/32	See Drawing VI		
2	15/16	1 1/2	1 7/8	10/32	1 3/4	1/8	4/40
2 1/2	1 3/16	2	2 3/8	10/32	2 1/8	1/8	4/40

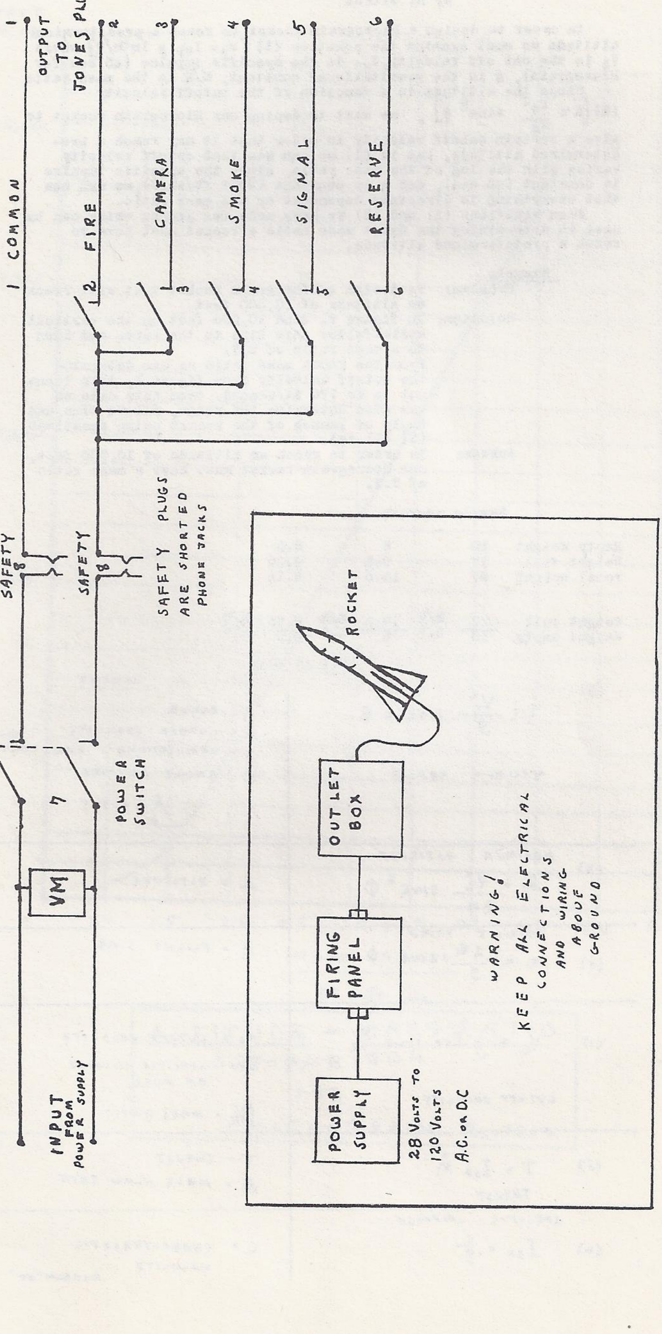
Machine Screw Data

Clearance Drill	Machine Screw	Tap Drill
10	10/32	21
19	8/32	29
28	6/32	35
32	4/40	43

Photos, 3 and 4, page 21, show the method of fuel packaging to be used in the fueling of the Micro grain rocket.

The capsules shown here are used in a 2½ inch rocket and are 2 1/16 inches in diameter by 1 inch in thickness; being covered, top and bottom, by tissue paper. The **mixed fuel is placed** in the capsule which has tissue paper on the bottom; the fuel islevaled off the top and the tissue paper is pasted in place, with wall paper paste and set aside to dry.

Capsules are made of 120 pound paper and rolled on a waxed form.


