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AIR-3

ACE INFORMATION REPORT

1 MOTOR INSTALLATION

2 CLUSTERING

3 STAGING

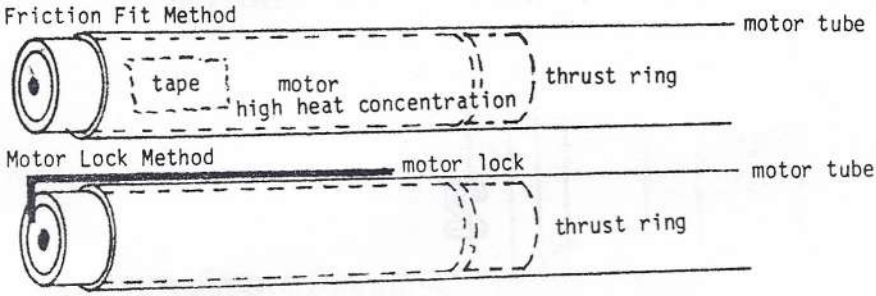
By Jerry Irvine and Korey Kline

ACE INFORMATION REPORT 1

MOTOR INSTALLATION

Until recently there were essentially two types of motor mounting methods; friction fit and motor lock. The friction fit system uses a motor tube with a thrust ring glued inside so the motor rests against it with 1/4" to 1/2" extended from the motor tube. The motor is held in place by wrapping tape around the motor until it fits snugly into the motor mount tube to prevent ejection of the motor case at deployment. The other system consists of a similar motor tube and thrust ring with an added motor lock which restrains the rearward motion of the motor at ejection. The engine "hook" or "clip" hooks over the rear end of the motor case.

FIGURE 1 - Customary motor installation methods



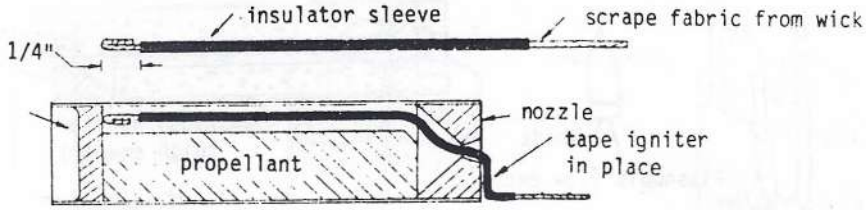
The primary disadvantages to the friction fit system are the problems associated with tape on the motor case (in the middle) and the need for a standard length motor with a given motor mount. Having tape on the motor can result in melting of the adhesives and bonding of the motor case inside the motor mount! Also it is quite common for a friction fitted motor to eject due to improper installation.

This may or may not result in recovery system deployment failure. The limitation to standard size motors is not usually a problem with the .69" diameter. However, the larger .94" and 1.125" diameter motors do not come in standard lengths. This can be a problem if you intend to use a long motor in a mount intended for short ones. A motor hanging out of the back of the rocket will work in some cases, but will reduce the margin of stability. One may compensate by adding weight to the nose of the vehicle or by designing a motor mount which accepts any length motor.

The primary disadvantage to the motor lock system is the inability to use longer motors. In all other respects it is superior.

In order to have maximum versatility of motor selection, a method was developed by Enerjet to permit any length motor to be used. The vehicle is constructed using NO THRUST RINGS! This permits any length motor to be used. The motor is prevented from sliding up the rocket during thrust by a ring of masking tape applied to the nozzle end. Either 1/2" or 3/4" masking tape is neatly and evenly wrapped around the nozzle end of the motor to the diameter of the motor tube outside diameter. The motor is secured in place by a layer of tape over the thrust ring/motor tube joint. This method permits any length motor to be used, can permit shorter motor mount tubes in many cases, and is easy and reliable.

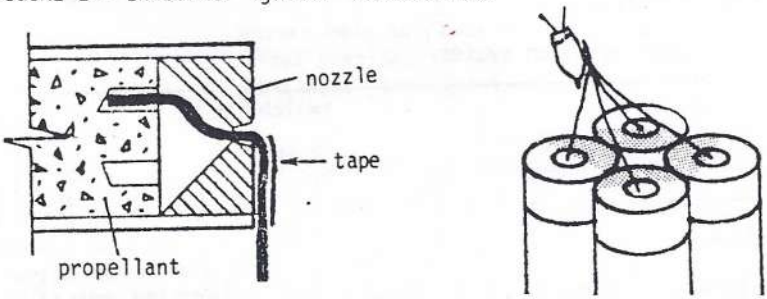
FIGURE 1 - Coreburner igniter assembly and installation



Endburning composites do not require a sheath. These are the most reliable to ignite and provide the most stimulating flights. The end of the Thermalite need not be folded. Each igniter should be inserted into the slot in the grain and taped in place with TWO layers of tape without covering the nozzle opening.

