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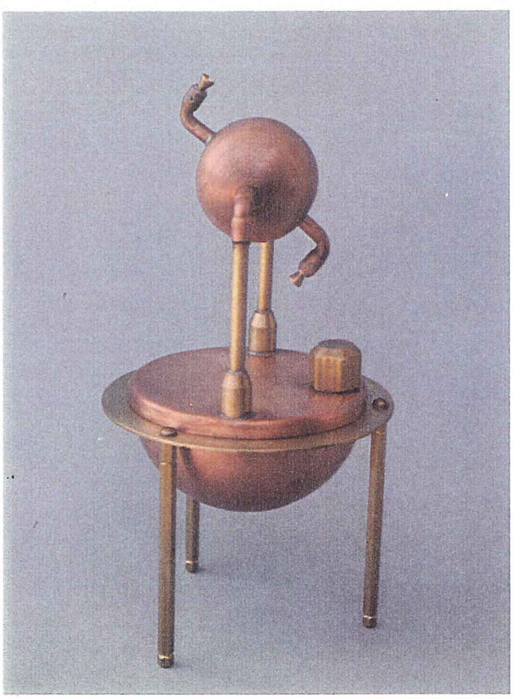
June, 1997

For the advancement
of rocketry and
astronautics

FROM SCIENCE PROJECTS TO ROCKET LAUNCHES TO HOME MADE REGULATORS



A BUSY 1997 SECOND QUARTER FOR THE RRS

RRS News

VOLUME 54, NUMBER 2, June 1997

The Reaction Research Society is the oldest continously operating amateur rocket group in the nation. Founded in 1943 as a nonprofit civilian organization, its purpose has been to aid in the development of reaction propulsion and to promote interest and education in this science as well as its applications. The Society owns and operates the Mojave Test Area, a 40 acre site located two and a half hours north of Los Angeles. Over the years, thousands of solid, hybrid, and recently, liquid propellant rockets have been static and flight tested. Currently, there are over 250 active RRS members throughout the United States and in several foreign countries.

This newsletter is a, more-or-less, quarterly publication issued by the Society as a technical journal and is intended to be educational and to provide communication between members and other societies. It is also the historical documentation of the activities conducted by the Society, as a whole, and by its individual members. Information regarding the RRS can be obtained by writing to:

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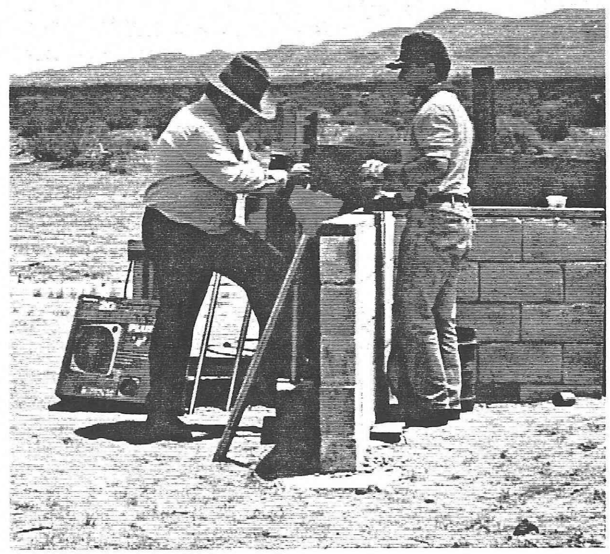

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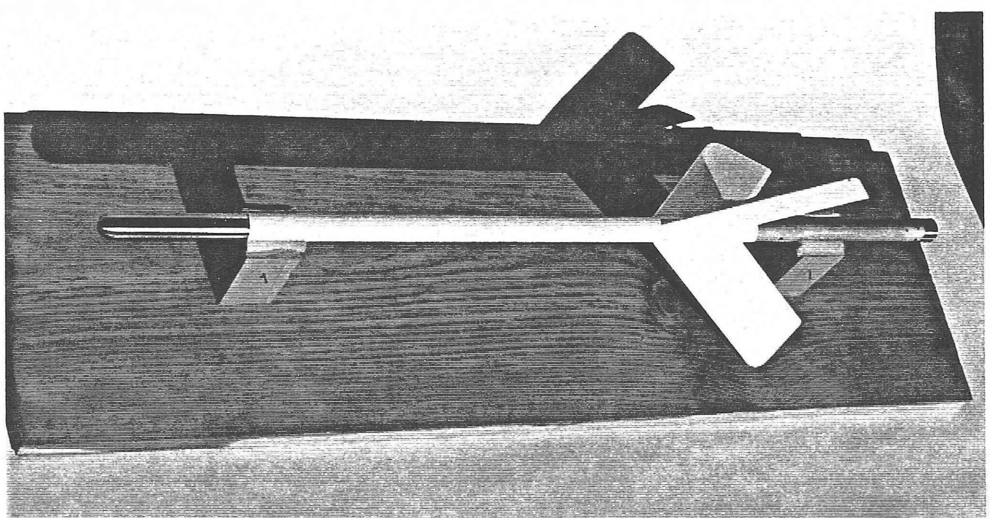

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The Wisp Test and Micrograin Evaluation

Measuring Specific Impulse with Kinematics

by Anthony Colette

Wisp Program Approach

If a stream-line rocket of known mass is launched at a 45 degree angle and travels from point A to point B the force required to travel this distance can be calculated. Dividing this force by the mass of propellant used, the propellant specific impulse can be calculated.

Description of Wisp Program

The Wisp program is a propellant testing method designed to measure the dynamic performance of a rocket propellant called micrograin. The performance of micrograin is expressed by its specific impulse (ISP). Like all other rocket propellants, the specific impulse of micrograin is related to the energy content of its combustion gases. Micrograin is made with a mixture of powdered zinc and sulfur usually in 80/20 (w/w) proportions. It is a popular propellant among amateur rocketeers due to its low cost and high impulse density. However, for all its popularity, it is still somewhat of a mystery propellant. For many years it has been suggested that the performance of micrograin is adversely affected by high acceleration rates. It has also been said that the high acceleration rates causes the powdered micrograin to fall too rapidly into the combustion chamber and thus be expelled with the exhaust gasses out of the nozzle before having a chance to react. If this is the case, static tests of micrograin will not give an accurate representation of micrograin's true performance. This is because static tests do not involve acceleration. Micrograin is also known to be sensitive to many other variables such as temperature, humidity, consistency, density, purity, and particle size. Any of these can have a significant effect on the performance of micrograin.

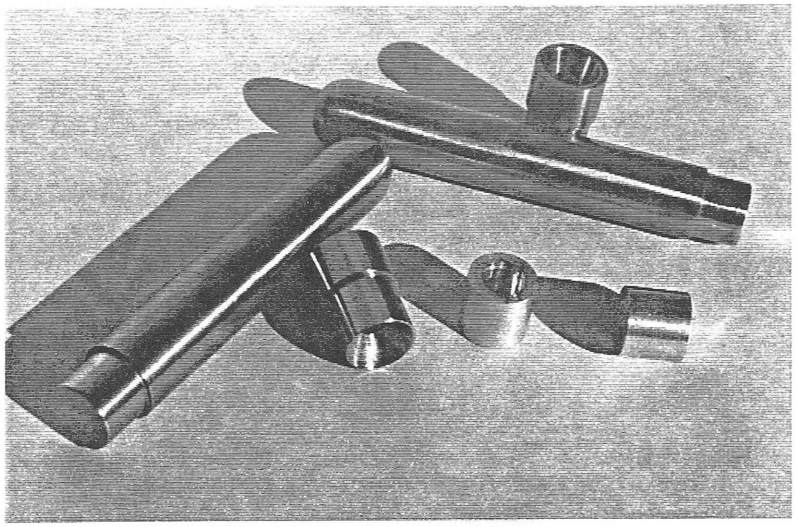
There have been many one time subjective micrograin tests concluded with "It looked like it worked well" and even some scientific static tests. But the Wisp test is different. It is designed to provide a statistical analysis of micrograin under the dynamic conditions of flight. For example, rather than putting a rocket motor on a test stand and static firing it to measure the results, the Wisp test measures the performance of micrograin by measuring the performance of a rocket in flight.

This particular method of testing was developed in 1984 by RRS member Bob Lesser. It is analogous to the ballistic pendulum test, where a mass is propelled to a velocity which is indirectly measured and recorded. Wisp is also quite similar to the specific impulse measurement method described in George Dosa's article "Thrust and Drag."

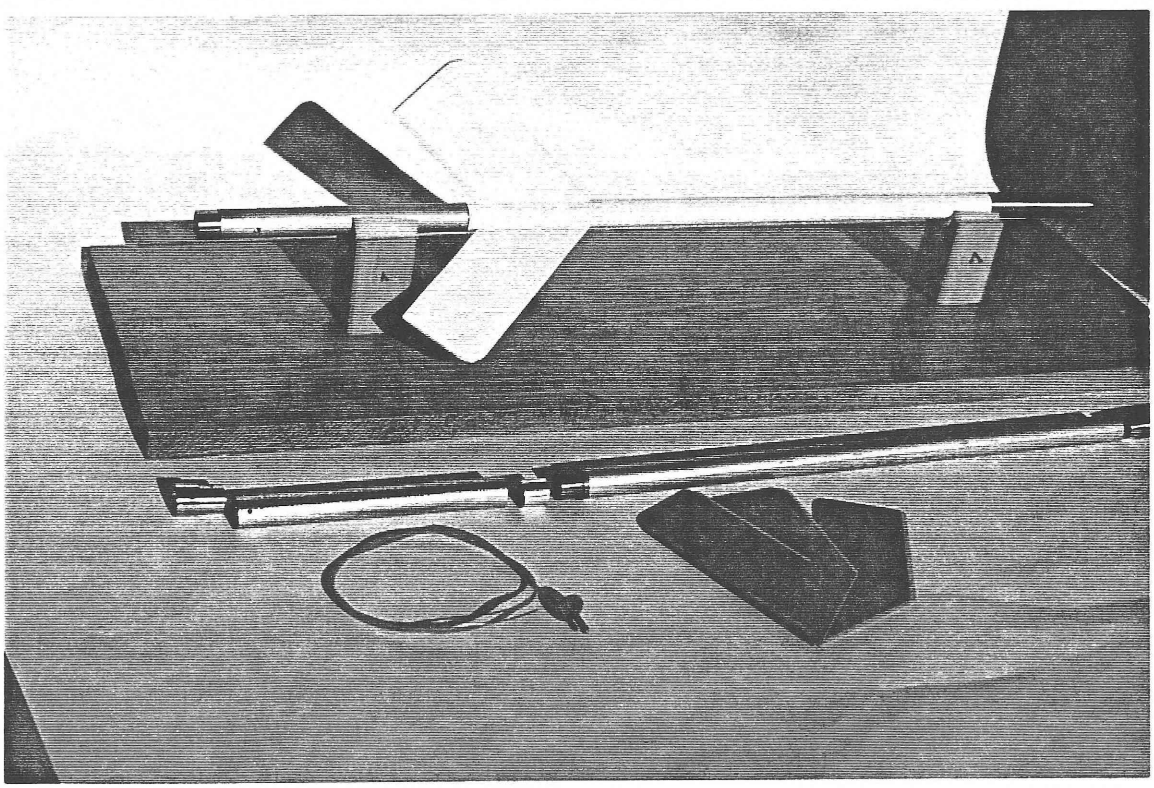
The Wisp is a simple rocket to build. It can be built in any high school metal shop with materials available at your local hardware store. The body is made of 5/8 inch steel electrical conduit. The detachable motor section is also made of the same conduit.

A solid piece of steel bar keeps the center of gravity as far forward as possible. It also keeps the rockets velocity low thereby lowering air resistance. The steel bar also serves as a very rugged nose cone.

The 3 fins are made of 1/8 inch plywood and glued to the steel tube with "Liquid Nails" adhesive. The leading and



The nose cones, nozzles and couplers were machined from bar stock



The individual Wisp components are shown below a completed vehicle

trailing edges are sharply tapered. The nozzle is machined from the same bar stock used for the nose cone. A graphite throat is optional. The burst disc, which is used to increase burn rate and chamber pressure, is made of standard gauge Formica. Finally a slip-fit coupler, also machined from bar stock, is made to provide a tight friction fit between the motor and main body.