OUTPUT TO JONES PLUG
1 COMMON
2 FIRE
3 CAMERA
4 SMOKE
5 SIGNAL
6 RESERVE
SAFETY 8
SAFETY 8
SAFETY PLUGS ARE SHORTED PHONE JACKS
7
POWER SWITCH
VM
INPUT FROM POWER SUPPLY
ROCKET
OUTLET BOX
FIRING PANEL
POWER SUPPLY
28 VOLTS TO 120 VOLTS A.C. OR D.C
WARNING!
KEEP ALL ELECTRICAL CONNECTIONS AND WIRING ABOVE GROUND

Optimum Design of a Micrograin Rocket

By R. Citron

In order to design a Micrograin rocket to reach a predetermined altitude we must examine the equation (1) [$V_o = I_{sp}\, g \ln M/R$] where V_o is the cut off velocity, I_{sp} is the specific impulse (25 sec for Micrograin), g is the gravitational constant, M/R is the mass ratio

Since the altitude is a function of the cutoff velocity (2) [$h = \frac{V_o^2}{2g} \text{ sine}^2 \phi$], we want to design our Micrograin rocket to give a certain cutoff velocity in order that it may reach a predetermined altitude, but in (1) we can see that cutoff velocity varies with the log of the mass ratio, since the specific impulse is constant (25 sec), and g is constant (32.2 ft/sec^2), we can see that everything is directaly dependent on the mass ratio.

From equations (1) and (2) we have made two graphs which can be used in determining the exact mass ratio a rocket must have to reach a predetermined altitude.

Example

Problem: To design a Micrograin rocket that will reach an altitude of 10,000 feet.

Solution: In figure 2. find 10,000 feet on the vertical scale-follow this line to the curve and down to a mass ratio of 2.7.
From the known mass ratio we can determine the cutoff velocity from figure 1, this turns out to be 770 ft/second. From this data we can also determine the range, flight time, and angle of launch of the rocket using equations (2) (3) (4).

Answer; In order to reach an altitude of 10,000 feet, our Micrograin rocket must have a mass ratio of 2.7.

Sample rockets

Empty weight	10	5	2.5
Weight fuel	17	8.5	4.25
Total weight	27	13.5	6.75

Weight full / Weight empty: $\frac{27}{10}$ M/R 2.7 $\frac{13.5}{5}$ M/R 2.7 $\frac{6.75}{2.5}$ M/R 2.7

EQUATIONS

	WHERE
(3) $R = \frac{V_c^2}{g} \text{ SINE } 2\phi$ MAXIMUM RANGE	R = RANGE; V_c = CUTOFF VELOCITY; g = GRAVITATIONAL CONSTANT; φ = ANGLE OF FIRE  φ = 70°
MAXIMUM ALTITUDE (2) $h = \frac{V_c^2}{2g} \text{ SINE}^2 \phi$	h = ALTITUDE
FLIGHT TIME (4) $t = \frac{2V_c}{g} \text{ SINE } \phi$	t = FLIGHT TIME
(1) $V_c = g\, I_{sp} \log_e M/R$ CUTOFF VELOCITY	V_c = CUTOFF VELOCITY; I_{sp} = SPECIFIC IMPULSE OF FUEL; M/R = MASS RATIO
(5) $T = I_{sp} \dot{M}$ THRUST	T = THRUST; $\dot{M}$ = MASS FLOW RATE
SPECIFIC IMPULSE (6) $I_{sp} = \frac{c}{g}$	C = CHARACTERISTIC VELOCITY