The use of two layers of tape prevents the Thermalite wick from seperating from the motor before ignition when the wick burns the tape itself.

FIGURE 2 - Endburner igniter installation



Most Thermalite "fast" burns at 2.5 inches per second. Check your batch prior to use. Delayed ignition of some motors can be achieved with extra Thermalite. Be sure to take into account the ignition time of the motor type, length of fuses on other motors, and desired delay. Thermalite burns almost instantly in a confined space.

ELECTRICAL CLUSTERING

Electrical clustering is the easiest on motors which can be started by an electrical igniter. Estes Solar igniters have only an 85% reliability rate thus should be used only to ignite wick clusters, not individual motors in a cluster. They can be ignited with 6 volt systems. FSI electric matches and flashbulbs are the superior electrical igniters where igniter size is not a factor. These can be ignited by very low voltage or large numbers of them can be ignited by a common launch system.

Electric matches do not fit in most motors. They are good for F100 (E48) and E60 (E26) primarilly. Electric matches can cause detonation of most composite motors due to nozzle clog.

Flashbulbs are also low energy igniters. The large size compared with all rocket motor nozzles do not permit direct ignition. Flashbulbs must be used to start pyrotechnic igniters on each cluster or motor. Electric matches and flashbulbs are not continuity safe on most systems.

The use of an AeroTech type electrical igniter requires the use of a more powerful 12 volt system, but provides a high degree of reliability for clusters of seven or less. Used in conjunction with a relay system, they can't be beat.

FIGURE 3 - Igniter Types

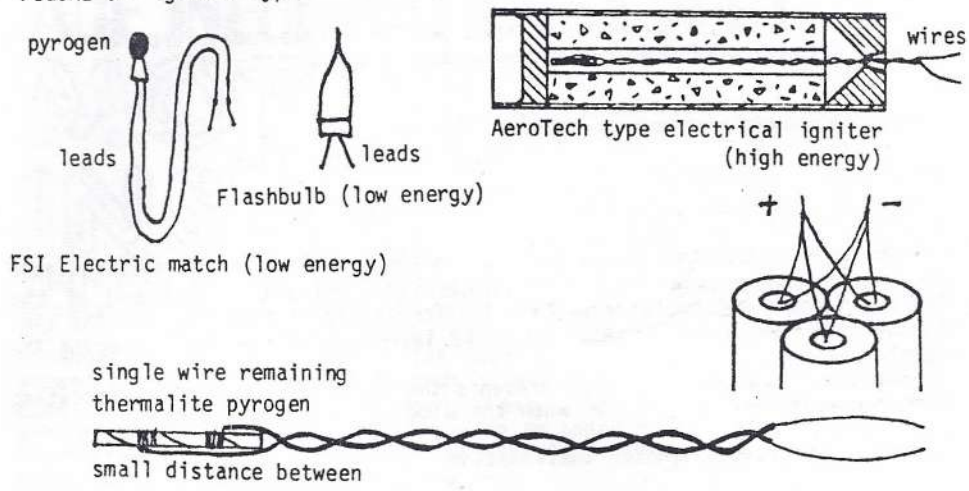
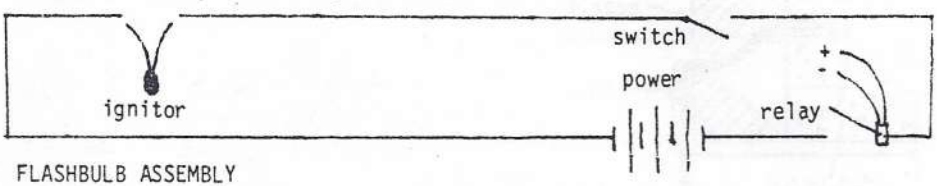


FIGURE 4 - Relay cluster ignition system



FLASHBULB ASSEMBLY

Purchase AG-1b type flashbulbs, flashcubes or equivelent and remove the flashbulbs from the enclosure. Use care not to break the wire leads. Purchase a wire wrap tool from Radio Shack along with 22 gague wire. Strip the wires on both ends. One end wraps on the flashbulb wire lead and the other end is where you attach the clips. It is not necessary to attach any wires if only one flashbulb or seperate clips will be used. It is best to stock up on flashbulbs because you will get hooked and start using them for everything! For most applications requiring leads, 6-12" is fine. A typical application is running a flashbulb to each of two stages or seperately ignited clusters.