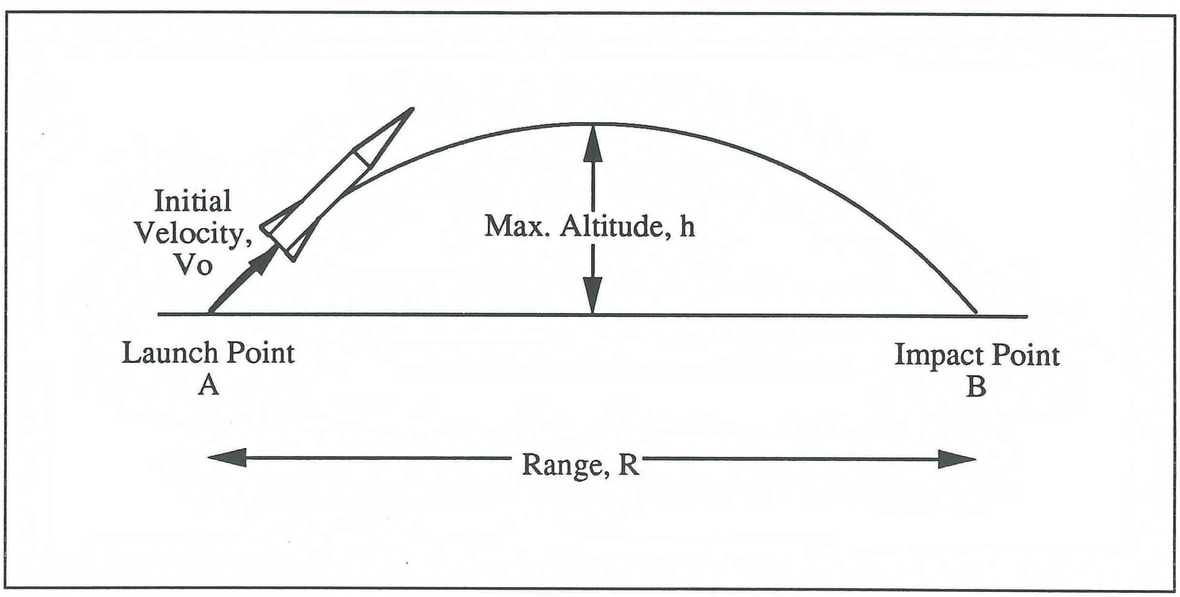
(For more details on the Wisp and how to build it, please refer to Bob Lessers Wisp article available in the RRS archives.)

The first idea was to fire the small rocket straight up and then calculate the specific impulse by measuring the time it took for the rocket to fly back down to the ground. Accurately measuring the rocket's flight time proved to be a little difficult. So firing it at a 45 degree angle evolved. The Wisp can be thought of as a lawn dart with high mass and low aerodynamic drag. When this lawn dart rocket is loaded with an exact amount of propellant and fired at a 45 degree angle it will travel some distance and then land, sticking itself nose first into the ground. By knowing the weight of the propellant, the weight of the rocket and the distance it traveled, specific impulse can be calculated.

Anyone who has observed a baseball in motion (or, for that matter, any object thrown into the air) has observed projectile motion. For any arbitrary direction of the initial velocity, the projectile moves in a curved or parabolic path. This type of parabolic motion is common to all projectiles. Assuming air resistance is negligible and the gravitational force remains constant over the range of motion, the trajectory of the projectile is very simple to analyze.

Note that the overall velocity vector, V, changes but the x component of the velocity vector, Vxo, remains constant during the entire flight. In other words, the "vertical" speed of the projectile is constantly changing, but the "horizontal" speed is constant until it lands.

To find time, t, height, h, initial velocity, V_o, and specific impulse ISP in terms



The parabolic trajectory of a Wisp fired at 45 degrees from the origin at t = 0 with an initial velocity Vo. The maximum height of the projectile is h and its horizontal range is R.

of range R, launch angle θ and gravitational acceleration, g, these formulas can be used:

Time to peak, $t_p = (V_o \sin \theta) / g$
Total flight time, $t = 2(t_p)$
Total horizontal range, $R = tV_o \cos \theta = V_o^2 / g$
Initial velocity, $V_o = V_j \ln(M_i/M_f)$
Exhaust Velocity, $V_j = (gR)^{0.5} / \ln(M_i/M_f)$
Specific Impulse, $ISP = V_j / g$

ln = logarithm to the base **e**
$g = 32.2$ ft/sec^2
M_i = initial mass at launch
M_f = final mass after launch

<u>A Trial Run of the Wisp</u>

A trial run of the Wisp test was conducted on 17 May 1997 at the MTA. A total of four Wisp rockets were launched. The propellant was 80/20 (w/w) micrograin. The propellant components, powdered zinc and sulfur, had conglomerated in their containers due to long storage and humidity. So before mixing, the individual components were dumped onto a table and rolled with a large dowel to break up the conglomerated pieces into coarse granules. The zinc and sulfur were then loaded into a large rock tumbler and allowed to mix for 3 hours while the Wisp rockets were weighed and prepared for propellant loading.

Wisp rocket #1 was loaded with 55 grams of propellant and one electric squib, bringing its initial mass, M_i, to 610.8 g. The rocket was then placed into a launch rack and carefully angled at 45 degrees. When the "all clear" was given, a ten second countdown was announced and the first Wisp was launched. With a short, sharp burst of flame and smoke the Wisp flew out of the launch rack. The burn duration was so short the propellant was depleted before the rocket emerged from its launch rack. This conveniently allows the Wisp to function as a ballistic projectile and follow a true parabolic curve. After a smooth flight the Wisp landed and stuck nose first into the ground 290 feet downrange from the launch rack. The distance traveled was recorded and the Wisp was retrieved. A small red flag was put in place to mark the landing spot. The Wisp was then reweighed for its final mass, M_f, which totaled 558.8 g. Note, it is important to measure M_f without removing the zinc sulfide ash remaining in the combustion chamber.

To measure the specific impulse, ISP, of this flight the exhaust velocity V_j must first be calculated.

$$V_j = (gR)^{0.5} / \ln(M_i/M_f)$$

$$V_j = \frac{(32.2 \text{ ft/sec}^2 * 290 \text{ feet})^{0.5}}{\ln(610.8\text{g}/558.8\text{g})} = \frac{966.63}{0.08897}$$

$$V_j = 1085 \text{ ft/sec}$$

The specific impulse ISP is equal to the exhaust velocity divided by the acceleration of gravity.

$$ISP = V_j / g$$

$$ISP = \frac{1085 \text{ ft/sec}}{32.2 \text{ ft/sec}^2} = 33.72 \text{ sec.}$$

Other flight characteristics which may be of interest to the Wisp experimenter can also be easily calculated using these formulae.

Initial velocity $V_o = V_j \ln(M_i/M_f)$
$V_o = 1085$ ft/sec x $\ln(610.8 \text{ g}/558.8 \text{ g})$
= 96.54 ft/sec = 65.82 mph

Time to peak $t_p = V_o \sin \theta / g$

$t_p = 96.54$ ft/sec x sin 45 deg. /(32.2 ft/sec^2)
$= 2.12$ seconds

Maximum height at peak $h = V_0^2 \sin \theta / 2g$
$h = (96.54 \text{ ft/sec})^2 \sin \theta / 2(32.2 \text{ ft/sec}^2)$
$= 102.33$ feet

Total flight time $t = 2(t_p)$
$t = 2(2.12) = 4.24$ seconds

Wisp rocket #2 was loaded with 64.5 g of propellant bringing its initial mass, M_i, to 621.4 g. This rocket traveled 263 feet with a final mass, M_f, of 571.0 g. The calculated specific impulse was 33.78 sec.

Wisp rocket #3 was loaded with 54.8 g of propellant bringing its initial mass to 610.7 g. This rocket traveled 245 feet with a final mass of 559.8 g. The calculated specific impulse was 31.69 sec.

Wisp rocket #4 was loaded with 64.4 g of propellant and one electric squib bringing its initial mass to 621.3 g. This rocket traveled 343 feet with a final mass of 569.5 g The calculated specific impulse was 37.49 sec.

Although these four rockets represent only a preliminary test, useful data was obtained. The mean value of specific impulse

Mean ISP = (33.72+33.78+31.69+37.49)/4
= 34.17 seconds

It can be seen that there is some variation in the measured specific impulse from rocket to rocket, but because this was only a preliminary test, scientific controls were not strictly enforced. For example Wisp #1 & #2 were launched in the morning when there was very little wind. Wisp #3 was launched in the afternoon when there were strong cross winds. The wind substantially altered the flight path of this Wisp.

Wisp #4 was launched the following day due to a large number of other experimental rockets being tested that day. The increase of specific impulse in Wisp rocket #4 may have been due to the use of a different batch of 80/20 (w/w) micrograin propellant.

The micrograin propellant from the prior day had been used up and a new batch of micrograin was made for the following day. Because enough micrograin would be necessary for only one more launch, this new batch was smaller. Consequently, mixing the propellant was simpler and more time was put into the mixing process. In fact, the new batch of micrograin was not mixed in a rock tumbler at all. For this batch, the zinc and sulfur were individually rolled, pressed and sifted. The two elements were then mixed together in a plastic container and sifted once again. This new batch of micrograin had a much finer consistency than the prior mix and did not the contain any of the irregular granules of zinc or sulfur the rock tumbler left behind.

The improved ISP of Wisp #4 was probably due to the difference in propellant mixing. More testing will have to be done to show that the mixing method was in fact the reason for this increase. But this will be for another day. In the next test more than 20 Wisp rockets will be fired and a reliable dynamic value for micrograin performance will be established.

Special thanks to: Bob Lesser, George Dosa, Tom Mueller and Matt Bell for their special help in this project.

Concept and Design for a Low Cost, High Flow Pressure Regulator

By Eric Claypool

About a year ago I started to gather all the equipment that I would need to fire a LOX/ ethanol engine. This engine is almost done, and I needed to start thinking about the support equipment that goes along with the engine. One of those items was a pressure regulator. I decided that I would attempt to build my own. One factor that I believe helped in the design was that I did not have more than a basic understanding of how commercial regulators worked. This allowed me to explore options I may have otherwise dismissed. The basic design I settled on is a spring-loaded piston regulator. I am staunch believer in the KIS principal and made every effort to keep the regulator as simple in construction, design and operation as possible.

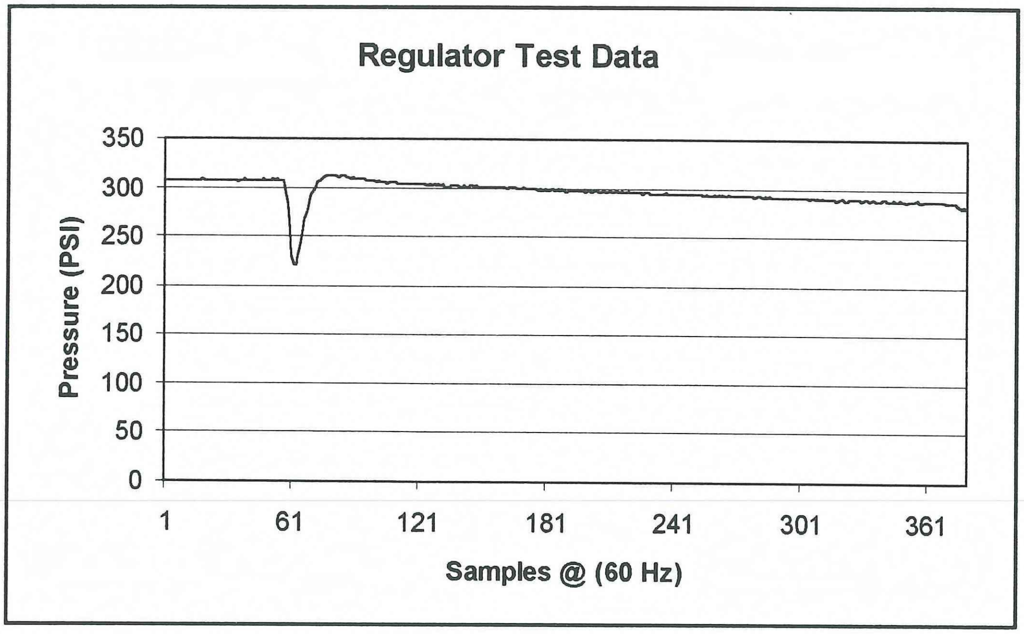
The regulator functions by adjusting the flow of gas from the inlet to the outlet by moving a piston. The gas travels into a grove in the piston at the inlet, and then through holes drilled in the piston to the outlet. The piston is pre-loaded by compressing a spring with a thumbscrew. This forces the piston down and opens the piston port. As gas flows, and the outlet pressure rises the piston will begin to move in the opposite direction. When the forces are balanced the piston stops and the regulator is delivering an appropriate flow of gas to maintain the required pressure. The force on the piston by the spring is the spring constant times the distance compressed. In our case the spring generates 376 lbf per inch of compression. The force generated by the piston due to the pressure at the outlet is, the area of the piston times the pressure. These are the two largest forces affecting regulation. Friction of the o-rings, and tank pressure can cause a slight error in the final regulated pressure, Usually less than 5 psi. The regulator is set by backing the thumbscrew out and applying pressure at the inlet. Then compress the spring until the outlet comes up to the desired pressure, and you're done!