R. CITRON '58

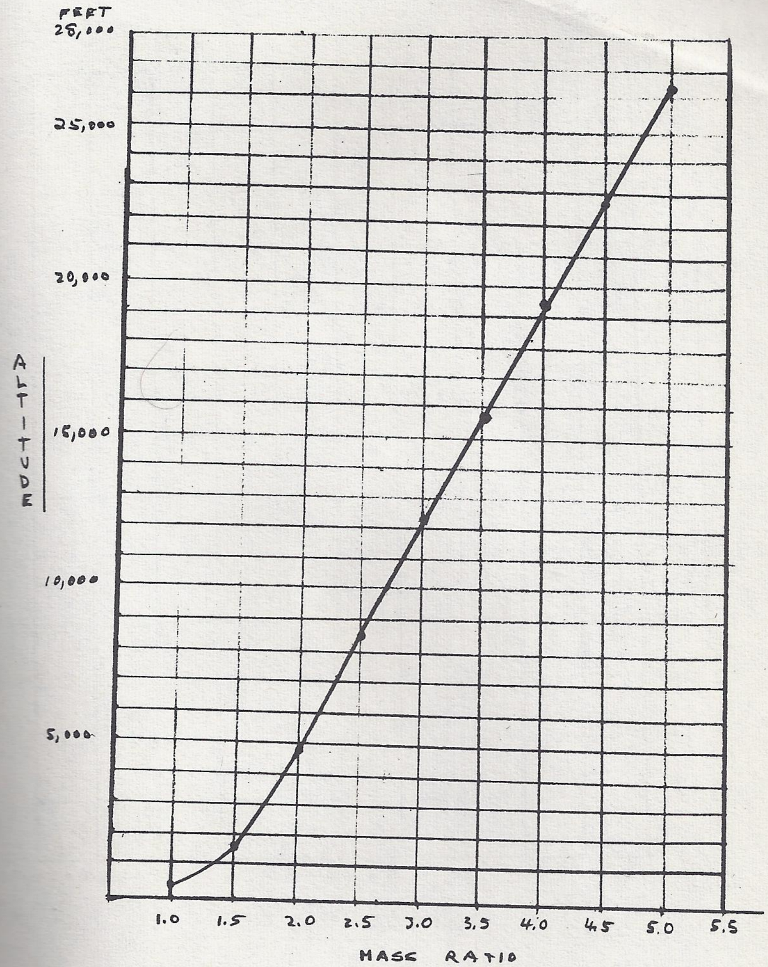
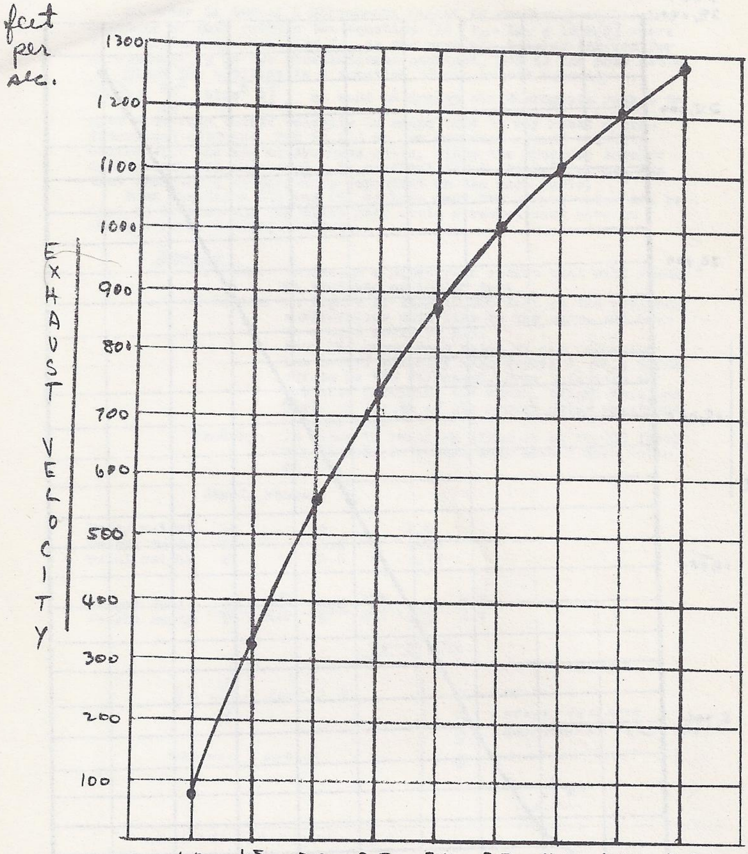