FIGURE 5 - Flashbulb preparation

NOTE: FLASHBULBS WILL IGNITE WITH THE CURRENT OF A CONTINUITY CHECK ON MOST SYSTEMS. DO NOT INSERT SAFETY KEY UNTIL TIME OF DESIRED LAUNCH.

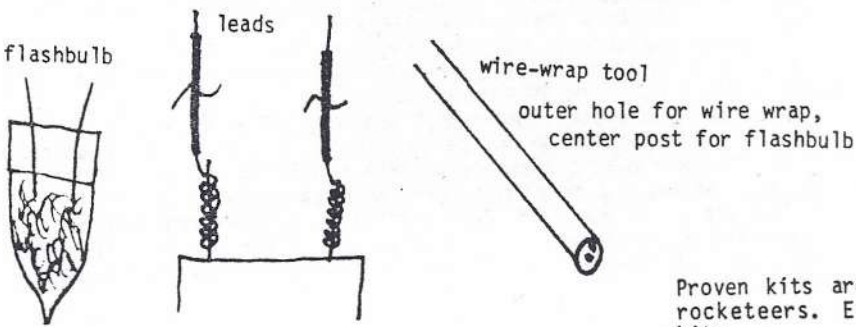


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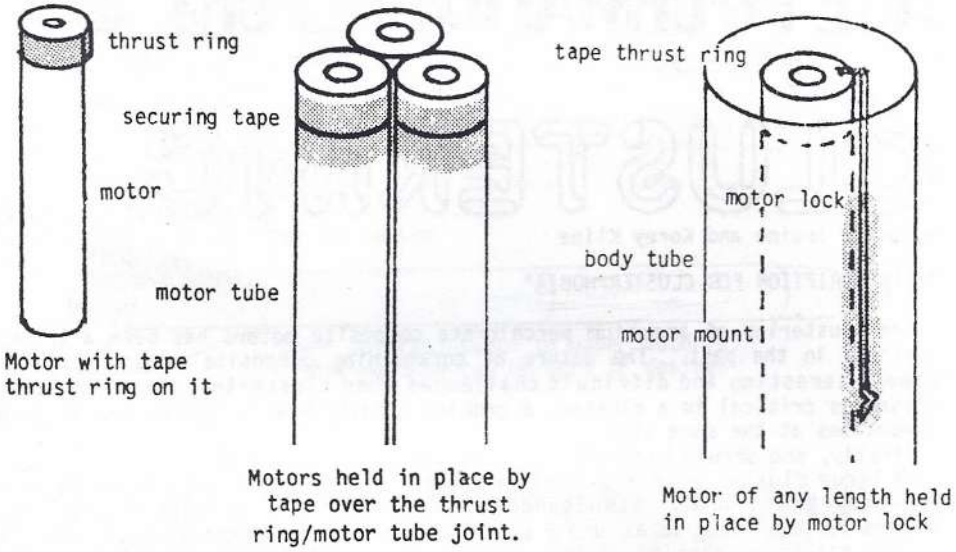
FIGURE 2 - Recommended motor installation technique



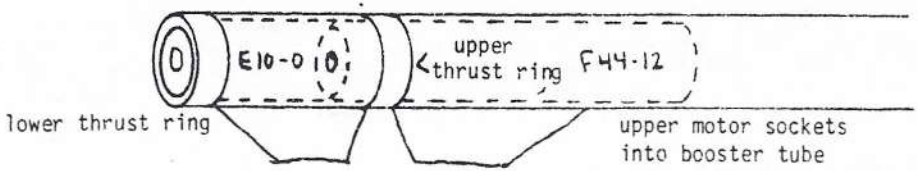
A variation of this system developed by myself utilizes this no thrust ring method and adds the time saving feature of a motor lock. Common motor locks have a bend at both ends to act as a thrust block and ejection preventor. With a masking tape thrust ring, a forward clip is no longer needed and any length motor may be used. Simply bend the back end up or cut it off and EPOXY the motor lock to the side of the motor mount. The lock must be extended out the back (nozzle end) the correct amount to accept the width of tape thrust ring you are using; usually 1/2". Motors over 160 newton-seconds require 3/4" tape thrust rings. A stock Estes engine hook is sufficient for any power motor.

MULTISTAGE MOTOR INSTALLATION

Of course if your two stage rocket has standard motor mounts simply repeat this process on all stages and motors. In the case of minimum diameter rockets a special procedure is required to both hold the motor in and socket the stages together.

The lower motor is prepared in the normal fashion. The upper motor simply has the thrust ring applied 1/2-1" from the end. This allows the rear of the motor to act as the stage coupler. Direct staging typically can occur up to 12" between motors.

