SOLID FUEL MOTORS

for

MODEL ROCKETS

CENTRAL ROCKET COMPANY

SOLID FUEL MOTORS for MODEL ROCKETS

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These plans will provide a practical method of producing devices for use in the study of jet propulsion, and for use in the construction of working models of missiles, rockets and the like. These methods can be applied in a safe manner. Devices made according to these methods will perform with a high degree of dependability. The methods can be applied easily by one who understands the principles involved. It is therefore our object to present these principles in necessary detail. Those not acquainted with the subject may find it necessary to dispel any ideas that a practical jet device can be prepared by placing a dry or loose powdered substance in a tube or pipe. Such practices are useless and extremely hazardous. There will be no reason for creating hazardous devices or conditions when these nethods are carefully applied.

Over 200 years ago it was discovered that a hollow cored solid mass of quickly combustible fuel, confined in a cylindrical case with an orifice at one end, could act as a self propelled missile having great velocity and capable of prolonged operation. Devices of this nature in double, and compound staged assembly were made at that time and successfully employed as an amusement and in warfare.* With the possible exception of certain new liquid fuel systems there has, up to this time, not been found a more practical rocket propulsion system. The recent success of military missiles employing shaped solid fuel testifies to its value. Our plans will deal with a solid fuel system of jet propulsion. Liquid fuels of any kind are extremely hazardous and require the use of apparatus entirely too complex and costly to be suitable for amateur construction.

FUEL

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In making our rocket motor the fuel will be formed with a central conical cavity extending inwards from a jet orifice. This provides a large area over which combustion may progress to evolve a sufficient volume of gases for propelling the rocket. Due to this condition a relatively slow and safe fuel can be utilized. Pressure within the motor case is likewise properly directed and the case is not subjected to high temperatures until a major portion of the fuel has been expended. To maintain the fuel mass in proper shape the fuel composition will require an ingredient having a binding or cementtitious character. The thermoplastic character of certain substances particularly bituminous materials such as asphalt and tars has been utilized in compounding rocket fuels. These materials have been melted and incorporated with oxygen containing substances. A great hazard is encountered in heating a mixture of this type, and its use is therefore not recommended. The thermosetting character of some materials such as natural and synthetic resins, and natural

* Frézier's "Traité Des Feux D'Artifice" Paris, 1747.

and synthetic rubber compounds may be exploited in using them as a combined binder and fuel component. The most successful rocket fuels including those used to launch artificial satellites are composed of an oxidizing material such as potassium perchlorate and a combustible binding material. This binding material is produced by a patented process in which a liquid polymer is formed by the chemical reaction between dichlorodiethyformal and an alkali polysulfide. This liquid material is capable of being converted to a tough resilient rubbery material at room temperature without appreciable shrinkage, by the application of curing agents. The properties of most of the above discussed materials are not adaptable for producing a rocket motor by means practical for amateur use.

Adhesive organic substances which are soluble in water or alcohol may be employed as binder ingredients in a fuel mixture. The following is an example:

Potassium perchlorate 3 parts, red gum (gum yacca) 1 part, alcohol-water 50-50 to dampen. These proportions are approximate--exact quantities will depend on rocket size and design. The material should be obtained in finely powdered form, and pure. Potassium perchlorate as well as other oxidizers should not be subjected to friction, grinding or impact particularly when in contact with any dry comminuted substance.

The materials are mixed on a large sheet of paper. Sift the mixture through a fine mesh screen several times to eliminate any lumps and insure complete mixing. Do not prepare more of the mixture than necessary for immediate use. The mixture must be dampened with alcohol (grain, wood, denatured) which is diluted half and half with water. Sprinkle the liquid slowly upon the mixture while rolling over and over with the hands (use rubber gloves if your skin is sensitive). The mixture must be dampened sufficiently so that it will cling together when it is squeezed and be evenly dampened throughout, A clean wood rolling pin can be used to facilitate dampening after most of the liquid has been added. Roll the material out, then break up the mass with the fingers, and roll again. Do not dampen to the extent that the material is tacky or viscid. It should retain a granular appearance while being definitely wet to the touch. Keep this material in a container covered to retain the moisture at all times while it is used. Add more liquid if it should become at all dry.

Caution: The material potassium perchlorate referred to above should not be confused with potassium chlorate! Do not attempt to use potassium chlorate. It is very dangerous and entirely unsuitable as a rocket fuel.

To use the fuel refer to the directions in the following pages. The conventional rocket tools illustrated in our drawings may be advantageously employed. Very little pressure is required to solidify this fuel mixture, but it is necessary that it be kept damp at all times. The prepared rocket motor must be dried at room temperature for 3 days or more depending upon the size of the motor.

One of the most successful and easily adaptable fuels that can be used to propel a rocket has an oxidizer consisting of potassium nitrate. The ordinary black powder made with potassium nitrate is considered to be unsafe for this purpose. A similar composition may be modified by the addition of a water soluble binder ingredient to make a satisfactory fuel. The following is an example:

water	*sufficient to dampen the mixture*
potassium nitrate	*3 parts by weight*
dextrin	*1/2 part by weight*
sulfur	*1/2 part by weight*
charcoal	*1 1/4 part by weight*

Obtain the materials in fine powdered form. Use the same method for mixing and dampening as was explained previously. Dampen the mixture well with water and keep it wet at all times. Use slightly more or less charcoal to adjust combustion in rockets of different sizes. A large rocket will require more charcoal. Dry the prepared motor for several days at room temperature. This fuel when properly consolidated in a fiberboard case will prove very effective, and if used with proper care, it can be recommended as entirely suitable.

Dimensions for Rocket Motors in Inches

Bore	*Spindle Length*	*Orifice Diameter*	*Length of Case*
3/8	1 5/8	9/64	2 1/2
1/2	3 1/4	7/32	5
3/4	5	21/64	7
1	7	15/32	9
1 1/4	8	1/2	10

These dimensions will be found satisfactory for most conditions, they may be altered to suit special requirements.

THE MOTOR CASE

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Rockets for military use and large diameter research models have of necessity, been made with metal casings. The use of metal casing of any kindcreates a hazard due to the projection of heavy fragments in the event of an exploded rocket, and because of the possibility of the heavy case falling upon persons or property. Metallic components used in rockets contribute to accidents. Experience has shown that a tube formed of convolutely wound laminations of a fibrous sheet material such as paper, will provide a rocket motor case having favorable physical characteristics, while possessing little, if any, of the hazardous properties of a metal case.

Commercially produced paperboard tube of correct dimensions will be found to qualify as the best rocket motor case material. Spiral or helical wound tube is not useful for our purposes. The reader who wishes to try out special sizes of rocket motors, or who is not able to secure commercial tube, can make the required articles with a little practice and study.