The 3/4-inch diameter regulator has a HUGE flow capability, much more than I needed. The combined orifice diameter of the regulator is 1/3-inch. It should be noted that this is larger than the standard opening in the valve on most tanks. I have run the regulator on several gasses; helium, argon, and mixed welding gas, all worked great.

The regulator is constructed out of a piece of 6061-T6 hexagon bar stock. The spring and o-rings were obtained from McMaster-Carr. The spring is a Chrome-Vanadium die spring. The o-rings are -016 Buna-N. The bar is drilled out to accommodate the piston, a spring, and a spring compressor. The piston is also aluminum. This regulator was drilled to except a 3/4-inch diameter piston and spring. This design is scalable down to about a 1/2-inch diameter bore, and up to any size required. Both the inlet and outlet ports were then drilled, and the cylinder bore was honed. The inside of the cylinder must be as smooth as possible. Any ridges or marks will either damage the piston o-rings, or prevent a smooth regulation of pressure. I also recommend using high quality o-ring grease. This will greatly increase the o-rings life. The regulator can be designed with an internal relief, but I recommend just plumbing an external one. I should note that when constructing the piston o-ring groves, the o-rings are set deeper than normal. If the o-rings are not deep enough, they will extrude into the inlet and be cut. This is the time when that relief will come in handy. There is a fine balance between sealing and being damaged. I found that adjusting the o-ring depth is the single most time consuming part of construction.

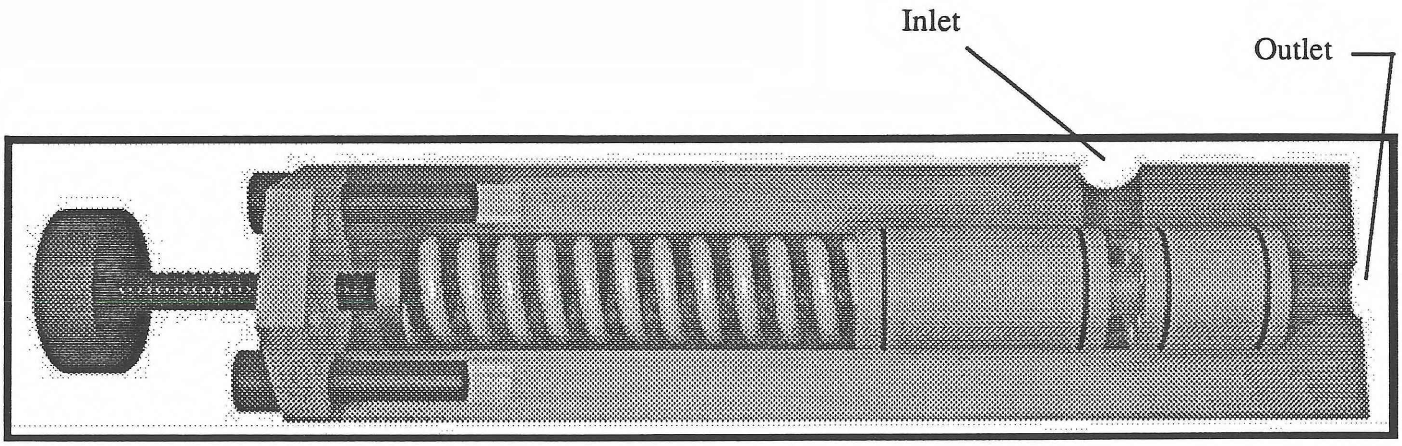
The data graph shows the pressure being regulated. The target pressure was 300 psi. For this test I had the regulator hooked up to the propellant tanks for my engine. The flow rate was about 3 lbs of water per second through the injector. The large dip at about one-second is when I opened the main propellant valves. You can see the regulator adjust itself to bring the pressure back up. It overshoots slightly and then maintains the required pressure for the duration of the test. The graph slopes slightly due to a low inlet tank pressure.

Designing the equipment for my engine has been extremely educational, and fulfilling. This regulator will be part of the equipment used when I fire my engine. I hope to fire my engine sometime in 1998.

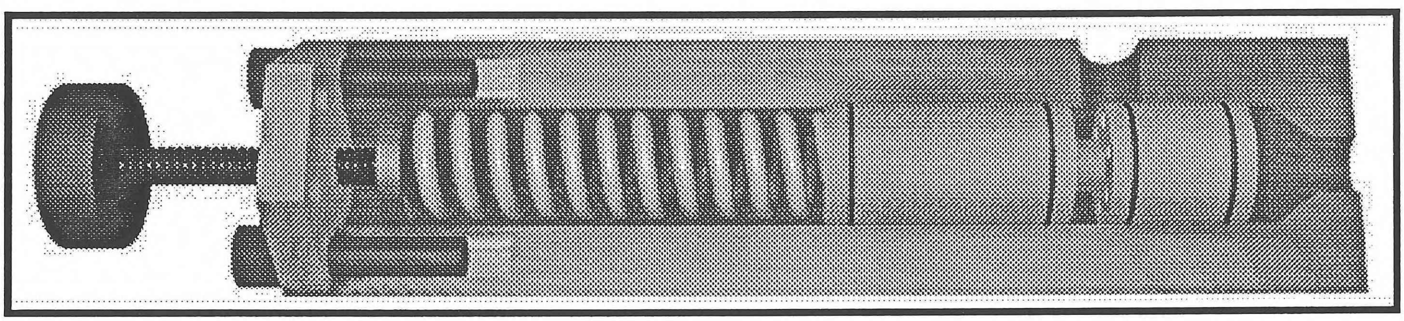


Regulator Information

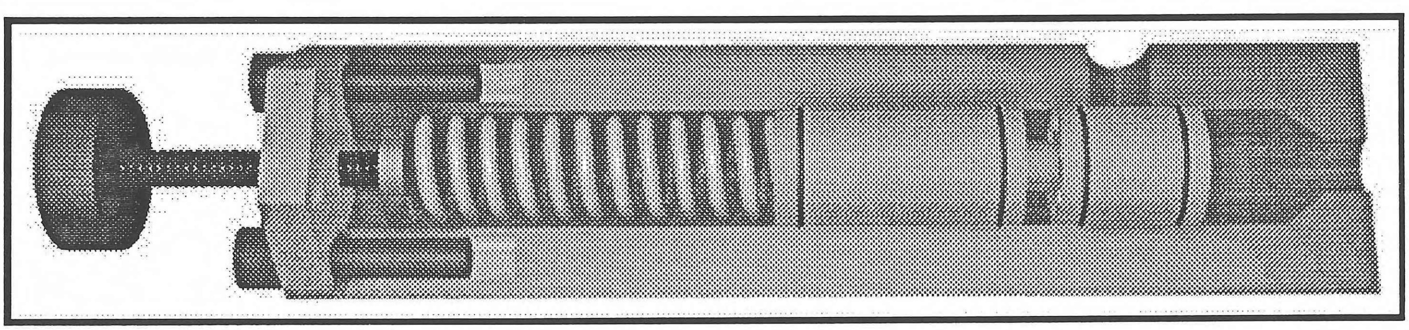
1. Maximum inlet pressure = 3000 psi
2. Maximum outlet pressure = 500 psi
3. Minimum outlet pressure = 150 psi
4. Combined orifice size = 0.3" diameter (on large regulator)
5. Piston diameter = 0.75"
6. Spring material is chrome-vanadium
7. Spring constant = 376 lb/inch
8. Spring length = 2.5"
9. O-ring material is -016 Buna-N



Regulator is fully open



Regulator is adjusting flow to maintain preset pressure



Regulator is closed

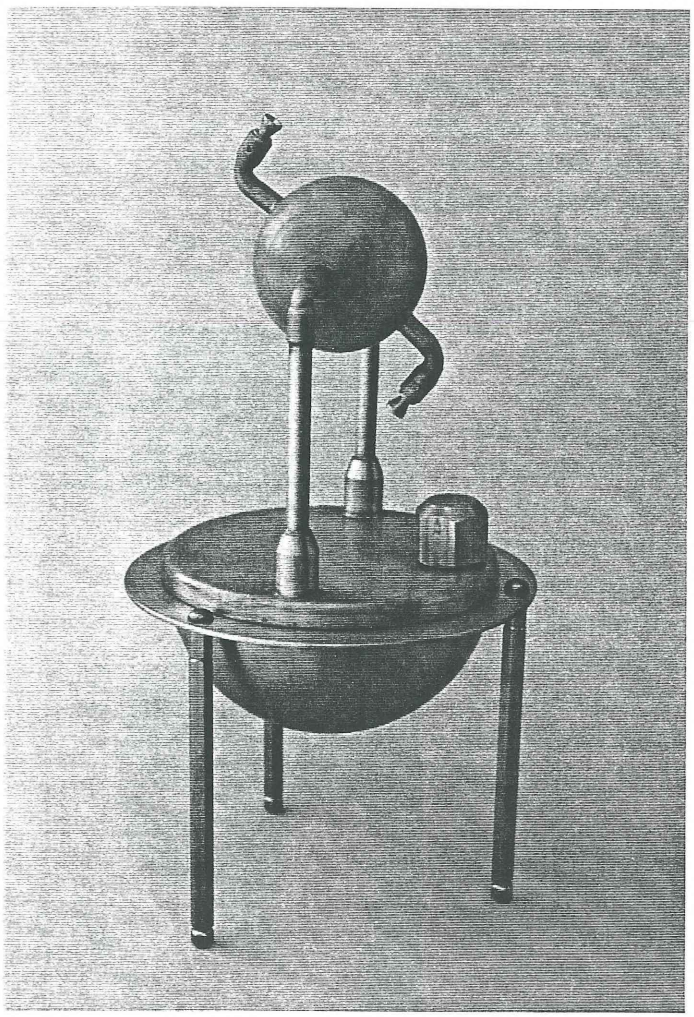
[Well, I did it again. I have forced my daughter to reorganize her 1997 school science project into an article for the RRS News. This was almost unavoidable since so few RRS members have sent in information to publish. To those of you who did, rest assured, you have earned the undying respect and gratitude of the RRS News staff (both of us !) -The Editor]

An Aeoli- What?!?

by Katie Crisalli

The purpose of my science project was to demonstrate and duplicate an ancient experiment that resulted in the first steam engine.

So, just what <u>is</u> an aeolipile (ee-ah-luh-pile) anyway? It doesn't look like much, that's for sure. So steam shoots out of it and a little doohickey on top spins around. So what? That's what people thought when it was first invented almost two thousand years ago. However, the signifigance of the aeolipile, as meager as you might think it is from looking at this little machine, has actually been enormous. The modern steam turbine came into being during the Industrial Revolution, and went on to power most of the world's ships and power plants. Related to steam turbines are gas and water turbines. Gas turbines power jet aircraft, rocket turbo pumps, ships and stationary power plants, while water turbines produce much of our hydroelectric power. Without the turbine, today's jet airplanes, that many of us ride in so frequently, would never have been possible, and ships might still be at the point of sailing vessels. Turbines have shaped a large and important part of our world today, and it all started with this little machine.



Aeolipile: a round vessel caused to rotate by escaping steam; an early example of jet propulsion.