FIGURE 3 - Multistage motor installation



CLUSTER MOTOR INSTALLATION

In the case of large numbers of clustered motors, install the central motors first and the outer ones last.

ACE INFORMATION REPORT 2

CLUSTERING

By Jerry Irvine and Korey Kline

"A PRESCRIPTION FOR CLUSTERPHOBIA"

The clustering of ammonium perchlorate composite motors has been a tricky business in the past. The nature of coreburning composite motors provides some interesting and difficult challenges when clustering. Since ignition timing is critical in a cluster, a problem arises; how to ignite two or more composites at the same time.

Firstly, one should use motors of the same type in a cluster or in the case of a large cluster with dis-similar motors, sequence the motors to go at a pre-programmed time. Simultaneous and symmetrical ignition of clustered motors is important to assure a straight flight. Clusters of four or more motors can be co-mingled as long as they are balanced (symmetrical). Mixing of motors can provide a more useful or fun aggregate time-thrust curve.

The motors recently released by AeroTech are much easier to ignite and use than say Composite Dynamics motors were. CD motors had a long start-up time from ignition. This complicated clustering. These motors can be used in conjunction with other motors if a one to two second delay to primary motor ignition is used.

Black powder motors ignite immediately. AeroTech motors ignite instantly. Crown motors ignite instantly. Be careful that if Thermalite wick is used all leads are the same length. This will assure ignition at the proper time. The igniter is the determining factor in ignition timing. If an electrical igniter is used, ignition will be nearly instant. If a wick type igniter is used, it will take one to two seconds for the motor to ignite.

PYROTECHNIC CLUSTER IGNITION

Generally this is the easiest and most popular type of clustering due to the ease of operation. Thermalite type igniters are inserted in each motor, bundled at the center of the cluster, and ignited by a common flashbulb or Solar igniter.

For black powder motors, a 1/4" fold should be made at the head end of the wick (Thermalite) up inside the motor to assure ignition. Each igniter should be inserted all the way in the motor and taped into place.

Coreburning composite motors should have a sheath wrapped around the wick to prevent premature ignition at the rear of the grain. The sheath can be a piece of shrink wrap tubing or a single layer of masking tape. 1/4" of the end of the igniter wick should be folded over as a pyrogen. High thrust coreburners should have the wires removed from the Thermalite to prevent motor detonation caused by material bunching up at the nozzle throat at ignition. Each igniter should be inserted to the head end of the motor and taped in place with TWO layers of tape without covering the nozzle opening.

COREBURNER PYROTECHNIC IGNITION

1. Remove fabric coating from wick
2. Remove wires from wick
3. Apply single layer tape sheath
4. Bend 1/2" exposed wick in half to form 1/4" pyrogen
5. Insert igniter all the way into motor and tape in place
6. Attach flashbulb or other igniter to wick

FIGURE 1 - Direct staging process

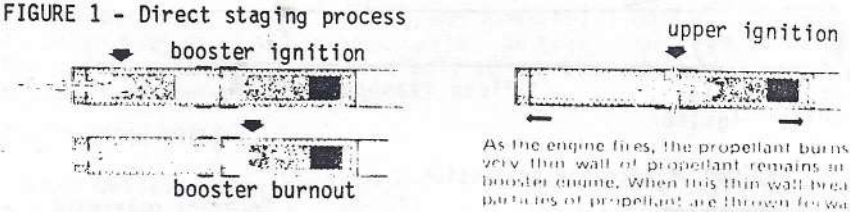
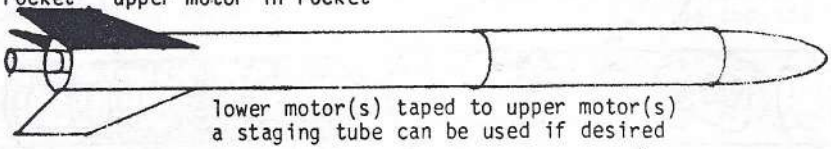


FIGURE 2 - Drop-staging



DELAY DIRECT STAGING

Delay direct staging is essentially the same as direct staging except a motor with a delay is used in the booster. This permits a period of coast between stages. The booster ejection charge ignites the upper motor.

An alternative method is to use a booster motor to ignite a fuse to the upper motor to provide staging delay. This method usually requires the use of "green fuse" (30 seconds per foot) as it is much slower than Thermalite wick (FSI igniters).

Due to the tendency for these type of rockets to head into the wind, it is best to fly only on a calm day. Delay direct staging is primarilly limited to very light high performance rockets.