Fourdrinier machine papers of many kinds, particularly kraft paper having a hot calendared hard finish, will be found to provide a suitable sheet material. Cylinder machine-formed paper such as pressboard is also an excellent material. Adhesive material of many kinds is suitable for laminating the tube layers, but ordinary wallpaper paste is both cheap and perfectly satisfactory. Add the dry wallpaper paste powder to cold water while stirring rapidly with a wire mixer. Make the paste as thick as library paste and allow to stand a few days if possible. The tack of the paste will improve with age. To prevent spoilage a preservative such as a few drops of phenol (carbolic acid) may be added after the proper tackiness has been attained. After deciding upon a size of tube, (for the average motor make the length of the tube equal to about 9 times the inside diameter and have the outside diameter about 75% greater than the inside), cut a piece of paper and roll it upon a metal rod or cylinder having the desired diameter. When a length is found to produce the desired wall thickness you are ready to proceed. Make sure in rolling the paper that the grain of the paper lies parallel with the forming rod. The direction of grain may be ascertained by folding or tearing the sheet. The paper will fold or tear most readily along its grain. It is difficult, if not impossible, to form a good case if the paper is not wound with the grain running in the proper direction. Also, in event of a burst rocket case, a properly rolled one will fragment into narrow strips while an incorrectly made case will break circumferentially into two solid pieces. Apply paste to the forming rod and to the top surface of the paper sheet which is placed on a hard smooth table surface. Lay the forming rod upon the pasted sheet adjacent the end of the sheet nearest to you and at right angles to the side of the sheet. Pick up the near end of the sheet and loop it over the rod. Now with pressure by the fingers of both hands, tuck the end around and under the rod and commence to roll the entire sheet around the rod. If the rod is started exactly at right angles to the sides of the sheet and if pressure is applied smoothly a tube of perfect dimensions is formed. If heavy paper is employed as sheet material it may be necessary to complete the pasted winding with an outer wrapping of thin paper to hold down the heavy winding. By gripping the wound tube with one hand, and the free end of the forming rod with the other hand the rod is extracted by a slight twist. The entire operation should be accomplished as rapidly as possible to prevent undue moisture saturation of the material prior to rolling. The wet case is dried by exposure to air while resting in a horizontal position.

THE JET ORIFICE

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An orifice formed of dry clay will operate perfectly in a well designed rocket motor, and if an improperly constructed rocket should burst the clay will shatter into harmless particulate matter. Almost any form of clean clay may be employed, but a special rocket grade will be best when obtainable. The clay should be well powdered fine and contain moisture to as great an extent as possible while maintaining a dry appearance. Keep the powdered clay in a closed metal container with a damp cloth or sponge to increase the moisture content. Do not allow the dampener to contact the clay. If reference is made to the illustrations and key it will be seen that the nozzle, or choke, is formed by tamping the loose material inside a case which is placed over a spindle. Ascertain, by trial, the exact quantity of loose material required to form a choke of the right depth, and then form the choke by tamping the entire quantity of clay at one time. The hollow ramming tool or drift used to tamp the clay should be tapped sharply with a wood or plastic mallet to compress the clay into a solid mass. The tool may be struck a number of times, usually six or seven times, with all the clay under it. Do not at this time remove the case from the spindle, but prepare to tamp in the fuel by first emptying out any remaining loose clay. It will be seen that the entire loading of a rocket motor can also be accomplished by ramming in the clay and fuel solid after which a central hole is bored to form the jet and core. While this method will work, it is not generally satisfactory. Although it is possible to operate a solid fuel motor without a central hollow core, it will be seen that only a small area of fuel is thereby utilized at one time. Conditions resulting during the combustion of a coreless fuel mass are detrimental to the motor case and not conducive to practical rocket operation. Along with rocket motors depending upon dry, loose fuels, the coreless solid fuel mass is not favorable because of physical character incompatible with a motor case of reasonable lightness in weight. Metal tubing will not hold a clay nozzle as well as fiberboard does.

A correct size for the spindle at its greatest dimension will usually be found to equal 1/3 of the inside diameter of the motor case. The spindle tapers slightly to its end to allow extraction from the rammed composition. Its length will usually be about 2/3 the length of the motor case.

FORMING THE FUEL MASS

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The prepared fuel composition should be plastic enough to adhere when pressed together, but dry enough so it will not readily cling to any surface. Introduce the material in small wads or chunks in an amount which, when compressed at one time, will equal only a small fraction of the length of the case. For example, no more than 1/2" of fuel should be tamped at one time in a case of 5" length. Use firm hand pressure on the ramming tool to compact the fuel mass, a few light taps with the mallet may be employed, but hard blows are unnecessary. (This entire method is not to be employed in filling a metal case of any kind). After enough charges of fuel have been placed to cover the top of the spindle, and a bit more, it is time to make the top clay closure using the same method as is used in making the jet choke. Withdraw the complete rocket motor from the spindle by twisting and gently pulling upwards.

PRIMING

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Some rocket fuels are not readily flammable and will usually require some form of priming. A good priming mixture can be prepared as follows: Six parts by weight of finely powdered potassium nitrate is stirred into enough hot water to form a thick paste. Into this is mixed one part of powdered sulfur and two parts of powdered charcoal. The mass of wet material is rubbed together and completely mixed. Add enough water to form a thick paint and with a small brush or pipe cleaner, brush the inside surface of the rocket motor fuel mass. Get the prime up into the hollow core. Another way to use the prime is to soak pieces of cotton wicking or soft string in the mixture. A little boiled starch added to the prime will make it adhere more readily. The soaked string is dried and may then be used to prime the rocket motor by inserting into the hollow core. This primed string is known as quick match, is quite flammable and should be kept in a closed container when dry. The prime material is safe anywhere as long as it is kept wet.

PREPARING THE ROCKET MOTOR FOR IGNITION

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When the rocket motor has been primed, it may be equipped with safety fuse according to this method. A length of at least 3 inches or more, depending upon the size of the rocket, is inserted with one end through the choke, leaving a sizable length protruding for igniting. Wrap a narrow band of pasted thin paper around the motor case adjacent the jet end so that about two inches of paper protrudes rearwards. Gather the end of the paper nose band around the fuse and tie with a piece of string to form a bag-like member for securing the fuse. The same method can be used to hold a squib in place for electrical ignition. A motor unit formed in this manner is ready for use as a complete rocket with the addition of fins adapted to stabilize its flight. A group of motors made according to our direction can be assembled to form compound motors and multiple staged rockets. In a compound motor, nose each unit separately and lead a piped quickmatch into each nose with a fuse igniting the match at one point. Pipe for quickmatch is made as rocket motor case by rolling a few turns of thin pasted paper on a 1/4" rod. In the pipe, a good quickmatch should communicate fire instantaneously to all parts it is led to. The match used for this purpose must be made from well mixed prime composition. In multiple staged rockets a hole in the upper clay plug of a first stage motor may communicate fire directly or by means of match to an upper stage. Some examples of how the motor can be adapted are to be seen in the photographs.