FIG 2

ALTITUDE - MASS RATIO
COMPARISON
FOR
MICROGRAIN R. CITRON

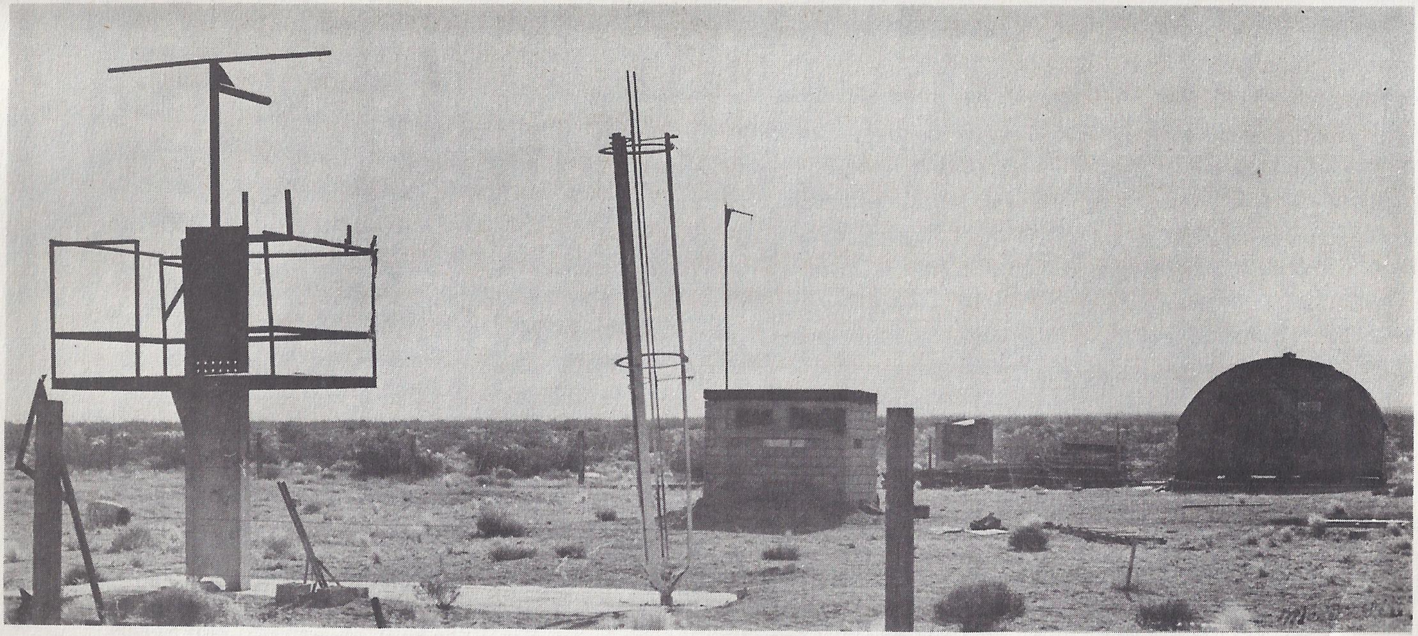


MASS RATIO

FIG 1.

EXHAUST VELOCITY – MASS RATIO COMPARISON FOR MICROGRAIN

R. CITRON



4000 pound static test stand. R.R.S.

Three rail adjustable launcher. P.R.S.

Concrete Blockhouse reinforced with steel. P.R.S.,R.R.S.

Quonset hut(metal) desert work shop. P.R.S., R.R.S.

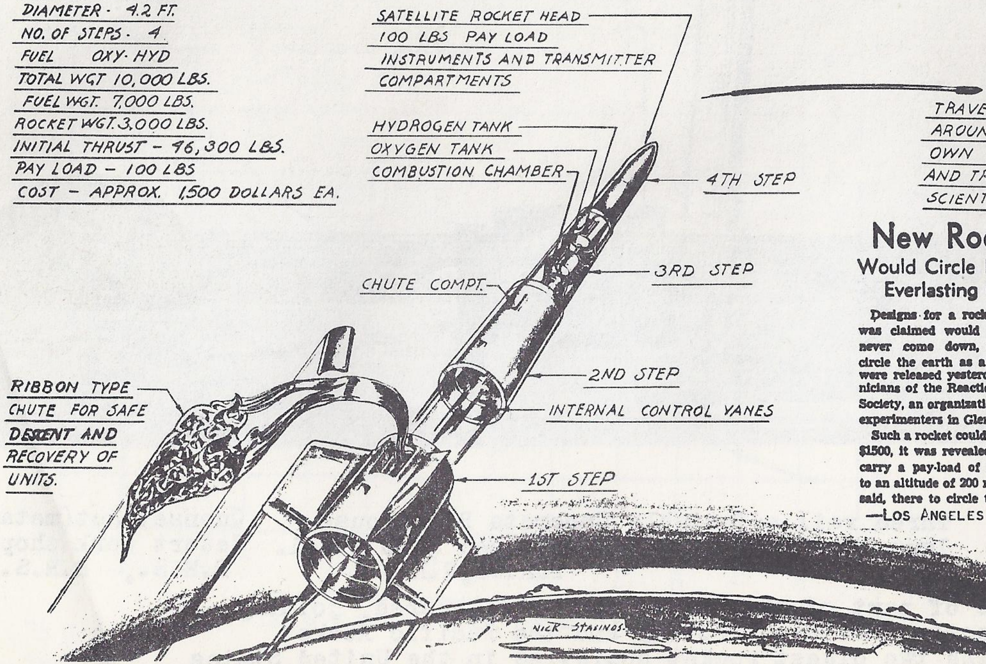
Photograph of part of the Mojave Test Area shared, jointly, by the Reaction Research Society and the Pacific Rocket Society. The two oldest rocket societies in the United States devoted to amature rocketry.