DISCONTINUOUS STAGING

This involves the ignition of both stage igniters on the ground. An instant igniter is used on the booster motor and a delay igniter is used on the upper stage. The result is a pre-programmed delay between staging. Be sure to take into account the ignition time of each motor, desired staging delay and differing fuse burn rates.

(fuse burn time) = booster burn time + booster ignition time + desired delay - upper ignition time. All figures are in seconds and tenths.

Thermalite typically burns 2.5 inches per second exposed and nearly instantly when confined. Green fuse burns 30 seconds per foot under virtually any conditions.

This system also allows the ejection of the booster prior to upper stage ignition if desired. Now it is possible to put a camera in the booster and recover it by parachute.

The primary application for discontinuous staging is to allow staging on long or blocked boosters. There is no need to have a channel for the booster motor to meet the upper motor. A bonus of this system is that a delay motor can be used in the booster to actuate a recovery system! One application is scale models with a nose cone on the booster

CONSTRUCTION TECHNIQUES

A coupler with a block on the bottom end is used between the stages. It acts as a coupler for the upper stage and a nose section for the lower stage.

One other design concept developed by Jerry Irvine uses no block and the lower parachute is protected from the exhaust by a layer of wadding. The parachute simply ejects out the top of the rocket through the coupler.

FIGURE 3 - Igniter placement for discontinuous staging

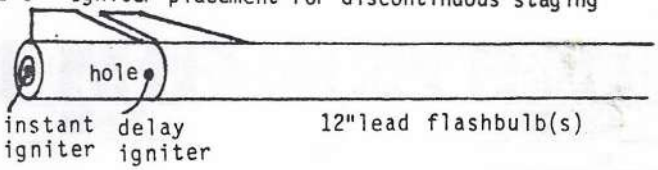


FIGURE 4 - Payload or recovery protection mode

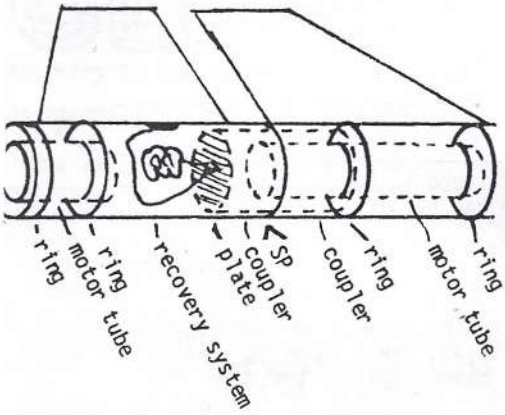
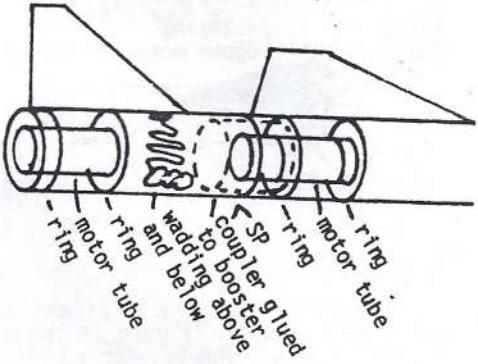


FIGURE 5 - Recovery only mode



ELECTRONIC AND MECHANICAL ACTUATORS AND TIMERS

Electronic staging is much talked about but rarely tried. This is because the system requires some basic knowledge of electronics, and most people are simply too lazy to bother with it. The clear advantage to electronic timing/staging systems is reliability and accuracy.

In fact, an electronic staging system might be used to activate several functions during flight. Applications include camera actuation, delay/ejection systems and staging time actuator.

Actuators can be as simple as a clothes pin with metal contacts on it. With this system, an insulative spacer is pulled from the clip (clothes pin) and actuates or arms the function by allowing two contacts to touch. This would typically be used to ignite the upper stage of a two stage rocket and to assure the upper motor does not go if the rocket does not. An actuator could also be used to fire a camera at staging or as a safety arm switch for an in-flight system.

Some of the most important things to remember when using electronic systems is to have redundant safety systems so the rocket cannot go off if dropped. Also lots of on ground testing to make sure it works first time every time. A fresh battery should be used on a flight test.

Passive actuators simply act as a safety key. Active systems are hooked up to the electronics or the in-flight launch system. Any active system requires a redundant safety function, typically by twisting two wires together. The key that is pulled out should be tied or bonded to the "yanking" item. This is usually the launcher, booster stage or payload tube.

Post ejection recovery systems can be actuated by nose blow. One application would be to allow a very high altitude rocket to tumble to a visible altitude before actuating the recovery/ tracking system.