PARACHUTES

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If a sheet of thin material such as paper, fabric or plastic film is cut to form a polygonal outline, strings can be attached at the corners of the sheet to form a small parachute. A parachute of this kind may be used to lower part or all of an expended rocket. The parachute should be carefully folded in accordion-like pleats to insure best results. The type of parachutes made for pyrotechny in Japan are admirably suited for this purpose, are quite inexpensive, and may be used a number of times. Use a few pieces of quickmatch under the bottom disk shown in the drawings to expel the parachute. A study of the drawing will provide all details for correctly using a parachute.

A solid fuel rocket motor must have a fuel mass entirely devoid of cracks, air bubbles, or soft areas. This factor of fuel unity can be secured if the fuel mixture is used with a wet binder, and if the fuel is carefully tamped in a properly made case. In launching your rocket use a guide rack to insure a correct course. Proper priming must be provided to completely fire the fuel. A rocket made correctly according to our plans will rise without hesitation when ignited. Elongated assemblies of rocket motors should be provided with side spin at the time of firing. Small side thrust motors may be attached directly to the assembly or to a rotary pad upon which the rocket is supported. Use a fuse sufficiently long to allow you to get 50 yards or more away from an ignited rocket. Wear safety glasses always when working with rockets.

In these directions and in the drawing we have illustrated a system which can be intelligently adapted to the production of rocket units of any desirable size and combination. The exclusive use of non-metallic components is urged. A soft rubber nose cone will eliminate fallout hazard when small rockets may be used in congested areas. Fins and other members may well be also made of soft pliable material. When it is desired to build a rocket of more than 1 1/4" bore, it is recommended that a number of motor units be assembled side by side in parallel arrangement to provide a large compound motor. A motor such as this can be used to power one or more parts of a multi-stage model. The compound motor can be enclosed in an outer shell or be exposed as part of the missile surface. This method of assembling small units has been used with great success by research workers and amateurs. The Army's Jupiter rockets were powered in this manner. Quick match can be used to convey ignition simultaneously from a primary ignition point to each motor in one group.

We hope that the reader may derive much pleasure and inspiration in making rockets, and will also enjoy safety by learning what NOT to do, as well as WHAT to do. IN THE INTEREST OF SAFETY:

Do not rub, grind, or strike any dry combination of chemicals; Do not use metallic materials for rocket components; do not use loose, dry, powdered material as rocket fuel. Plan to ignite any rocket only after all possible safety precautions have been taken. Use a method of ignition such as fuse to permit getting 50 yards or more away from any rocket you fire.

When firing any device you make, be sure to consider where it may land and what possible effect may result. Carelessly or improperly made devices are apt to perform with unexpectedly hazardous action. Don't take chances.

Always keep away from a device that fails to ignite until all possibility of hang-fire is past. A good rule is, to stay away until you are satisfied it is safe to inspect--and then wait another 15 minutes!

KEY TO DRAWINGS

Fig. 1 is a sectional side view of a spindle on which a rocket case may be charged to obtain a hollow core. An upright frusto-conical member 1 having an outwardly inclined shoulder portion 2 and a shank 4 is secured to base member 5 by means of a nut 6. A cylindrical section 3 at the base of shoulder 2 is adapted to engage the mouth of a rocket case. The spindle is preferably made by turning a metal rod on a lathe. The base 5 may consist of a block of wood.

Fig. 2 is a group of sectional views of rocket case charging tools. All are similar except for length. They consist essentially of a metal rod 7 having a wood handle 8 and are bored hollow 9, 10 to fit over the spindle 1, Fig. 1. A separate rod may be used having a chamferred edge 11 to seat clay for the jet nozzle. A half length tool such as is illustrated may have a small bore to fit the spindle top section. A short rod 13 used for consolidating the fuel over the top of the spindle and for making the top clay plug has a flat end surface 12. The tools are preferably made of brass, copper or aluminum or wood. Do not use steel or iron for making rocket tools.

Fig. 3 is a sectional side and end view of a basic, solid fuel rocket motor. The motor case 15 is a cylindrical tube of convolute wound paperboard in which an annular plug of clay 18 is solidly rammed to form a jet orifice 20. Solid fuel 16 is solidly packed in the case which is engaged over the spindle 1, Fig. 1, to form a hollow core 17. A portion of the fuel 19, extends upwards from the top of the spindle at least a distance of 1/2 the diameter of the case. A solid closure plug of clay 14 is formed above the fuel.

Fig. 4 is a sectional side view of the upper end of a rocket motor on which a compartment 24 consisting of a cardboard cylinder has been attached for carrying a parachute 23. A hole 27 is drilled through the top clay closure plug 14 and filled with fast burning fuel. Additional fuel 26 may be loosely placed over the clay plug. A cardboard disk 25 rests on top edges of the rocket motor case 15. Granular material 28 such as sawdust is packed around the parachute 23. A disk of cardboard 22 rests over the granular material and under a rocket heading 21 (nose cone) formed of light wood or preferably sponge rubber. The parachute may be tied to head 21 to the rocket motor case, or to another article carried inside the compartment.

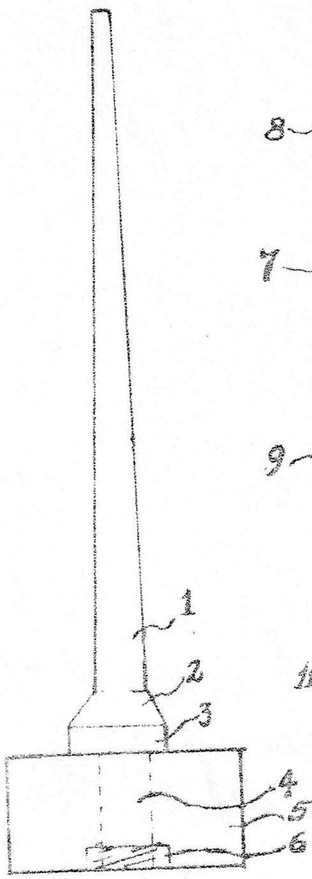


FIG. 1.