THE REACTION RESEARCH SOCIETY'S PROPOSED DESIGN FOR A SATELLITE ROCKET

Early proposal of Satellite Rocket. 1948
Reaction Research Society design.

FACTS ABOUT THE SATELLITE ROCKET

- LENGTH · 42 FT.
- DIAMETER · 4.2 FT.
- NO. OF STEPS · 4
- FUEL OXY·HYD
- TOTAL WGT 10,000 LBS.
- FUEL WGT. 7,000 LBS.
- ROCKET WGT. 3,000 LBS.
- INITIAL THRUST – 46,300 LBS.
- PAY LOAD – 100 LBS
- COST – APPROX. 1,500 DOLLARS EA.



New Rocket
Would Circle Earth in Everlasting Orbit

Designs for a rocket which it was claimed would go up and never come down, but would circle the earth as a tiny moon, were released yesterday by technicians of the Reaction Research Society, an organization of rocket experimenters in Glendale.

Such a rocket could be fired for $1500, it was revealed. It would carry a pay-load of instruments to an altitude of 200 miles, it was said, there to circle the earth in one and one-half hours at a speed of five miles per second.

At that velocity, the rocket would not fall back to earth but would take up a permanent orbit around the earth, the experimenters believe. A transmitter would supply data to surface receiving stations on cosmic ray counts, high-altitude weather data and other information.

The rocket, which would be approximately 42 feet long, would be built in four sections or steps, each with a separate fuel supply and rocket motor. Three of the sections would fall back to earth on ribbon parachutes, as their fuel is exhausted.

—LOS ANGELES HERALD-EXPRESS, JUNE 24, 1948

From the experiance of the writer the following procedure has been found to be the safest way to fire a rocket with the minimum amount of danger to all parties concerned.

1. Do not carry loaded rockets in your car, load them only before you are ready to fire.
2. Do not use any fuel in the rocket but Zinc and Sulphur
3. When rocket is being loaded install the igniter.
4. Before placing rocket in launcher have all people not directaly concerned with the launching keep out of the area and under cover.
5. Before connecting power lines to the rocket be sure thelines into and from the panel are disconnected.
6. Keep safety plugs to the panel in your possesion.
7. Return to the firing area, blockhouse and start your count down at two minutes annoucing this over a public address system.
8. Connect leads from the rocket to the panel. (see note # 11)
9. Announce 1½ minutes. Inform observers what you are doing as there is danger of misfire from now on.Be sure to look around you and see that every one is under cover if they are not stop your count down and firing until they get under cover.(If count down has to be stopped restart at point 7)
10. Announce 1 minute. Again check to see that every one is under coverif they are not stop your count down and firing. (If count down has to be stopped re start at point 7)
11. Connect power leads to the panel.
12. Start your count down. 45 seconds, 30 seconds, 15 seconds, (at the 15 second count install the safety plugs in the panel) 10, 9, 8, 7, 6, 5, 4, 3, 2, 1, Fire. On the 10 second count make a last look around and if any one is not under cover stop your count down and firing; remove safety plugs. (If count down has to be stopped re start at point 7)
13. Stay under cover until you are sure that the rocket is down.
14. In case of a mis fire be sure every one stays under cover until 5 minutes have elapsed and you are positive your rocket is still not burning.

In order to have a safe well managed firing you should have the following people for the various jobs.

Testing director, to be in charge of the complete firing assisted by at least two people so if a problem arises they can decide just what course to follow.

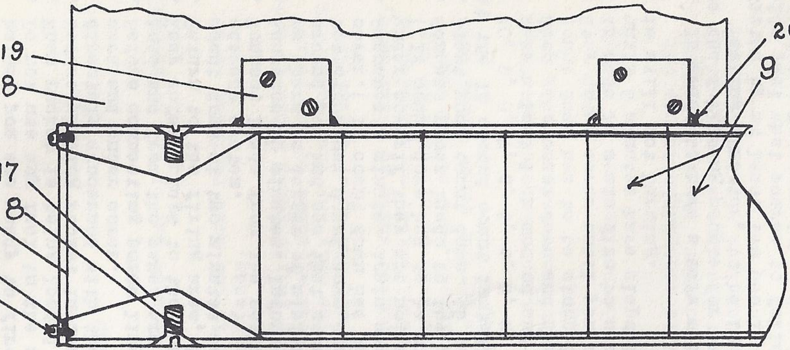
Firing Crew, to take care of installing the rocket in the launcher and firing it, this should be done by two people. One remains in the block house near the firing panel as the other member makes the final connection of the line to the rocket.There should be as few people involved in this as possible if morehelp is needed others should be delegated to help in the case of the larger more complex rockets.