Heron (or Hero), the man who invented the aeolipile around 75 A.D., was from Alexandria. He was a Greek mathematician, engineer, and inventor, among other things. Heron was noted for his practical, rather than his theoretical work, unlike many inventors of his day. He was knowledgeable on many subjects and wrote on the theory of hydraulic devices, simple machines, the center of gravity, surveying and its instruments. Heron also created the formula for the area of a triangle, which is sometimes attributed to Archimedes.

The name aeolipile was derived from the Latin "aeoli pila", which means "ball (or cap) of the god Aeolus". Aeolus was the Greek god of the wind, and since the machine functions by shooting out pressurized steam, the name is an apt one. By definition, the turbine is "a rotary machine which converts the kinetic energy of a stream of gas or liquid into mechanical energy". In general, there are two types of turbines. The first is an impulse turbine, which is driven by the force of a fluid striking it. The second form, a reaction turbine, is the same type as the aeolipile. In this type of turbine, the nozzles are mounted on and, consequently, revolve with the rotor.

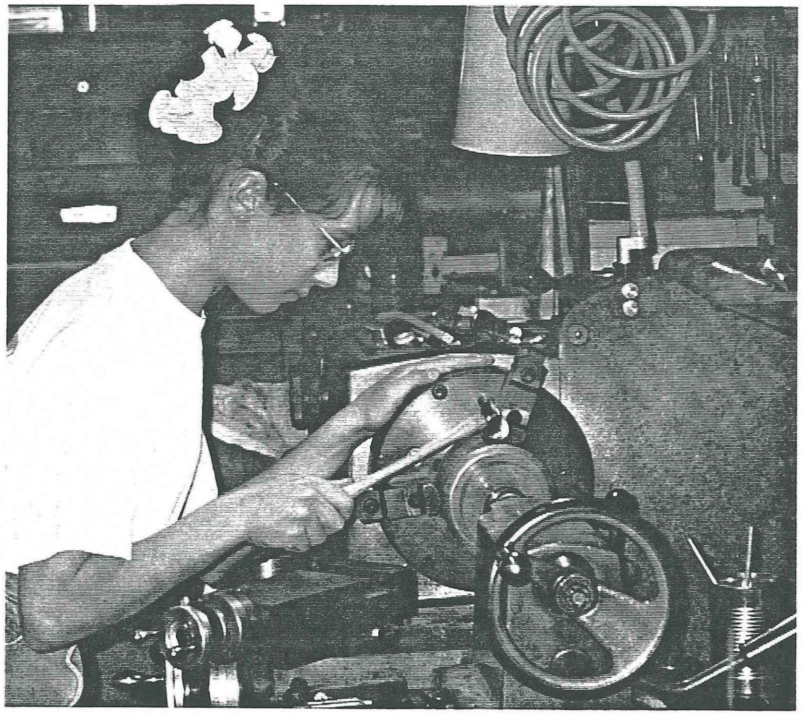
The aeolipile is a single-stage turbine, but later American and English designs were multiple stage ones, with several bladed rotors connected to a single shaft and each stage becoming progressively larger. Multiple stage turbines are made in this fashion to extract all the available energy from the steam, water, etc. which is driving it. A *steam* turbine is a rotary machine that converts the heat energy and pressure of steam into mechanical energy. In a typical steam turbine, the steam strikes curved or angular blades connected to the main shaft, which causes the rotor to spin. Then the steam is directed outward and meets the stationary blades fastened to the shell of the turbine. These blades redirect the steam into the next set of spinning blades, and the process is repeated for the length of the turbine until all the steam's energy has been converted into mechanical motion.

Some examples of other types of turbines are windmills and pinwheels, which are fairly simplistic air turbines. Used to grind grain or pump water, windmills were the first type of useful turbines. However, they were slow and immobile. The water wheel is an example of a water turbine. An example of a simple gas turbine is an old and traditional German candlestick, with decorative rotating figurines, powered by warm air rising from candles through a wooden turbine.

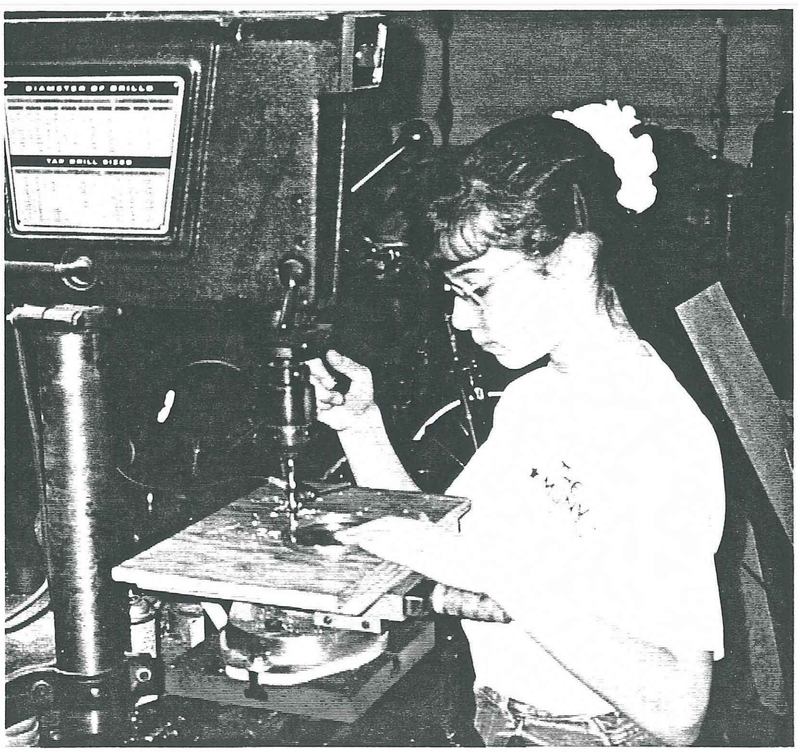
Actually, though, the aeolipile was considered little more than a toy for centuries. Its principles were unused until the Industrial Revolution in the nineteenth century. People began using steam to drive turbines. This made these mechanisms faster, more effective, and able to generate more power. In addition to this, these new steam turbines could be built small enough and powerful enough to propel themselves. By World War II, most of the ships in the world were powered by steam turbines. Around the same time frame, in 1940, a young aeronautical engineer in England named Sir Frank Whittle invented the first jet engine. This device was a very lightweight and incredibly powerful turbine. The jet engine, however, did not use steam. It was powered by burning hydrocarbon fuel and air.

Today, the main uses of steam turbines are in ships and power plants. Gas turbines have a few

Cutting the copper plate to make the top of the boiler



Hammer forming the lip around the edge of the boiler top.



Drilling the three holes in the boiler top plate.

more uses. As well as being used in power plants and ships, gas turbines are widely used in jet aircraft and turbo pumps for rocket engines.

It's amazing, isn't it? Sometimes the most brilliant inventions, the ones that often change the world, are also often ignored and dismissed for years, decades, or sometimes centuries! And then, when the technology is right, they are rediscovered and begin to change people's lives as the steam turbine did in the Industrial Revolution. And then everyone wonders "why we didn't think of that years ago".

Principles

The aeolipile, both at the time it was originally built and when I reconstructed it, is designed based on a variety of scientific laws and principles. Perhaps the most obvious of these is Newton's third law of motion. This law states that for every action there is an equal and opposite reaction. The aeolipile demonstrates this by ejecting steam under pressure from the nozzles, which causes the sphere, or turbine, to spin. Another principle demonstrated was the conversion of energy by burning fuel to make water into steam. The aeolipile also demonstrates the relations between temperature and pressure of a gas. Water is heated to generate steam and the heated steam drives the turbine. A fourth principle demonstrated was the principle of a force couple. This is the principle of two forces that act over a distance. Specifically, the perpendicular elbow fittings that guide the steam out of the machine create a couple and result in the rotation of the turbine. In this particular instance, the pivot points are holding the center of the turbine stationary while the steam is pushing on it in opposite directions, causing the sphere to spin.

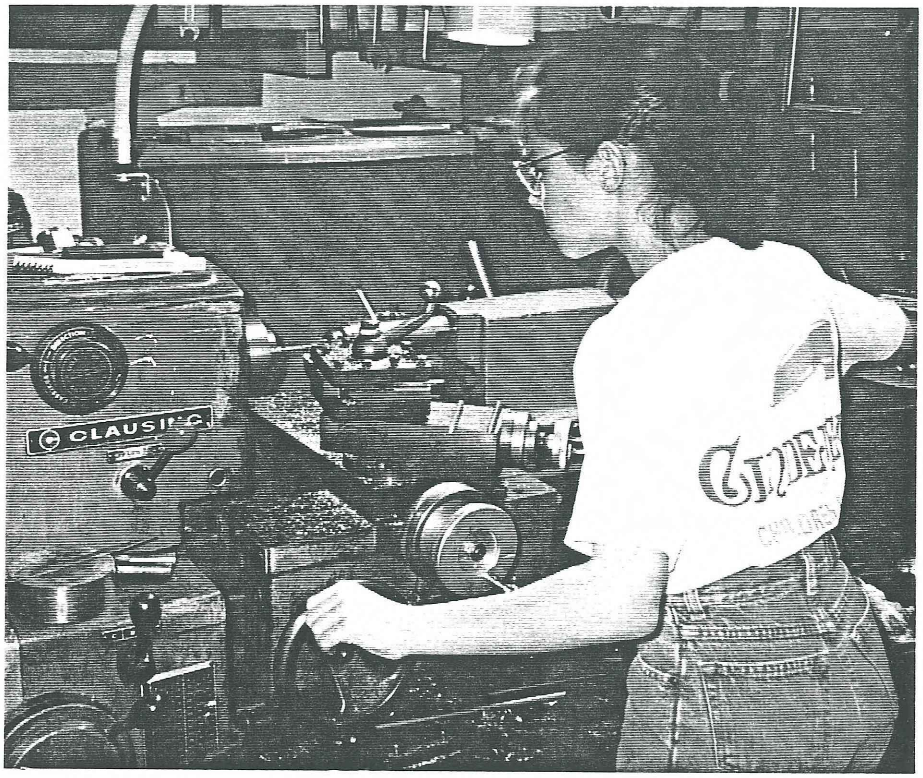
Another aspect of this project which is not, in a technical sense, a principle, but is worth mentioning, is why I used the materials I did. For instance, I used the solder in this aeolipile because I knew it would join the various pieces easily and withstand the level of heat it was going to be subjected to. I used the brass for its durability and resiliency, and I used the copper for its malleability (especially when hammer-forming the boiler lid).

The last principle I used was not a part of the original aeolipile, but was an outgrowth of my science project, "Land Rockets," from last year. In that project, I built a rocket-powered go-cart and tested different types of nozzles to see which one would create the most thrust and, therefore, speed. I found that the DeLaval nozzle worked the best, and so, to make the aeolipile work more effectively, I added this type of nozzle to the steam escape apertures. The DeLaval nozzle works with a converging/diverging orifice, and so increases the gas velocity as the nozzle narrows. When it widens again, the gas accelerates even more, and, therefore, the nozzle maximizes velocity.

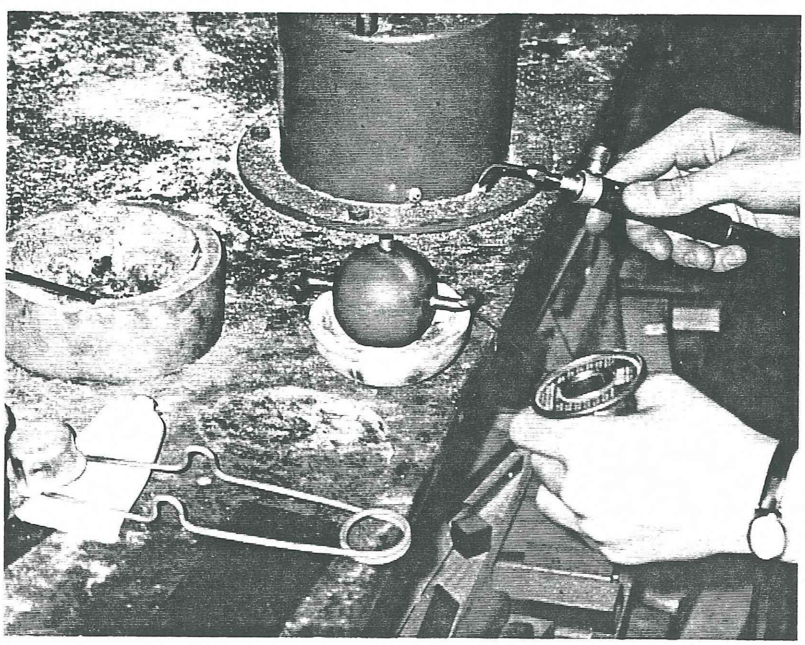
1) The first thing I did was to gather the necessary materials. I purchased the copper floats used for the main boiler and the rotating sphere, as well as several assorted parts from a local plumbing shop (including elbow fittings, brass tubing, a copper pipe cap, etc.). With everything ready, the next task was to separate the larger copper float down the middle, since I only needed half of it for the boiler. It was soldered together in two halves, so I heated the solder with a torch and pulled the two halves apart. Then I cut a 4 1/2" circle out of sheet copper on the bandsaw, and hammer-formed a 1/2" strip around the edge to form a lip. This was done by hand on a steel mandrel mounted in the lathe.