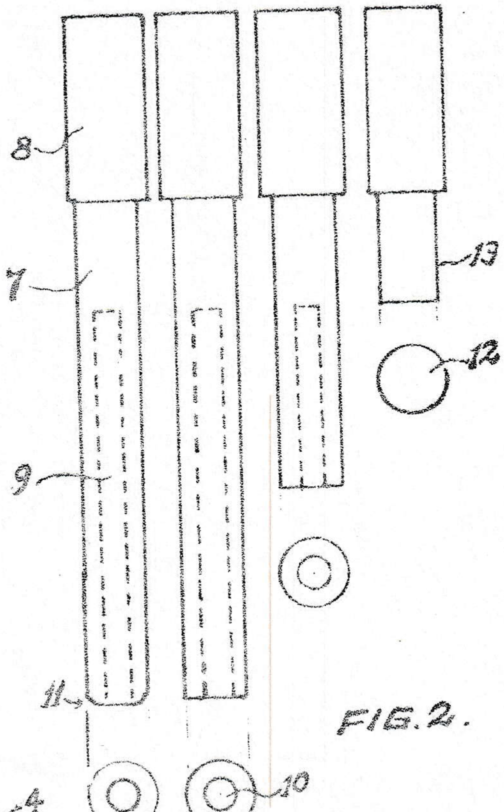


FIG. 2.

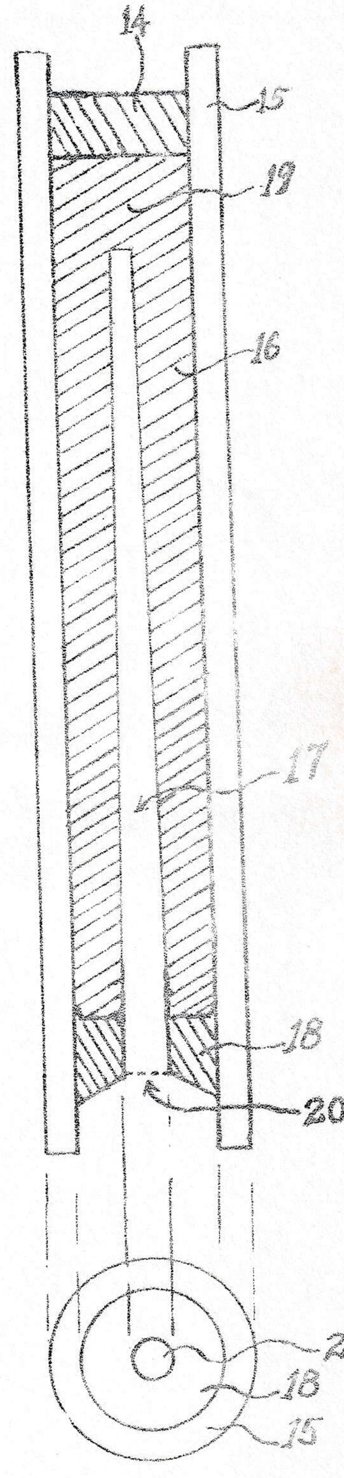


FIG. 3.

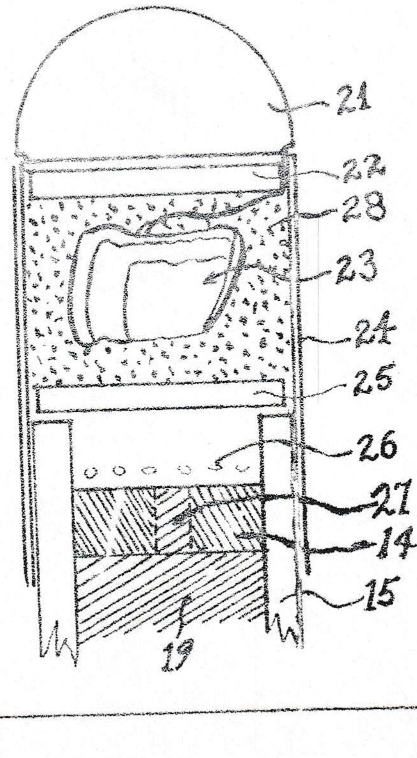


FIG. 4.

NOT TO SCALE

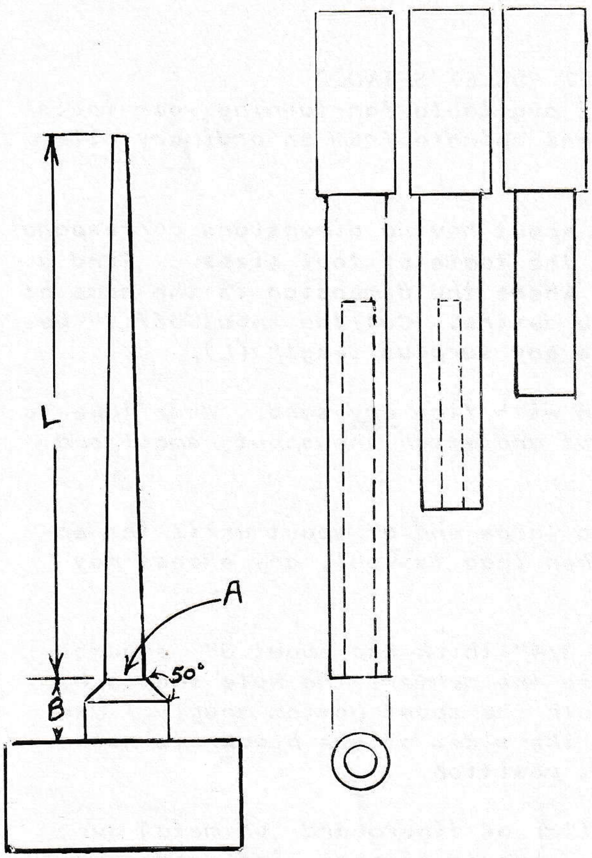


Table of dimensions for spindles			
MOTOR Inside Diam	L LENGTH	A NOZZLE Diam.	B Orifice Section
1/2"	3 3/16"	7/32	5/8
3/4"	4 3/8	5/16	3/4
1"	6	3/8	1
1 1/4"	7	7/16	1 1/4
1 1/2"	7 3/4	5/8	1 1/2

These sizes may be modified to suit special conditions. Nozzle diameters should be reduced slightly for slow burning fuels. Angle of nozzle at orifice may be altered if desired. Spindle should be formed of steel, aluminum, brass or hardwood. Taper angle is not important as it merely provides "draft" to allow the spindle to be extracted easily after a motor is rammed. It is possible to make a usable spindle by filing, but a lathe turned product is preferable. If spindle is formed of wood it should be impregnated with wax. Bees wax is tougher and more pliable than ordinary paraffin or the like.

Spindle Base. A block of hardwood will serve as a satisfactory spindle base. Form the spindle with a tang which is threaded to receive nut and lock washer. An alternative type of base consists of a metal plate which is welded directly to the spindle, or if desired, the plate may be bored, and threaded to receive a bottom threaded portion of the spindle.