FIGURE 7 - Actuator circuit

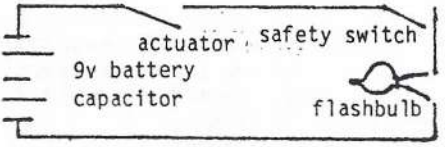
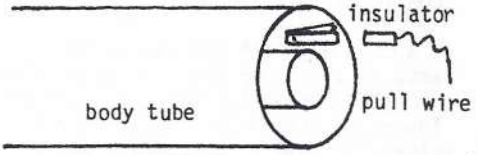


FIGURE 6 - Actuator assembly



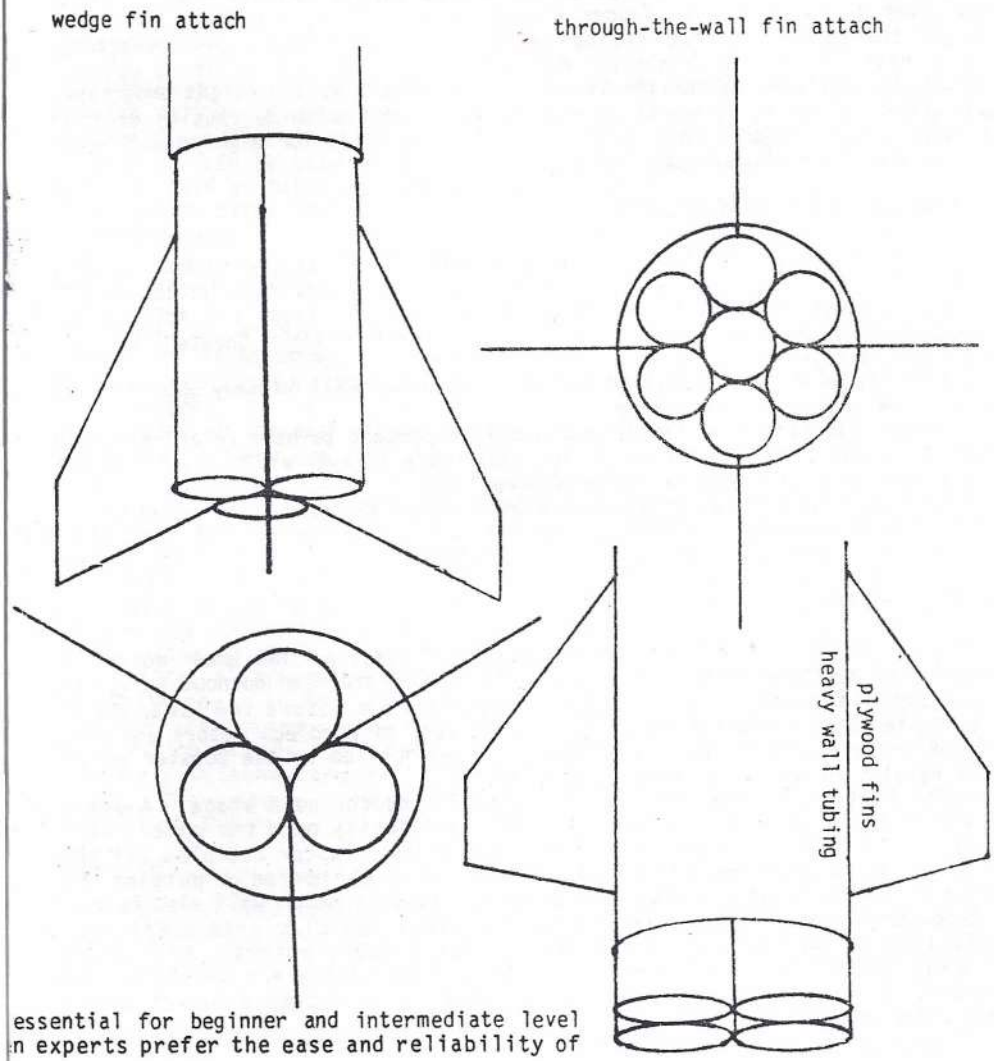
Remember that flashbulbs ARE NOT CONTINUITY SAFE!! Use only a safe launcher such as an A&A or home built. An Estes type system can be used if the safety system is activated only at the time of launch. Always test a flashbulb on your system for safety.

CONSTRUCTION NOTES

When building clustered models it is best to use heavy duty tubes and plywood fins. This also reduces landing damage potential. Extra large fins should be used as well as elastic shock cords. It is also essential to use sufficient guidance for launch. 1/2" x 8' rods for over one pound rockets and F clusters is recommended. A 1/4" x 5' rod should be considered a minimum.