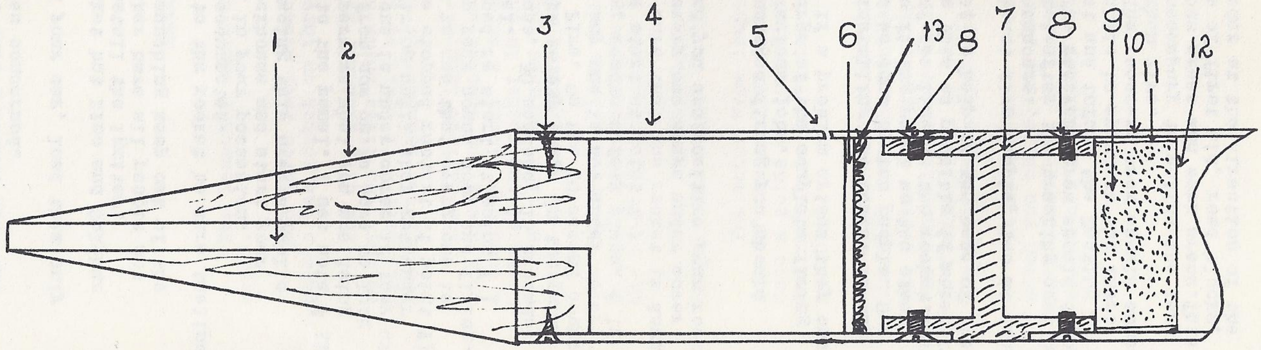
Tracking crew composed of at least five people, two at each tracking station and one at the blockhouse.

Recovery crew to find the rocket after the tracking crew has informed them that it has landed. The recovery crew should determin the exact location of the rocket and inform the Testing director that it is safe for the public to approach the inert rocket, after pictures are taken. The recovery crew should consist of at least two people never more than five.

A group of as many people as necessary to police the test area and keep people out of dangerous areas and work areas.This group of people should be in charge of first aid, road blocks, and in general keeping people in order at the direction of the testing director.

A public information officer to handle the public address system and inform the public as to the firing condition at all times.





1. Air intake 1/4 inch hole, 2. Nose cone, wood or metal; 3. Two of six wood screws, 4. Tracking fluid tank 5. #63 hole in tank. 6. Tank bottom 7. Bulkhead, 8. Four of twelve bulkhead screws, 9. Micrograin fuel, 10. Motor tube, 11. Capsule, 12. Tissue seperator. 13. Weld or solder seal. 14. Ring retainer screw one of six, 15. Ring retainer, 16. Burst disc, 17. Nozzle, 18. Fin, 19. Fin bracket and two 4/40 fin attachment screws, 20. Weld holding fin bracket in place.

The author will give a $25.00 education award for the best article submitted to him each year.

All articles will be judged each August and you will notified not later than October 15, of that year.

The rules are.

1. You must be a student between the age of 14 to 20 years of age. Boy or Girl.
2. You must send at least three photos of your project, if you have built one .
3. You must include a picture of yourself.
4. All material must be typed on 8½ x 11 white bond paper.
5. The permission of your parents must be given to allow the publication of your material and pictures.
6. If you are a member of a rocket society, or study group you must state the name and address of the person in charge of your activities.
7. Your work must be original and never published before.
8. You must not violate any local ordances regarding fire or the flight of rockets.
9. It is not necessary to build or fly a rocket to compete. Theoretical as well as actual projects are acceptable for competition.
10. If you wish a reply you must enclose a self addressed stamped envelope.
11. Do not send your project; just the manuscript and photos.
12. All material remains the property of the author and cannot be returned.
13. The decisions of the judges will be final.
14. If you build a rocket you shall not use any fuel but Zinc and Sulphur.

    The fuel will be used in the dry powdered form and will not have been melted or contain any other chemicals.

All manuscripts submitted may be related to theory or practical application of, Rockets, Missiles, Space Flight or Anti-gravity.

If your material is published you will recieve a copy of it.