Rammers (drifts) may be formed of hardwood dowel stock, or aluminum, brass or white metal rods. Do NOT use steel or iron for making rammers. Prepare at least three rammers of different lengths. The long rammer should be hollow bored to engage the spindle at the nozzle area. The medium length spindle should engage the spindle at a point half way towards the top. The short rammer is not bored, as it is used to consolidate the fuel portion above the spindle.

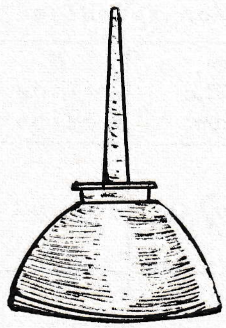
TIPS ON USING LOADING TOOLS

Do not use heavy hammer blows upon the drifts. Employ a mallet stroke of only 3 or 4 inches to tap the drift sharply. Always dampen fuel being used with these tools. Do not dampen the clay used for making nozzles. Clay should be fine, dry powder. Turn the motor tube around the spindle between taps to prevent excessive pinching or distorting of spindle. This is most important with spindles made of wood.

Central Rocket Company
P O Box 89
Waupaca, Wisconsin

Revised January, 1960

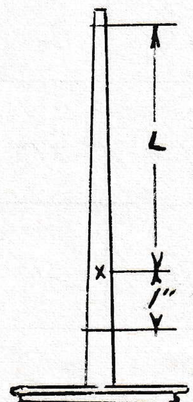
OILER SPOUT ROCKET SPINDLE



If a metal lathe is not available for turning your tools you can make an excellent spindle from an ordinary oiler can.

Select an oiler with a spout having dimensions corresponding to those listed in the table of tool sizes. Find a place on the spout (X) where the dimension is the same as the throat (nozzle) you desire. Cut the spout off 1" below this point. Remove any surplus length (L).

Fill a small box or can with fine dry sand. Wrap tape to close small end of spout and stick the spout, small end down, into the sand.

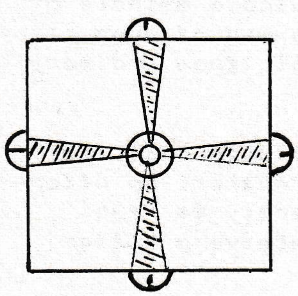


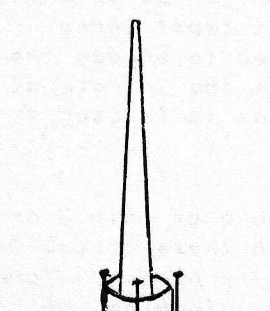
Melt lead and pour into large end of spout until the entire spout is full. When lead is cool, any excess may be filed away.

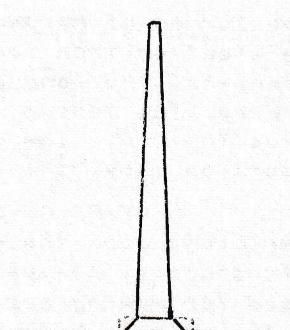
Prepare a wood block 1 3/4" thick and about 3" square. Bore a hole 1" deep into the center. The hole should be just large enough to hold the spout bottom snugly. Use wood screws applied at the sides of the block to hold the spout in an upright position.

Place a cylindrical collar of fiberboard or metal over the spindle. The collar should have an inside diameter the same as the inside diameter of motor tubes you intend to use with the spindle.

Use small nails or brads to hold the collar in position with the spindle exactly in the center. Heap dry sand around the outside of the collar. Fill the space inside the collar with melted lead. When the lead is cool, remove the collar and shape the upper edge of the lead knob with a file.







INSTRUCTIONS FOR USING ROCKET MOTOR LOADING TOOLS

If the spindle in your tool set is made of wood it is supplied ready waxed and ready for use. After being used for loading a rocket mptor it should be re-waxed each time before it is used.

Rub beeswax on the surface of the spindle and polish with a piece of paper to obtain a slick finish. If your tool set contains a metal spindle, the spindle requires no special treatment other than to be kept clean. Set the spindle upon a solid bench or use a concrete block as a support.

Engage a fiberboard tube over the spindle and deposit one scoopful of dry powdered clay into the tube. Carefully insert the long hollow drift into the tube and around the spindle. With a plastic, wood or hard rubber mallet strike the drift squarely, using a sharp 7 inch stroke. Apply a total of 9 blows. Between each blow, raise the drift an inch or so and rotate it to another position. Between each 3 blows, hold the spindle base firmly with one hand, and with the other hand rotate the tube 1/4 turn, being careful to apply pressure only at right angles to the spindle so that the tube is not lifted or moved upward.

When the clay nozzle has been formed and any surplus dust tapped out of the drift you may commence to load the fuel. Continue with the long drift. Apply 6 blows for each scoopful of fuel. Rotate the tube as directed above.

When the fuel is solid halfway up the spindle start using the medium length drift. Continue with the medium length drift until the top of the spindle is even with the packed fuel. With the solid drift tamp in 1/2" of fuel above the spindle top.

We recommend the use of dampened fuel in which a binder ingredient is incorporated. When a motor loaded with a fuel of this type is fully dried it will operate perfectly without a top closure of any kind. If a top closure is required to form a bulkhead between upper parts of a missle, you can form a clay plug over the fuel using the solid drift. Clean the hollow drifts with a piece of stiff wire.

Do not use metal tubing for making rocket motors.

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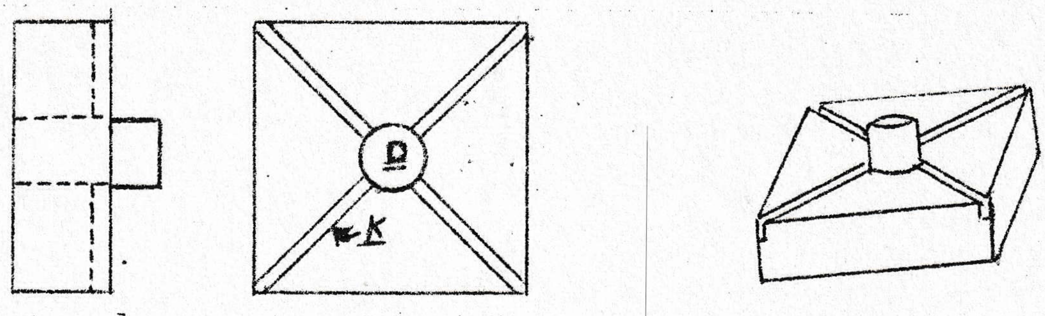
How to Make Fin Aligning Jigs