The use of stronger parts overall is recommended. ACE Rocket Manufacturing can satisfy all of your parts needs in this area. U.S. Rockets and ACE Rockets carry a full line of high power capable model and experimental rockets for a variety of applications.

FIGURE 6 - Clustering configurations



essential for beginner and intermediate level
n experts prefer the ease and reliability of

ACE INFORMATION REPORT 3

STAGING

Please review AIR-2 before beginning.

A composite propellant is one which consists of two or more ingredients. Our vernacular of "composite" usually refers to an ammonium perchlorate/PBD composite fuel and "black powder" refers to a potassium nitrate/coal/sulfur composite. I sometimes refer to them as composite A and B. Common vernacular is composite or black powder. Model and experimental motors can also be made of Potassium Perchlorate in some cases.

I have no intention of listing every combination of motors for staging, but rather the methods used for staging and design concepts for two stage rockets.

Generally speaking it is best to use a high thrust booster (lower stage) and lower thrust sustainer (upper stage) motors. This is primarilly needed to get the rocket to stabilizing velocity. For performance considerations, try to have the vehicle weight for each incremental stage as close to optimum weight as possible. Since the rocket looses weight as the flight progresses and stages fall off, it would be wise to use motors with decreasing optimum weights in the upper stages. This specifically calls for high thrust lower motors and lower thrust upper motors.

GENERAL CONSTRUCTION TECHNIQUES

Generally use larger fins on the lower stages unless the rocket is very stable already. Stability can also be improved with extra nose weight of 20% or so. Highest performance on many two stage combinations can actually be improved with added weight in many cases. Consult "Flight Sheets" (tm) for exact answers.

A 1/4" diameter hole should be cut in the booster wall in many applicationa to provide access or gas escape.

In order for stages to tumble down it is important to have relatively high aspect ratio fins. Fins which are not very swept will also prevent stabilization of the booster after seperation.

When a vehicle will be drop-staged very large and preferably swept back fins should be used. For safety considerations; to prevent "18 seconds of terror", the vehicle should be very, very stable.

DIRECT STAGING

This is the easiest and most common method of staging. The lower motor has no delay or ejection charge and shoots a flame forward near burnout to ignite the upper stage motor. In the case of black powder motors the lower motor can ignite the upper motor directly. In the case of AeroTech motors and most composites a standard igniter is installed and ignited by the booster motor. This results in a nearly instant ignition.

Multi-stage vehicles consist of a set of fins for each stage. A motor mount is designed to direct the lower flame directly onto the upper motor nozzle. In some cases the pressure from the lower motor can blow off the stage prior to upper motor ignition. This can be minimized by putting the stage on tight. A hole in the tube above the booster motor will also help.

Drop-staged vehicles are normally single stage vehicles with sufficient stability to tape motors on the rear of the primary motors. With drop-staging the inert motors used for boosters fall freely and safely to the ground. This is an easy and fun way to make any very stable rocket into a two stage vehicle.

FIGURE 8 - Secondary recovery system

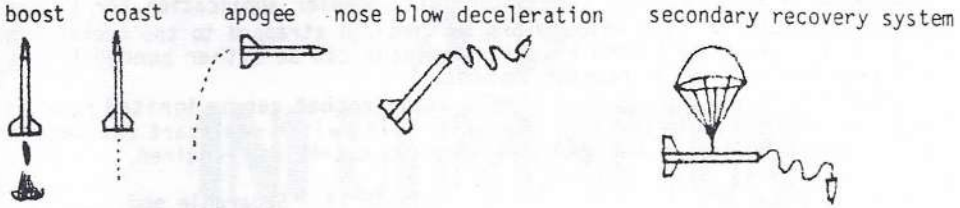
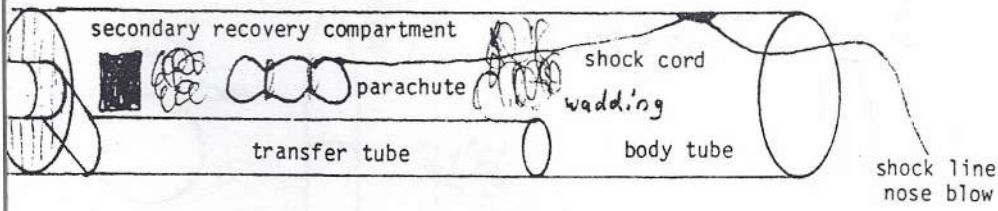


FIGURE 9 - Secondary recovery construction ideas



CONSTRUCTION TECHNIQUES

An actuator system should be designed and installed with low weight and drag as primary considerations. The best actuator/ safety systems are two pieces of spring steel about 1/4" x 3" x 1/64". A piece of cardboard or fiberglass can be used as the "safety key". When possible the actuator system should be fully enclosed inside the rocket for low drag.