2) After the lid had been formed, I drilled 3 holes in it - one for the pivot support arm, one for the steam supply pipe, and one for the water fill port (I did this drilling first to avoid the pressure that would have been created if I had soldered the lid onto the boiler first). Then I soldered the half-sphere to the boiler lid.

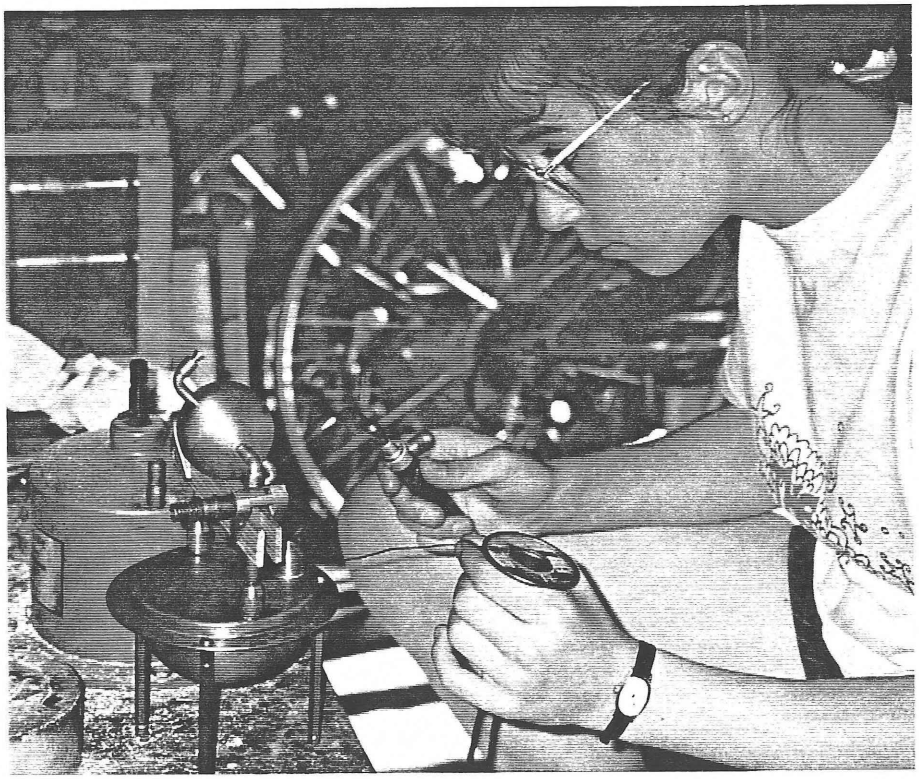
3) The next part I created was the brass stand. I cut a 5" circle out of brass sheeting with the



Machining the legs for the little brass stand.



Soldering the steam elbows to the spinner ball.



Finishing the assembly by soldering the steam supply and pivot support tubes in place on top of the boiler.

bandsaw, and then cut a 4" circle (just slightly smaller than the lip of the main boiler) out of the center of that with the lathe and a circle saw drill bit, leaving a 1/2" wide ring. Then I used the drill press to drill 3 small holes for screws at equal intervals around the ring. To form legs for the stand, I cut 1/4" hexagonal brass barstock into 4" pieces, made a few decorative cuts, and then drilled and threaded a hole in one end of each. Then I attached these legs to the stand using three small brass screws.

4) Then, I put the water fill port and cap into the third hole drilled in the lid (the water fill port was made from a fitting purchased at a plumbing shop) and soldered it in place. Above the boiler, two pipes support the spinner ball (or turbine). One pipe is only a pivot arm and the other brings steam from the boiler up into the turbine. The next step was to cut the required pipelines to the appropriate length (approx. 3 1/4"). I used the lathe to make the little brass pivot piece, and cut some copper tubing on the bandsaw for the steam supply slip-fit.

5) Attached to the turbine on my aeolipile are a pair of elbow fittings which lead the steam out through the tiny DeLaval nozzles. These demonstrate the principle of couples- each elbow fitting forms a couple with the pivot or steam supply points. The principle is this - the steam flowing from the elbow fittings, which are perpendicular with the surface of the turbine, is pushing in opposite directions while the pivot/ steam supply points hold the center of the turbine stationary, and this causes the sphere to spin. So the next step was to solder the elbow fittings onto the ball, and then machine the tiny DeLaval nozzles, which I soldered into the fittings by cutting tiny holes where they flared out slightly and pushing the solder through those holes where the hot metal melted it. Then I attached both pipes, including slip-fit and pivot piece, with the copper ball in the center. I used

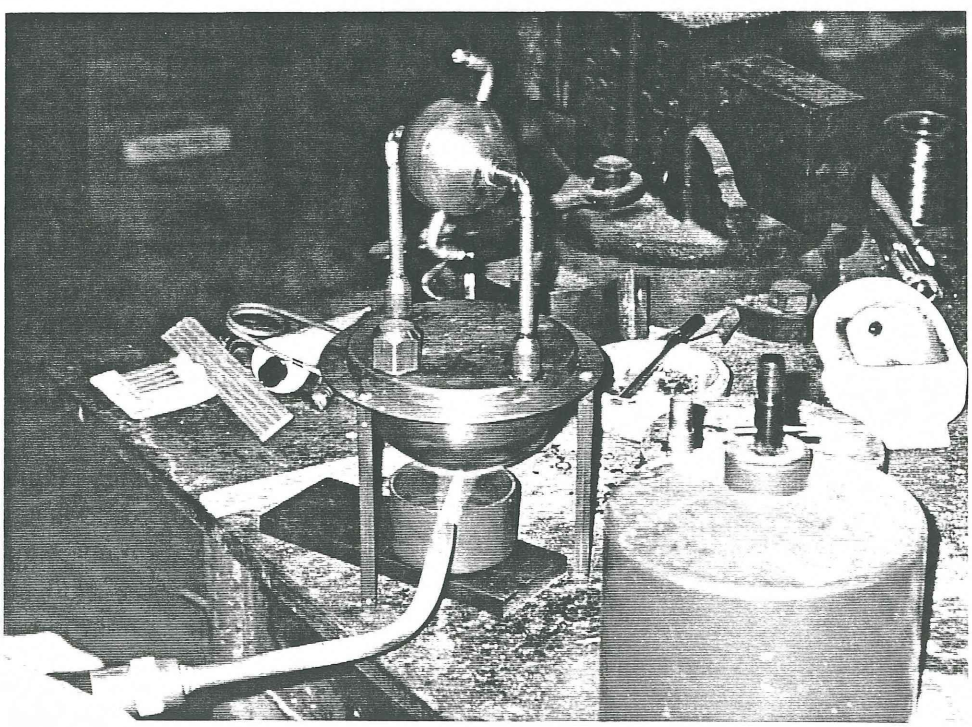
some blocks of wood and C-clamps to keep everything square, but had some difficulty in keeping the pipes perfectly vertical while I soldered them, and from slipping down through the holes into the main boiler. To fix this problem I machined some little brass fittings out of 1/2" round barstock, designed to help keep the pipelines erect. (I later learned that this didn't keep them exactly square because the hammer-formed lid wasn't perfectly flat, but it did keep them from falling into the boiler).

6) When the automaton was assembled, I found out it didn't work at all. This was due to the fact that the hole I had made in the turbine for the steam wasn't perfectly aligned with the pivot. Therefore the pipelines were pressing against opposite sides of the ball and inhibiting free motion. (The turbine had to be able to spin at the slightest provocation because, with the size of the machine, there wasn't the capacity to create lots of pressure, and therefore the sphere had to spin easily, without much exertion).

7) To fix this, I had to make the hole in the sphere where the steam came in slightly larger and off to one side so it would be centered with the pivot. This made the hole too large for the pipe, so I machined another brass adapter fitting that accommodated the different sizes on opposite ends. I pulled the pipes apart and squeezed the ball back on, and it (*phew*) was able to spin freely.

8) Testing! I lighted the alcohol pan under the aeolipile and, after a while, steam shot out of the nozzles (a good sign - that meant that the solder hadn't blocked up any pipelines and that the slip-fit wasn't leaking). But there wasn't enough velocity to make the ball spin. I tried adding more heat by using a torch in addition to the alcohol flame. This generated much more steam and the turbine began to spin !!!

No matter how much turbines have changed over the centuries, it was fun and interesting to build a working model of the very first one, the aeolipile, and find out why and how it works. And no matter how many years go by and how much technology changes, it will always be fun to hold a pinwheel (another toy turbine) out the car window.



With extra heat from a bigger torch, the aeolipile begins to spin very fast. Success!

Bibliography

1. Grolier's Encyclopedia. "Hero of Alexandria". ©1993. Grolier Electronic Publishing, Inc.

2. Grolier's Enclyclopedia. "Turbine". ©1993. Grolier Electronic Publishing, Inc.

3. The Ancient Engineers. L. Sprague de Camp. ©1960. The MIT Press.

4. The Way Things Work. No Author Listed. ©1967. Simon and Schuster.

Materials List

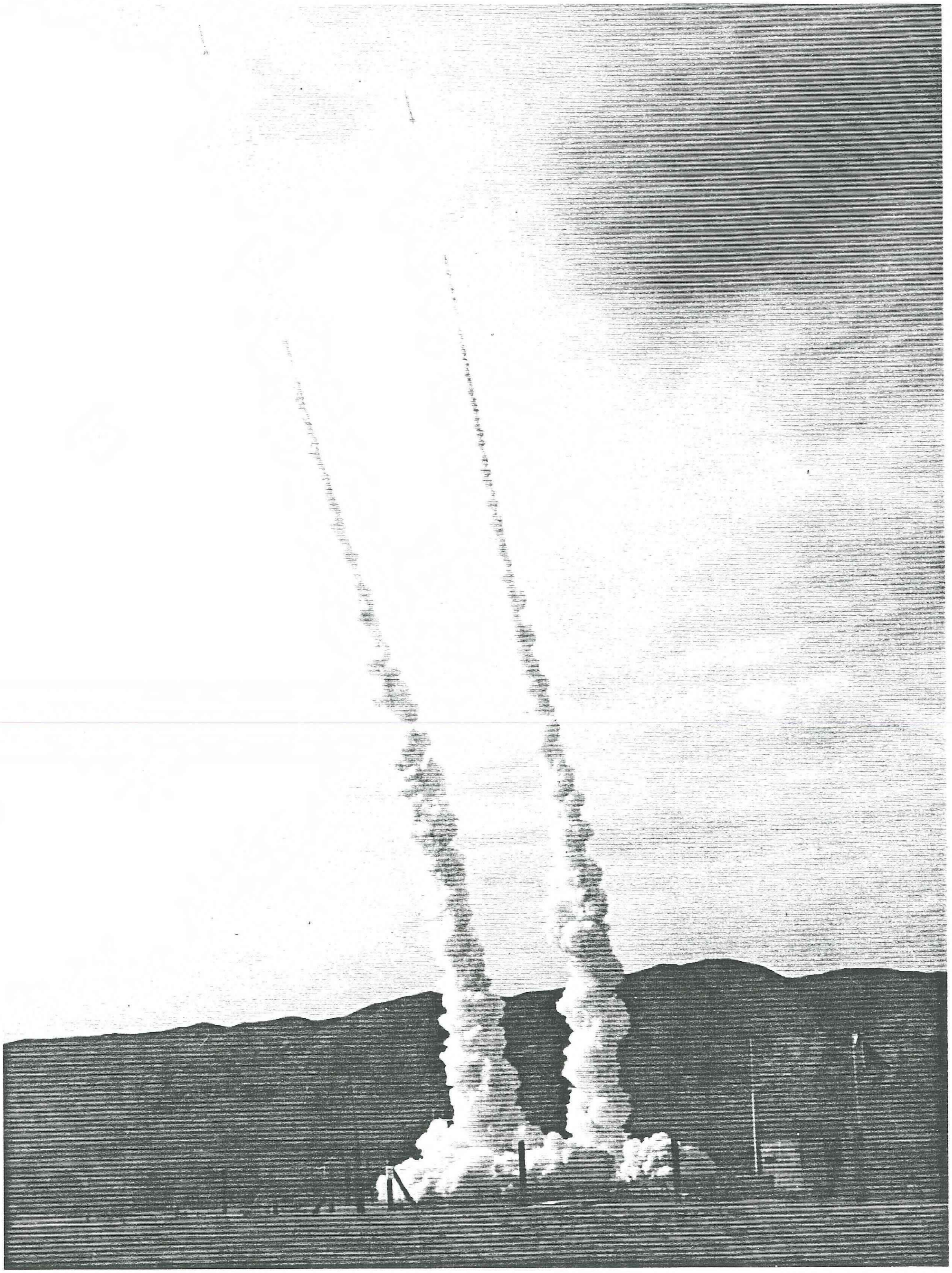
Materials:

- copper tubing (1/4")
- copper spheres (4 and 2" diameter)
- round brass barstock (3" of 1/2", 5" of 1/4")
- hexagonal brass barstock (12" of 1/4")
- 25 sq. in. copper sheeting (1/16")
- solder
- flux
- Scotchbrite
- 1 bottle alcohol
- 2 cups water
- matches
- copper pipe cap (2")

Machinery and Tools

- drill press
- lathe
- bandsaw
- oxy-acetylene torches
- soldering iron
- assorted open-end wrenches
- hammer
- file
- pliers
- assorted drill bits
- hand taps
- deburring tools

30 Years Ago ....



On April 9, 1967, the second "Project Live Fire" was held by the RRS at the Mojave Test Area. This was a public firing attended by over 250 people in promotion of student experimental rocketry. The sixth launch of the day is captured in the above photograph. This was a simultaneous launch of two identical RRS Beta vehicles built by George Dosa. The photo shows remarkably symmetry, considering the normal variations expected with hand-packed zinc-sulfur propellant.

Fire in the Desert

May 17, 1997

by David Crisalli

We had been a little thin on rocketry work and all too heavy on work parties for several months. However, in May of this year, another of the solid propulsion classes had been rescheduled for the middle of the month. Since it was a small class, we fell into the old trap of trying to conduct two operations at one time at the MTA. While it all came off fairly well, coordinated operations are never easy or preferable....another lesson re-learned.

The general firing went very well and saw some excellent projects come to the moment of truth. The first firing of the day was a composite propellant rocket with a parachute recovery system built by Vince Granato. Vince had built his own launcher, in addition to the rocket, proving yet again that experimental rocketry makes for a very broad engineering experience. With the assistance of several other members, Vice got the launcher raised and the rocket ready to fly by mid morning. However, at the end of the count, there was a loud report and a bright flash. The rocket case burst on the rail throwing parts and propellant everywhere. It was a classic example of a "RUD" (that is, a Rapid Unscheduled Disassembly). The launcher was also a little the worse for wear too.

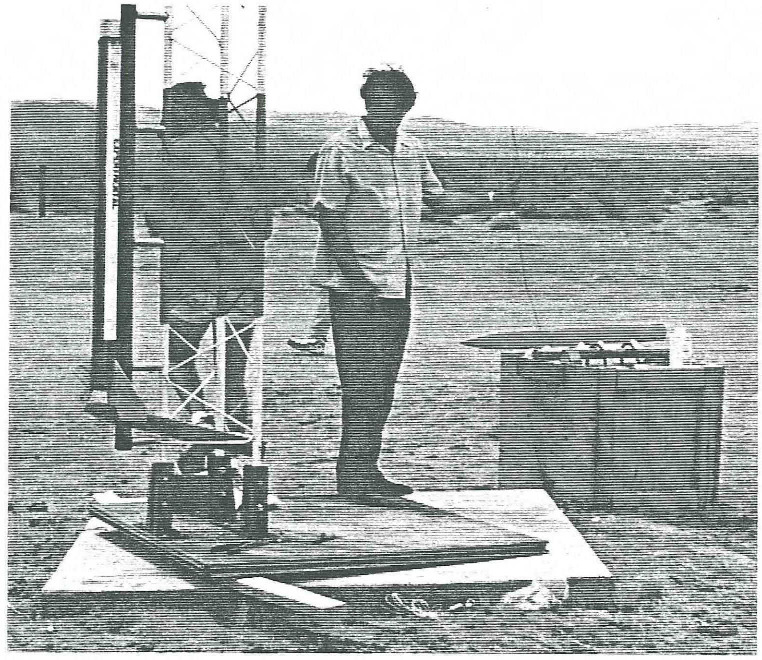
As part of the ongoing preparations, a drum load of zinc-sulfur propellant was mixed to fuel the several micrograin rockets that showed up. One of the photos here shows several of the smaller vehicles built by Bob Shimke and Paul Montgomery. Jim Swenson and Josh Montgomery had brought standard Betas to fly. The second flight of the day was Jim Swenson's Beta which flew beautifully out of the George Garboden short Beta rack.

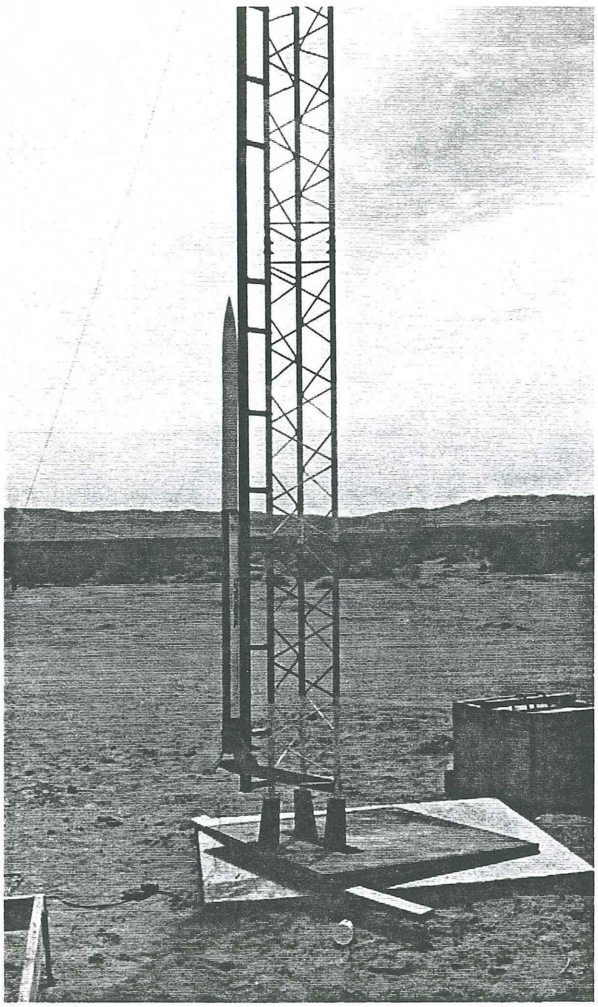
Anthony Colette had prepared for several flights of the WISP vehicle covered elsewhere in this issue. The small motor sections were carefully loaded with propellant and weighed. A specially built launcher was employed and the vehicles were launched to the north at a 45° angle. Their impact points were marked with small flags and the distances to the launcher carefully measured. The third and fourth flights were of WISP rockets.

Josh Montgomery was in the process of getting his Beta ready for launch when it was discovered that the parachute recovery system was not functioning. Since Vince Granato's rocket had carried an Adept altimeter system, I suggested that, if it hadn't been destroyed in the blast, Vince might be willing to let Josh use it. In a typical example of amateur rocketry generosity, Vince was happy to donate the altimeter to the flight. However, it had been slightly damaged in the explosion. Nonetheless, in yet another example of helpful camaraderie, Rene Caldera jumped right in and repaired the device while Josh was getting the rocket ready. The flight was another perfect Beta launch, but alas, despite all the great effort, the parachute did not function and the rocket was not recovered.

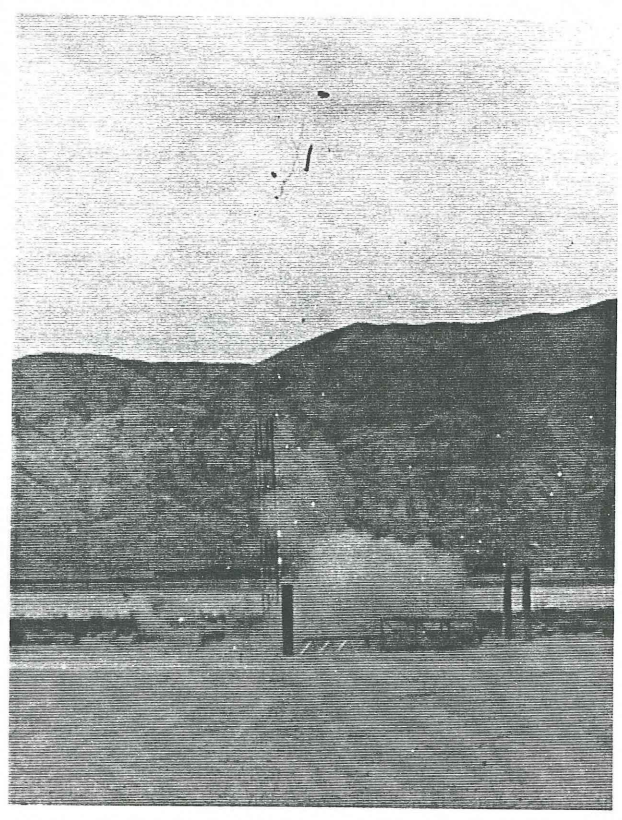
Despite the confusion of conducting two operations at once and the failures that had occurred, the major and most important goals of the firing had been met. The members who had stepped into the arena to try their hand had studied the problems, invested time and effort, built hardware, and, finally, risked all in the launch attempt. Some experiments worked completely, some partially, and some not at all, but all had been worthwhile methods of learning.

Vince Granato sets up the launcher and prepares his composite propellant rocket for launch.

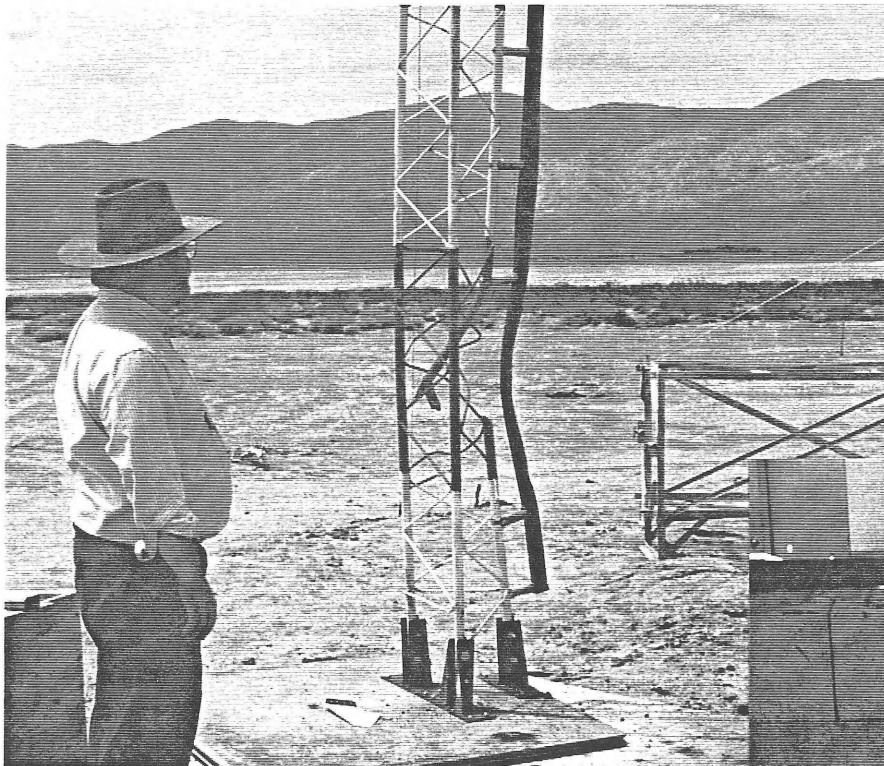




Left - Vince's rocket on the rail just before the flight attempt. Unfortunately neither the launcher or the rocket looked like this a few minutes later.