All material should be sent to B.J. Humphreys Jr. P.O. Box 90391 Los Angeles 45, California previous to August first, as material recieved later than this date will be judged in the following year.

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MOSES BROWN SCHOOL SCIENCE CLUB

Rocket Program Information Sheet

SAFETY PRECAUTIONS, NOT IN ORDER OF IMPORTANCE; to disregard any of these for the sake of convenience is to invite serious trouble.

1. Permission from all parents whose children attend a rocket launching.
2. A launching site far removed from heavily populated areas; the site should provide adequate protection against injury from flying bits of metal. Rockets capable of reaching extreme altitudes will be fired over the sea.
3. Use of a fuel made up of a mixture of powdered zinc and sulphur. This fuel will not detonate under pressure alone but must be ignited by sustained temperature. No fuel other than the zinc-sulphur mixture is considered.
4. Use of a remote-controlled electrical firing system which puts everyone concerned a safe distance—at least seventy-five (75) feet—from the rocket. Use of a fuse or matches is strictly forbidden.
5. Strict supervision of each launching by the Science Club adviser. Anyone who does not obey the adviser in the matter of taking cover and of remaining clear of the rocket in case of a misfire is not allowed to attend any more firings.
6. In the event of a misfire, the ignition circuit is broken and the rocket is allowed to stand a few minutes before the adviser approaches it. Under no circumstances is anyone to approach a smoking rocket.
7. No one is ever allowed to play with a rocket, and anyone who carries on dangerous work outside of club time or ignores safety rules is immediately expelled from the club.
8. The rocket is fired at an angle of not more than eighty degrees (80) from the horizontal to ensure that it does not fall in the vicinity of the launcher. The launcher itself must guide the rocket for not less than twice the length of the rocket.
9. The club has a qualified adviser.
10. The nozzle of the rocket is not smaller in diameter than one-third the diameter of the fuel section.
11. Seamless tubing is employed. ,Steel
12. The fuel is never heated when being made; it is simply stirred together. Neither is the mixture used as an igniter heated.

By permission of the Editor
of MODEL AIRPLANE NEWS • August, [illegible]

Partial List of Rocket Societies

American Astronautical Federation
P.O. Box 1734
Washington 13, D.C.

American Rocket Society
29 West 39th Street
New York 18, N.Y.

Boise Rocket Research Society
1107 North 16th Street
Boise, Idaho

Chicago Rocket Society
10630 South St. Louis
Chicago 43 Illinois

Intermountain Rocket Society
1425 Emerson Avenue
Salt Lake City 5, Utah

M.I.T. Rocket Research Society
Walker 305
Mass. Inst. Technology
Cambridge, Mass.

Pacific Rocket Society
P.O. Box 15671
Del Valle Station
Los Angeles 15, Calif.,

Reaction Missile Research Society
Box 1199
State Collage, New Mexico

Reaction Research Society
P.O. Box 1101
Glendale 5, Calif.,

Sociedad Argentina
Interplanetaria
tucuman 950
Beunos Aires
Argentina

Oesterreichische
Gesellschaft feur
Weltraumforschung
P.O. Box 192
Wien VII/62
Austria

Canadian Rocket Society
619 Roslyn Ave,
Montreal, Canada

Danish Interplanetry Society
P.O. Box 31
Copenhagen-K, Denmark

British Interplanetary Society
12 Bessborough Gardens
London, S.W. 1, England

Gesellschaft fuer
Weltraomforschung
Reinsburgstrasse 54
Stuttgart-W, Germany

NederlandseVereniging voor
Ruimtevaart
Anna Paulownaplein 3
s'Gravenhage, Holland

International Astronautical
Federation
P.O. Box 37
Baden, Switzerland

If you have any names to add to this list please send them to P.O. Box 90391 Los Angeles 45, California.

My thanks to;
Jim Medsker; for his contribution of several years interest and assistance at launchings.
Steve Marstaller; for his efforts to get the pictures for this booklet.
Bob Citron; for his calculations related to Micrograin rockets.
Gene Cox; For his art work.
The many members of the R.R.S. and the P.R.S.; for their assistance in all phases of rocketry.

B.J.H.

**Second Edition
Will Include
Full Size**

Print of Rocket

Static Testing

**Additional
Information
Related
to
Amature
Rocketry**

**To
Be
Released
August 8,
1959**

By

**B.J. Humphreys Jr.
P.O. Box 90391
Los Angeles 45,
California**