The electronics package should be wrapped in foam or tissue paper to prevent damage.

MERCURY SWITCH STAGING

This is one of the oldest and least safe and reliable electronic systems. Some of the disadvantages include occasional insufficient deceleration to activate the system. If it doesn't go when desired, it will go at turnover after apogee!

It is one of the easiest systems to make, requiring no previous electrical experience. Always use a safety system with mercury switch ignition!!

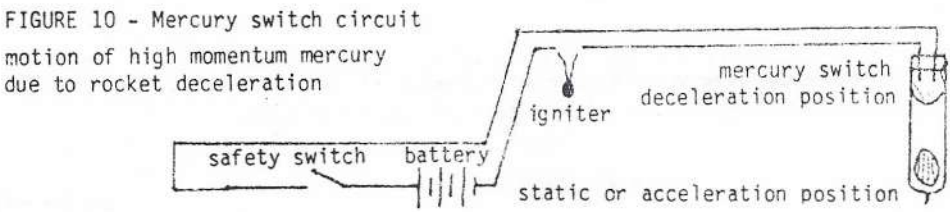
The theory of the system is that upon deceleration of the rocket at booster motor burnout the high density mercury metal will be thrown forward over electrical contacts. This completes a circuit and actuates the device, usually an upper stage.

In practice, however, some motors have two thrust spikes and others allow the rocket to decelerate sufficiently to prevent the mercury from traveling all the way (1") to the contacts. Once the mercury touches the contacts then it may not stay there long enough to fire a high energy igniter.

Therefore, always use an electric match or flashbulb as the igniter and use excessive power to fire it. This will help the most. Then use very high final thrust motors. Not regressive trace or low energy endburners. The deceleration rate is a big factor in reliable operation.

Mercury switches are available from Radio Shack or electronics supply stores. The battery is typically 6 volts. The new Poloroid battery is good if you have the room. If not, go for as much power as you can fit.

FIGURE 10 - Mercury switch circuit



CONCEPTS

Activated parallel staging is a potentially popular application for timers or simple actuators. Pods with motors in them and strapped to the rocket can be ignited at anytime in the flight. The pods can be either bonded to the vehicle or fall off after booster burnout.

Clusters of seven motors in a single stage rocket can be ignited four on the ground and three in the air. A simple pull switch can start the second "stage" motor igniters. A timer could be used but is not required.

FIGURE 11 - Fixed pod ejection is ducted into main tube

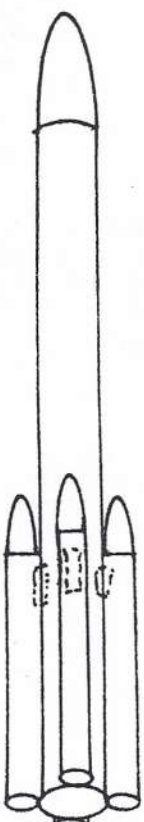
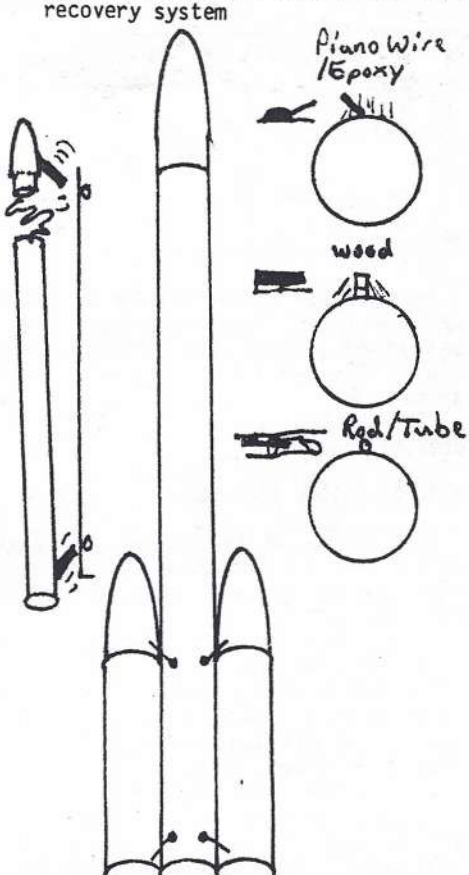


FIGURE 12 - Seperable pod nose blow releases pods and deploys recovery system



SUMMARY

Given that the basic clustering and staging alternatives are "electrical" and "pyrotechnic", pyrotechnic (use of fuse) is within the capability of most people.

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