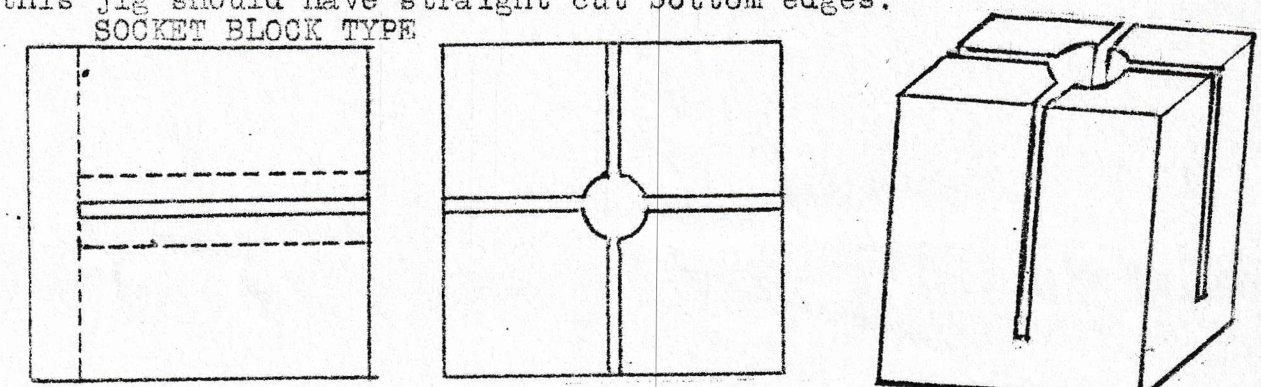
Accurate spacing and alignment of fins is necessary for getting good flight stability with your model missile. One of these simple rigs will make it easy to apply the stabilizing members.

FLAT BASE TYPE



Use a square piece of ordinary wood board of about 3/4" thickness. A center hole is bored to receive a wood dowel peg (D) of diameter equal to the inside of your missile tube. When the missile is supported on the dowel peg, the fins are inserted into saw kerf slots (K) made on the surface of the board. Use fast drying cement or glue on each fin inside edge. Press all four fins firmly against missile body. Allow sufficient drying time before removing the missile. Fins used with this jig should have straight cut bottom edges.

SOCKET BLOCK TYPE



With more surface for supporting the fin members this device provides best alignment and is adapted for use with fin members having slanted or curved bottom sections. Any block of wood or plastic material may be utilized to form the jig as illustrated. The slots may be formed with a saw blade of a thickness corresponding to the fin material you intend to use.

The missile hull is firmly supported in the center socket which should be bored accurately parallel to the slots. A thin coating of wax will help prevent cement from sticking to the jig. When the fins are applied with cement or glue, wind string or rubber bands around the assembly to press the fins firmly against the hull.

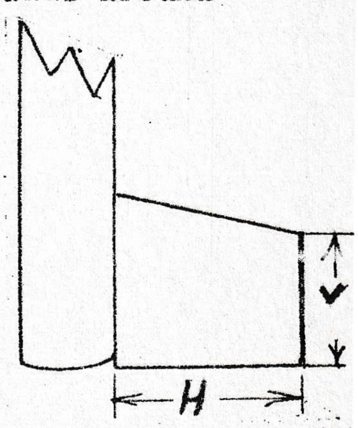
SIZE OF FINS

The minimum fin size for any particular model missile may be estimated with fair accuracy as shown.

V - fin vertical dimension
H - fin horizontal dimension
L - over all missile length
D - missile hull diameter

$$\frac{L}{6} = V$$

$$D \times 2 = H$$



Remember to keep sufficient weight in nose cone and forward section of missile to help counterbalance the weight of the motor and fuel if you want good flight stability.

ELECTRICAL IGNITION

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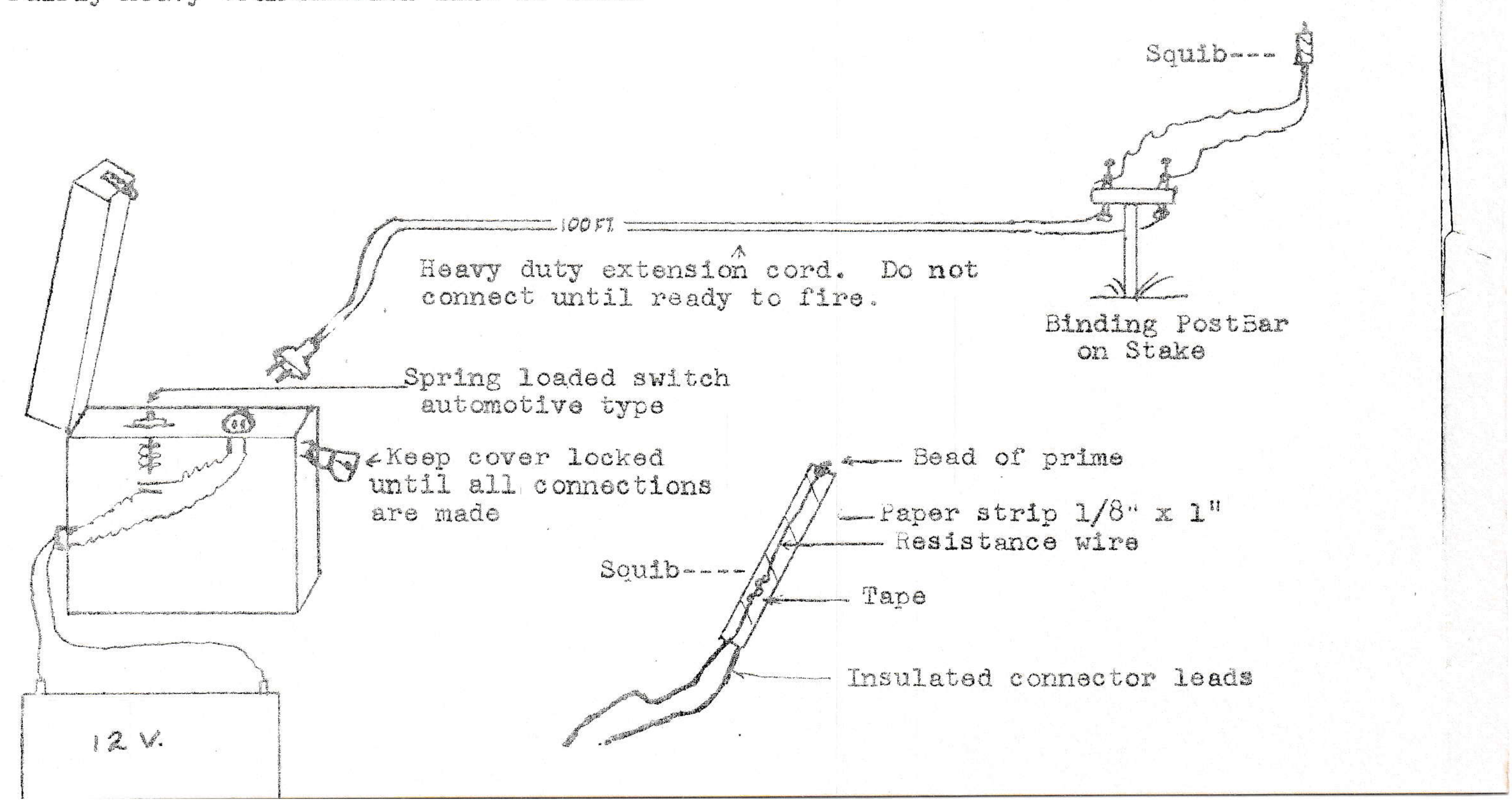
When it is desired to ignite the fuel charge of a rocket motor at an instant of time under precise control, it may be desirable to employ electrical means. Of the various devices which can be applied, the commercial electric squib is perhaps the most useful. Other methods including the so-called hot wire contact system, and the type of hot wire which is applied to a secondary fuse are apt to result in a variable time delay. Also, these methods usually require a rather high amperage electrical source. The commercial squib will operate on a very weak durrent and for this reason has been known to operate accidentally because of current induced in the wiring circuit from R.F. energy, static, lightening, etc. Electric squibs are not the same as electric blasting caps which are highly dangerous and useless for rocketry.