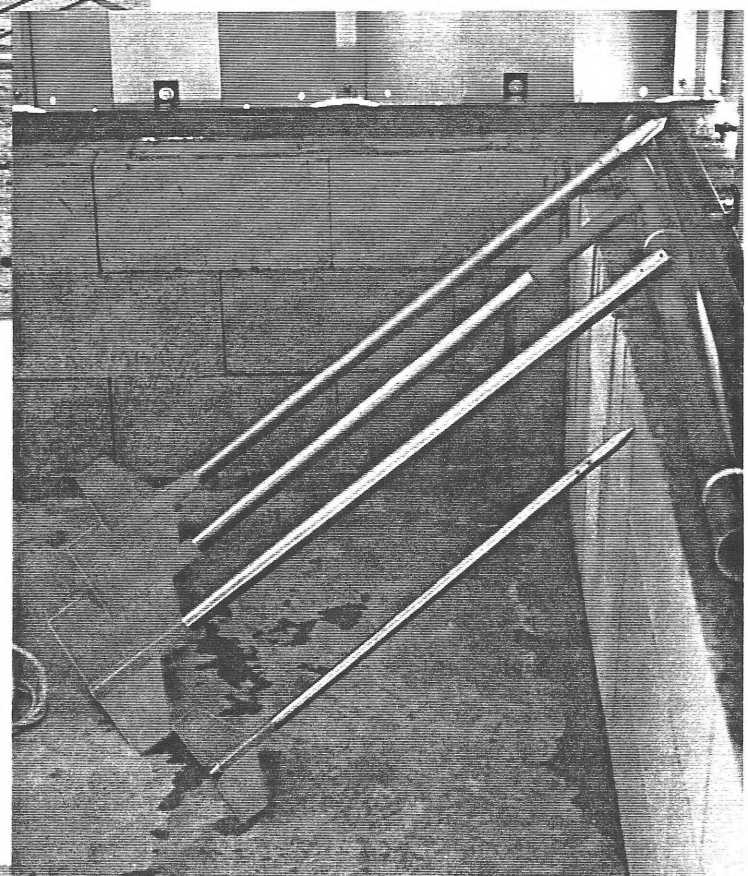


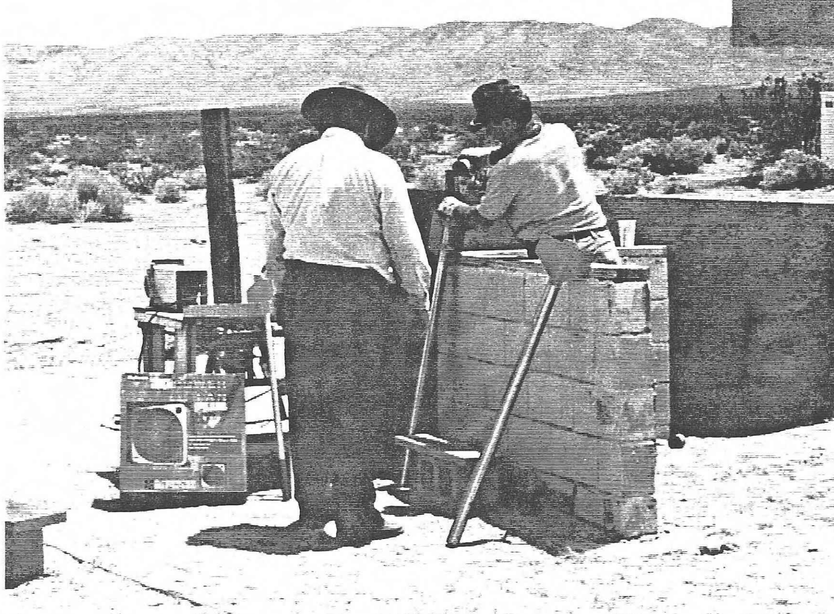
The explosion of Vince's rocket as observed from the bunkers.



Niels Anderson surveys the now slightly altered launcher.

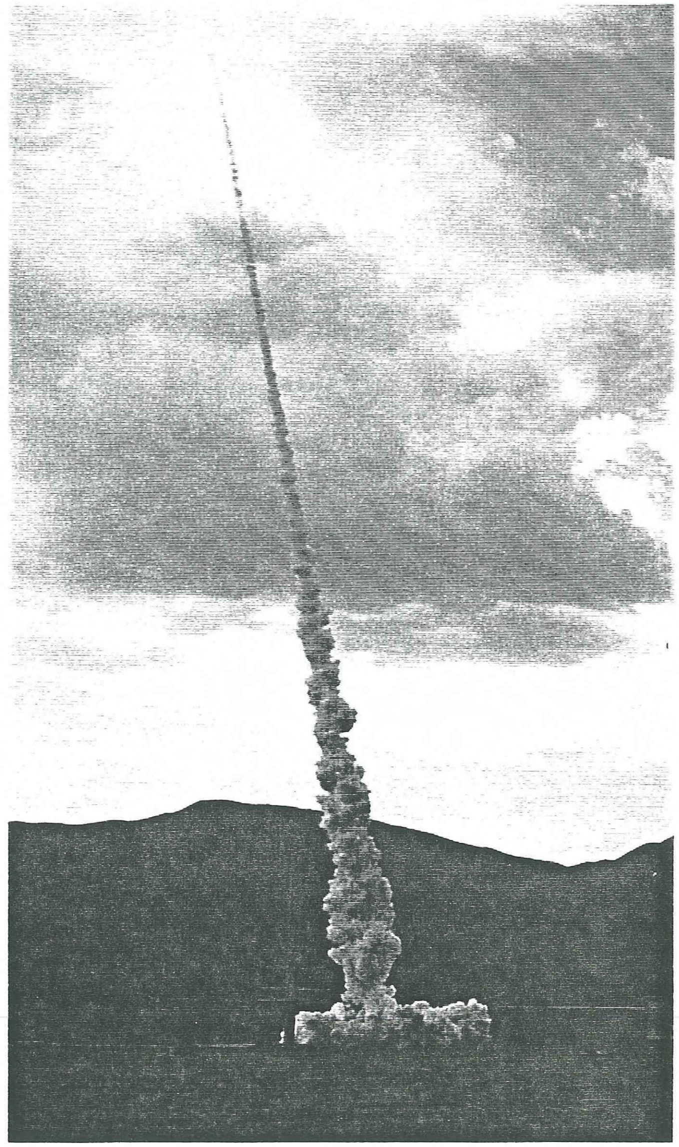
Right - Some of the zinc-sulfur vehicles built by Bob Shimke and Paul Montgomery.



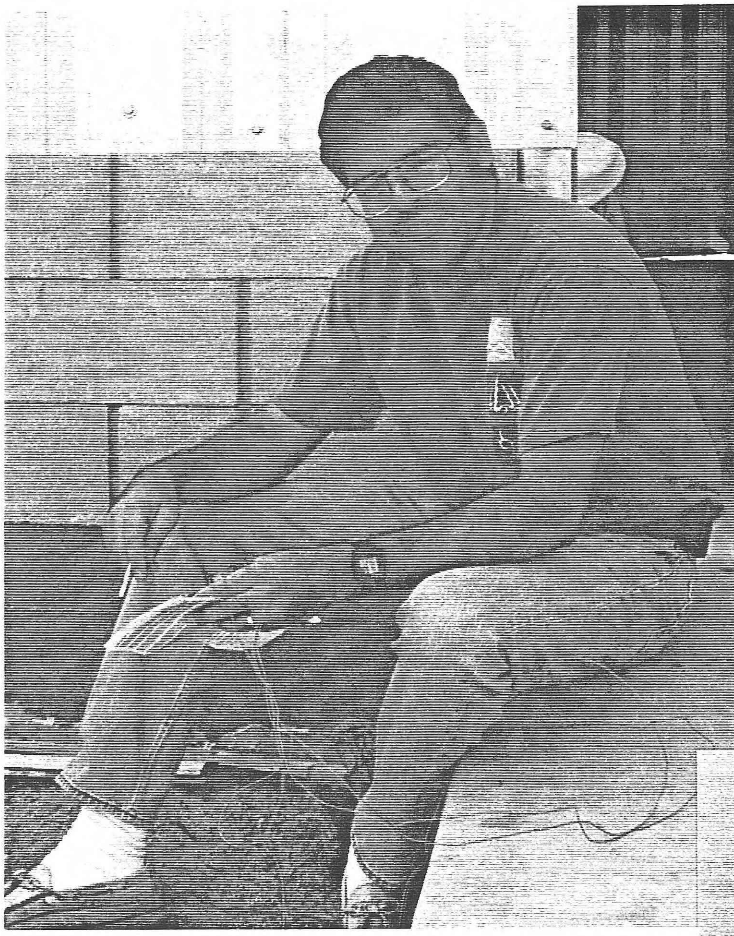


The pyrotechnic operators load zinc-sulfur into the Betas.

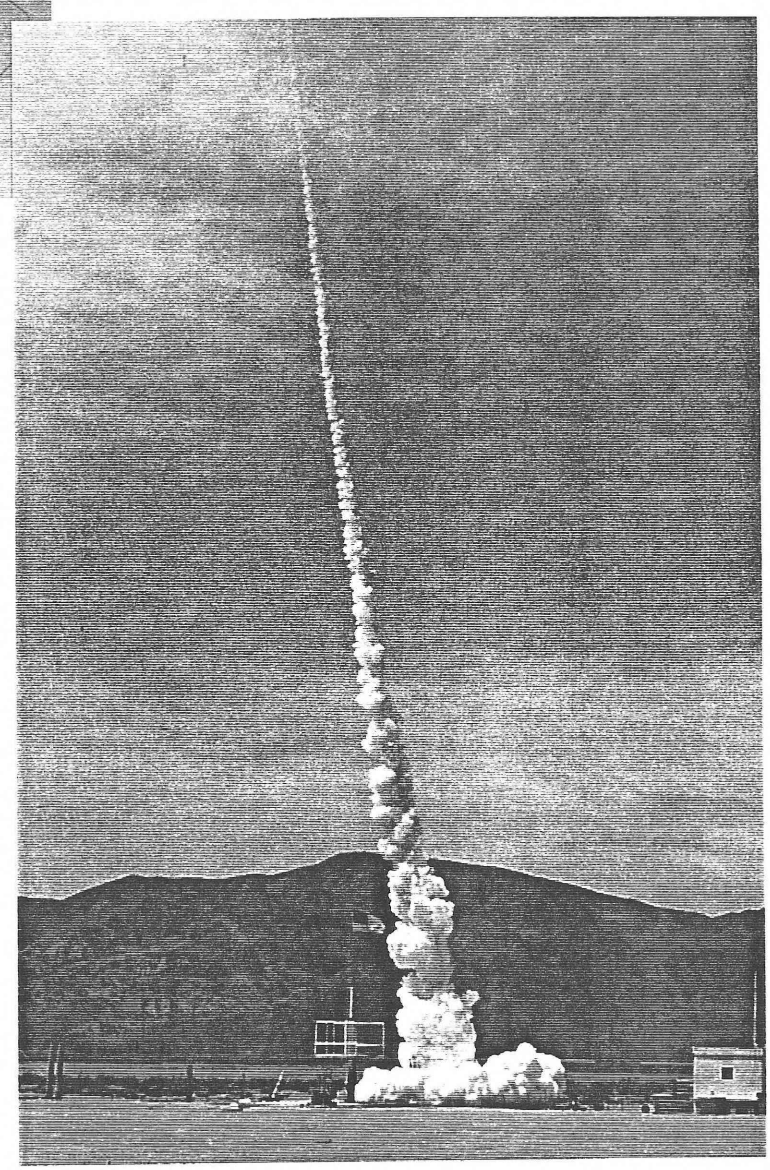
Jim Swenson's Beta takes off in a hurry making an impressive exit from the compound.