A form of electrical squib made according to the following instructions will operate the same as a commercial squib and will require a safely large amount of electrical energy, though considerably less than some, of the devices previously mentioned. Secure a length of fine iron or nichrome wire (about 28 ga.) very fine copper wire may be substituted if nichrome or iron wire is not available. A piece of the wire about 1½" long is connected by soldering to one end of each of a pair of 5 ft. long insulated copper wires (16 ga.). The short wire is then bent centrally to form a V shape and placed over a strip of cardboard with one leg of the V on each side of the strip. The entire assembly except for a small portion of the apex of the short wire is then wrapped with scotch tape. After this procedure, the exposed tip is to be coated with a thick paste made of prime mix such as was described under the title of "Priming" on another page. When the bead of prime mixture has been dried the squib is ready for use. The squib should be attached to a rocket jet aperture which has been primed and provided with a paper nose band as was described under "Nosing and Fusing".

The following procedure must always be used:

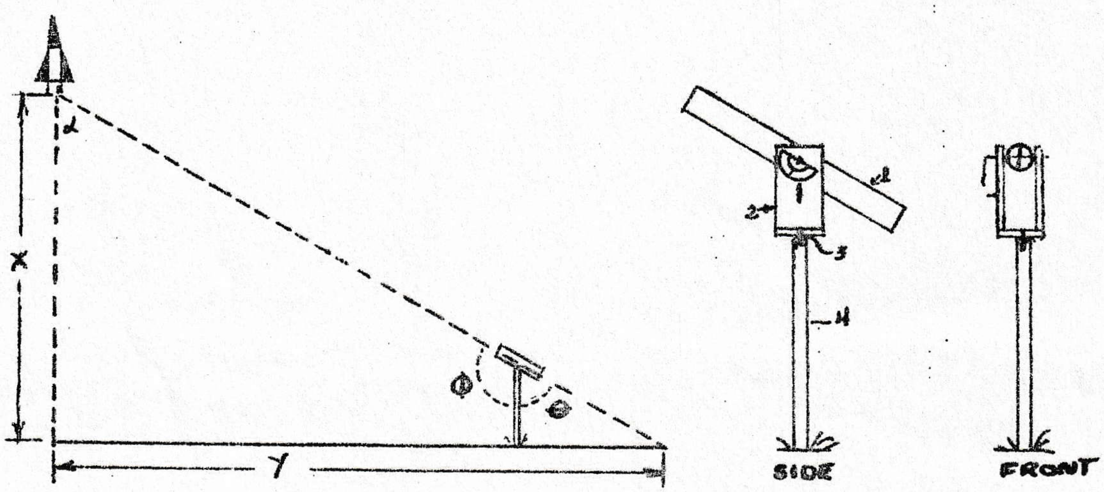
Do not attach the squib until the moment before the rocket is to be ignited. Do not connect the squib wires to the transmission line until you are certain that the transmission line is disconnected from the power source. Use a switch box having a cover which can be locked to prevent accidental connection or tampering.

A 6 or 12 volt auto battery will usually provide sufficient current if a fairly heavy transmission line is used.



To Determine the Altitude of a Rocket

Trigonometry can be usefully applied to find the altitude of an object such as a rocket when the object remains visible in its flight. The rocket is sighted with a theodolite or similar optical instrument at a known distance from a point directly under the rocket. When a measurement is made of the angle of incidence thereby established, the altitude may be directly computed. If a precision instrument is not at hand, it is possible to make close estimates of the required measurement with a device we will describe. An elongated hollow cylinder (1) such as a paper tube has stub shafts attached to its sides to permit vertical movement when mounted between the arms of a wood fork (2). The wood fork has a stub shaft (3) attached to its base to permit horizontal movement when the shaft is engaged inside the top end of a support pipe (4) which is firmly planted in the ground. The sighting tube may be equipped with cross wires and lenses to improve its performance. An inexpensive protractor is attached to the end of one of the tube shafts and aligned with the longitudinal axis of the tube.



$\frac{X}{Y} = \tan\theta$

$\theta + \alpha = 90°$

$\Phi + \alpha = 180°$

$\Phi - \theta = 90°$

$\Phi = 90° + \theta$

$\tan\Phi = -\cot\theta$

FORMULA: $X = -Y \operatorname{ctn}\Phi$

Y IS MEASURED

Φ IS MEASURED

CTN Θ FROM TABLE

EXAMPLE: $Y = 200$

$\Phi = 140°$

$X = 238$

Φ	-ctnΦ	Φ	-ctnΦ	Φ	-ctnΦ
100	0.176	132	0.900	154	2.05
105	0.268	134	0.966	156	2.25
110	0.364	136	1.04	158	2.48
115	0.466	138	1.11	160	2.75
120	0.577	140	1.19	162	3.08
122	0.625	142	1.28	164	3.49
124	0.675	144	1.38	166	4.01
126	0.727	146	1.48	168	4.70
128	0.781	148	1.60	170	5.67
130	0.839	150	1.73	175	7.11
		152	1.88		

Glossary of Rocketry Terms

Acceleration. The rate of increase of speed of a moving body. Rocket acceleration is usually measured in terms of gravities (g's), one g being an acceleration of 32 feet per second.

Airfoil. Any thin flat surface used for support or guidance of a rocket in flight.