Anthony Colette, enjoying the shade available inside the new building, prepares WISP rockets for flight test.



Rene Caldera helps with an impromptu rebuild of an electronic altimeter in the field.



Josh Montgomery's Beta streaks skyward on a pillar of smoke and flame.

Bits and Pieces

Internet Address Request - There have been several requests recently for the Internet addresses of any members who have them. People have been sending them in a little at a time so, if you would like your Internet address published in the next RRS Newsletter, please send it to D. Crisalli or S. Claflin. In front of the membership roster we are including a list of the ones we have to date. For those on the list, please check to make sure we have all the dots and slashes and "@"s all in the right places. **I GET A LOT OF COMPLAINTS ABOUT E-MAIL ADDRESSES BEING INCORRECT OR LEFT OFF THE LIST - I CAN NOT FIX THIS UNLESS PEOPLE SEND ME UPDATES !!!** The Ed.

Back Issues of the RRS Newsletter - For those members who may be interested, copies of the last several RRS Newsletter issues are available for $10.00 each (including postage). This offer includes;

- Volume 51, No. 3, July 1994 (LOX/alcohol rocket, venturi design part I, 30 April 94 firing report and color photos)

- Volume 51, No. 4, Oct. 1994 (10,000 lb thrust liquid engine, 1950 hydrogen peroxide rocket, zinc/sulfur performance, venturi design part II)

- Volume 52, No. 1, Feb. 1995 (GOX/plexiglas hybrid engine, October '94 firing report, facility upgrade plans, liquid rocket pyrotechnic valves)

- Volume 52, No. 2, Aug. 1995 (LOX/ethanol engine design, Firing reports - March '95 (Liquid static tests) & May '95 (Zinc/Sulfur), Work party reports on facility improvements)

- Volume 52, No. 3, Oct. 1995 (LOX/alcohol rocket flight, Work party report, RRS composite propellant work, NO2/methanol engine design, Zn/S two stage flight test, Assembly of a large liquid rocket)

- Volume 52, No. 4, Dec. 1995 (Nitrous Oxide and Rubbing Alcohol Motor, United Kingdom Perspective on Amateur Rocketry, "Rollerons" - Roll Stabilization for Amateur Rocket Vehicles)

- Volume 53, No. 1, Mar. 1996 (1500 pound thrust Hydrogen Peroxide engine, 1995 in Review, Electric Matches, Legal transport of propellants, Robust nosecone design)

- Volume 53, No. 2, Jun. 1996 (Work Party Report, Lox / Kerosene - 1000 Pound Thrust Test, Rocket Powered Go-Cart, Resistor Igniters, Liquid Rocketry in Denmark, Micro Hybrid)

- Volume 53, No. 3, Sep. 1996 (Beginning Solid Propulsion Course Report, Burning Rate Exponents, Bates Grain Design, Solid Rocket Ignition, Resistor Igniters, New Building Work Party Report)

- Volume 53, No. 4, Dec. 1996 (Black Rock Flight to 50 Miles, 1996 Review, September 1996 Firing)

- Volume 54, No. 1, Mar. 1997 (Micro Hybrid Part II, RRS Hybrid History - Hybrid Bike, LOX / Particle Board Hybrid, LOX / Tar Paper Hybrid)

- Volume 54, No. 2, Jun. 1997 (This issue)

Contact D. Crisalli if you need back issues and make the check payable to the RRS.

Membership Roster - Just a reminder again - please check the information on the enclosed membership roster and verify it. **If anything is incorrect or has changed, please contact Frank Miuccio with any corrections by telephone or mail. He is on the list and we made sure his name, address, and phone number were OK.**

Reaction Research Society

P.O. Box 90306, World Way Postal Center, Los Angeles, CA 90009

Membership Application

Corresponding Membership is for those interested individuals who live outside the immediate area and/or cannot attend meetings and firings. Corresponding members receive the Newsletter and have all privileges of Associate members except firing privileges (unless he/she is sponsored by a Honorary/Administrative/Associate member). There is no age limit for corresponding membership. $30.00 annual dues.

Associate Members are "active" members who have all the privileges of Administrative members except that of serving as a project or testing chief or in any other manner being in charge of a Society's technical or scientific research activity. They are not eligible to vote at meetings of the membership or for officers of the Society or hold office themselves. Associate membership is an initial active membership and can lead to an Administrative membership with approval of the Executive Council after certain Society requirements are met. Associate members must be 18 years or older. $35.00 annual dues.

Trial Membership has all the privileges of Corresponding Membership for a duration of 30 days. Non-members attending launches are required to become Trial Members except for children. The nominal fee will be credited to a full membership if the individual upgrades within 30 days. $3.00

Type of Membership (Please check one)

Corresponding ___ Fill out complete form **Associate** ___ Fill out complete form **Trial** ___ Fill out Gray portion only

First Name	Middle Initial	Last Name	
Street Address			
City	State	Zip Code	
Home Phone	Business Phone	Occupation	Date of Birth
List of Special Skills			
Membership in Professional or Scientific Societies		Internet Address	
Phase of Rocketry Most Interested In			

Disclaimer: I, the undersigned, by my action in joining the Reaction Research Society, agree to indemnify and hold harmless the Reaction Research Society, its appointed pyrotechnic operators, each of its members, officers, and agents from and against all claims, damages, or injuries direct or consequential arising out of any participation in activities associated with rocket test operations. I understand the potential hazards involved with rocket launch and static test activities. I also recognize that violations or non-compliance with the directions (pertaining to safety) of the Pyrotechnic Operator in charge of any particular event, may result in suspension of my participation in firing events.

______________________ Signature __________ Date

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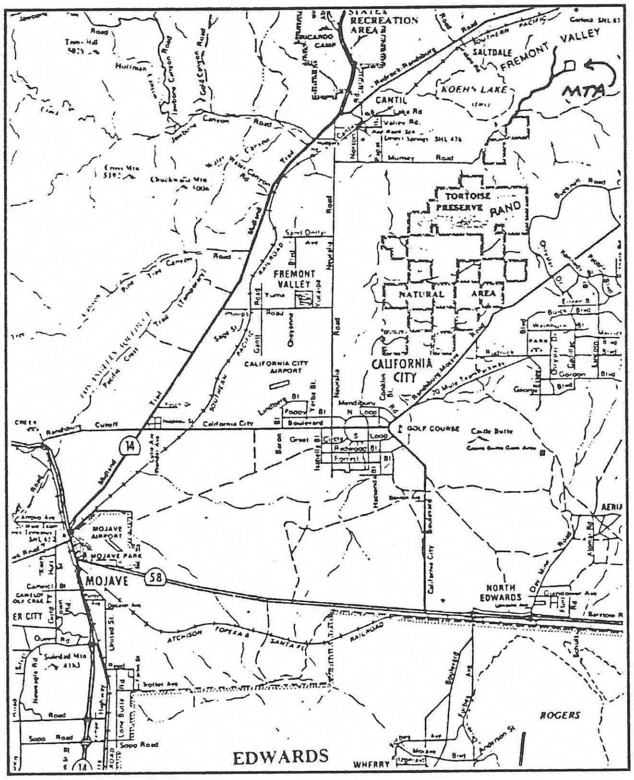

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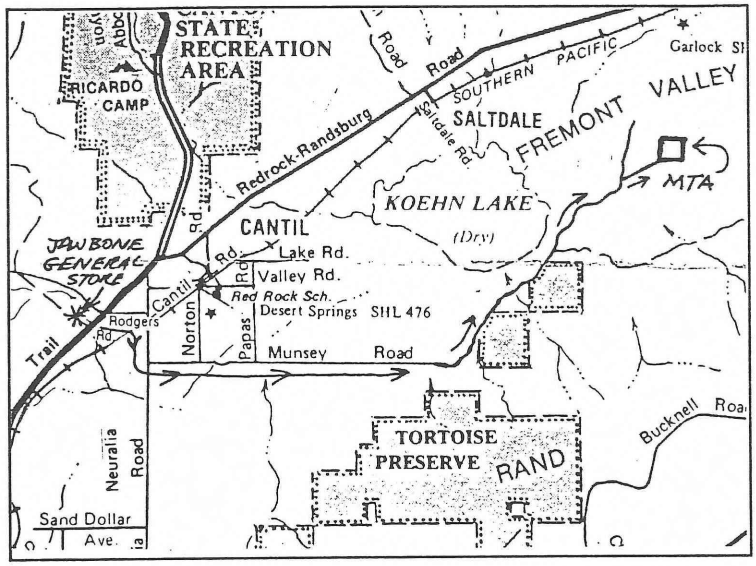

Directions to the

Reaction Research Society Mojave Test Area

The Mojave Test Area is located in Kern County, between the towns of Mojave and Randsburg. To get there from the Los Angeles area and vacinity, take the most direct route to the town of Mojave on Highway 14. North of Mojave, Highway 14 continues toward the north east. Approximately 20 miles out of town and just past the Jawbone General Store and over a bridge, is a turnoff to the right called Rodgers Road. Take this turnoff and continue approximately 0.8 miles to Neuralia Road. Turn right on Neuralia and continue for 1 mile to Munsey Road. Turn left on Munsey and continue east. The road is paved and in good condition for about 4 miles. It turns into a fairly well maintained dirt road at this point and is passable except during severe rains. During the winter months, the road can have some large mud holes after a hard rain. Trucks and 4x4 vehicles usually do well. Low riders may have trouble. A mile or two after the pavement ends, the road forks. Keep to the left at this point. It is easy to follow the road for the remaining few miles, but it can be quite a rough ride over the often "washboardy" surface. The road winds to the north east and passes right next to the edge of Koehn Dry Lake. Do not believe the name! For most of the year, if you try to drive out on the lake bed, you may wind up a permanent fixture of the terrain. Stay on the road. This low point at the edge of the lake bed is the area most likely to turn into a swamp during the rainy season. A short distance further along, the road forks again. This fork is 7 miles from the end of the paved road. This is the junction of Munsey and Range Road. There may be an RRS sign here unless your the first one out to the test site. If not , turn right anyway. You are now headed east toward the MTA on what may be loosely termed a road. Hold on to your hat and go slow. The good news is that there is only 1.1 miles to go before you reach the MTA.

The nearest service station to the MTA is the Jawbone Canyon general store on Highway 14. Most travelers to the test site stock up on food, gas, and whatever else they need in Mojave. There is a Stater Brothers and a Thrifty just at the north edge of Mojave where 14 heads out to the north east. There are also several fast food establishments in town. For those who might like to stay in a hotel for the night instead of camping out at the MTA, the Scottish Inn (805-824-9317), Motel Six (805-824-4571), Travel Inn (805) 824-2441, and Western Inn (805) 824-3601 offer acceptable accommodations for a reasonable price.

The desert is a harsh and unpredictable environment almost any time of the year. Flash floods and sudden desert thunderstorms can occur at any time. From March through November, rattle snakes are fairly plentiful. Do not put your hands or feet anywhere you can not see and make a fair amount of noise as you move about. The snakes are more afraid of an encounter than you are and will vacate the area if you do not surprise them. Black widows are also very plentiful. It is usually cold in the morning and hot during most of the day. It has snowed on us in the winter and summer temperatures have reached over 120 degrees. Bring substantial, comfortable shoes and a sun hat. Sunglasses and sun screen are also recommended. Food and water are essentials.. Bring at least one gallon of water for each person per day. Food should be prepared picnic style for convenience and coolers with plenty of ice are worth the trouble to prepare and haul.

Bring your cameras - the more the better. And bring plenty of film. Ample time is usually available for picture taking of crews getting rockets ready for flight. Getting good pictures of rockets in flight is tricky but can be done - sometimes on purpose, but most times by accident. Bring binoculars, chapstick, toilet paper (we do not have running water but we have an acceptable outhouse), and camping gear if you plan to stay overnight. The Reaction Research Society welcomes you to the Mojave Test Area and the excitement of amateur rocket testing.