Area Ratio. The ratio between the mouth area and the throat area of a rocket nozzle.[1]

Booster Rocket. An auxiliary rocket having a large thrust and short firing time, used during preliminary acceleration of a large rocket.

Braking parachute. A device used to lower a falling rocket nose-cone safely to earth.

Burning time. The time required for a rocket's fuel charge to become exhausted.

Burnout. The point at which a rocket's fuel charge becomes exhausted (the German Brenschluss is sometimes used).

Catapult. A mechanical device for imparting an added initial acceleration to a launching rocket.

Center of Gravity. The point at which all the mass of any flying body may be considered to be concentrated.

Chamber Pressure. The pressure generated in the combustion chamber during firing.

Chemical Fuel Motor. A true rocket motor, using propellants supplying their own oxygen (as opposed to airstream engines, which obtain their oxygen from the air).[1]

Chugging (Chuffing). Intermittant combustion due to incorrect mixture, low temperature or poor chamber design.

Combustion Chamber. The space in which the fuel charge is burned in a rocket motor or jet engine.

Delayer. A substance incorporated in the fuel charge of a dry-fuel rocket to decrease the rate of combustion.

Dipropellant. A combination of two substances used as a rocket fuel.[1]

Dynamometer. A device for indicating and recording the thrust of a rocket motor during a test (also called a reaction balance).

Earth's Gravity. An acceleration directed toward the center of the Earth of 32 feet per second.

Escape-gravity Acceleration. Acceleration required to overcome the acceleration of gravity.[2]

Escape Velocity. The velocity needed for an object to escape the gravitational attraction of an astronomical body. The escape velocity of the Earth is 7 miles per second.

Exhaust Velocity. The speed, relative to the rocket, at which the exhaust gases leave the nozzle of a rocket.

External (or ballistic) Efficiency. The ratio between the energy usefully employed in propulsion and the kinetic energy developed by the jet.[1] (See also thermal efficiency.)

Final Mass. The mass of a rocket at the end of powered flight.

Fin-stabilized Rocket. A rocket which does not rotate in flight, but is stabilized by means of fixed airfoils.

Free Flight. The portion of a rocket's flight which follows the combustion of the fuel or the turning off of the rocket motor.[1] (Free flight is not to be confused with free fall, which is the movement of a mass through space under the influence only of its own momentum and gravitational attraction.)

Free-flight Angle. The angle of a rocket with respect to the Earth at the beginning of free flight.

Free Rocket. A rocket which has no flight control devices other than fixed airfoils.

Fuel. The combustible component of a rocket propellant. However, this term is often used to denote the entire propellant.

g. Symbol for gravity, the unit of acceleration.

Hull. The outer casing of a large rocket.

Impulse. The total output of a rocket motor during a firing; equals average reaction multiplied by time.

Igniter. A device for igniting a rocket motor. A squib.

Initial Mass. The mass of a rocket at the beginning of flight.

Initial Velocity. The velocity of a rocket at the beginning of powered flight.[1]

Jet. The stream of gas ejected by a reaction motor.

Jet Propulsion (Rocket power). Propulsion as a result of ejecting a stream of rapidly moving gas or other substance through a nozzle.

Landing Gear. Equipment, ordinarily a parachute and release mechanism, used to bring a rocket gently to Earth after a flight.

~~Launcher. The device~~ from which a rocket is shot.

Launching Angle. The angle, measured from a horizontal plane, at which a rocket is inclined at launching.[1]

L/D Ratio The ratio of length to diameter of a rocket motor combustion chamber.

Liquid-fuel Rocket. A rocket burning liquid propellants.[1]

Loaded Weight. See initial mass.

Lox. Liquid oxygen.

Mass Ratio. The ratio between the total initial mass and the final mass of a rocket.

Match. Black powder fuse. Quick match

Motor. (Also jet motor, rocket motor, thrust motor, reaction motor) The device that provides thrust for a rocket.[1]

Multistage Rocket. A group of two or more rockets arranged so that as the motor of one burns out, that of the next fires automatically.

Nose Cone. The hollow section at the top of a rocket. Instruments and parachutes are carried in the nose-cone.

Nozzle. The orifice through which the jet is ejected from a rocket motor.

Oxidizer. The oxidizing component of a rocket propellant. Ordinarily contains oxygen available for combustion.

Parachute release. A device used to eject a landing parachute from a rocket.

Payload. The useful load carried by the rocket, in addition to its necessary structural weight and fuel.[1]

Pounds of Thrust. A measure of the power developed by a rocket motor.

Powered Flight. The portion of a rocket's flight during which the rocket motor is in operation.[1]

Propellant. The chemicals used in a rocket motor to produce the driving jet.

~~Proving Stand. See test stand.~~

Pyrotechnic Fuel. A Solid Propellant, which supplies its own Oxidizer as part of the mixture.

Reaction. The recoil or "kick" produced by the jet of a rocket motor.

Reaction Motor. The general term for all types of motors and engines that operate on the basis of expanding and escaping gases.

Rocket. A projectile powered by a reaction motor which does not require air in its operation.

Rocketry. The field of study of rockets, including theory, development, research and experimentation.

Shot. A rocket flight.

Single-Stage Rocket. A rocket in which all the motors operate at once.

Solid-fuel Rocket. A rocket propelled by a solid pyrotechnic propellant a dry-fuel rocket.[1]

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Solid Propellant. Solid Rocket Fuel.

Sounding Rocket. A research rocket carrying instruments to investigate the upper atmosphere.[1]

Squib An ignitor, consisting of an electrical bridge with a coating of a pyrotechnic composition.

Step-rocket. See multi-stage rocket.

Static Testing. The testing of an aircraft or rocket engine in a special cell or stand that is instrumented to record aspects of operating efficiency.[2]

Telemetering. A method of varying radio waves to record pressures, torque, lead, temperatures and velocity of an object moving on the ground or in the air. Also can be used to transmit physiological reactions, such as brain waves and pulse rates of mammals in flight.

Test Stand. A structure which holds a rocket or jet engine for static testing.

Thermal Efficiency. The ratio of the kinetic energy developed by the rocket jet to the thermal energy content of the fuel.

Third Law of Motion. Sir Issac Newton's statement of the principle upon which the reaction motor works: "To every action there is always an equal and contrary reaction; the mutual actions of any two bodies are always equal and oppositely directed."[1]

Throat. The narrowest part of a rocket nozzle.[1]

Thrust. The push produced by a rocket motor.[1]

Tracker. A mechanism for observing or controlling a flying rocket from the ground, or the man operating such a device.[1]

Trajectory. The curve which a rocket describes in moving through the atmosphere.

Warhead. See nose-cone.

X-hour. (Zero-hour). The time at which a rocket is launched.

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