RRS News

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REACTION RESEARCH SOCIETY, INC.

VOLUME 53,
NUMBER 2
June, 1996

For the advancement
of rocketry and
astronautics

Solid Rocket Courses

Liquid Rocket Testing

MTA Facility Improvements

The RRS is on the move in 1996 !

RRS News

VOLUME 53, NUMBER 2 JUNE 1996

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 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 200 active RRS members throughout the United States and in several foreign countries.

This newsletter is a more-or-less quarterly publication by the Society and is intended 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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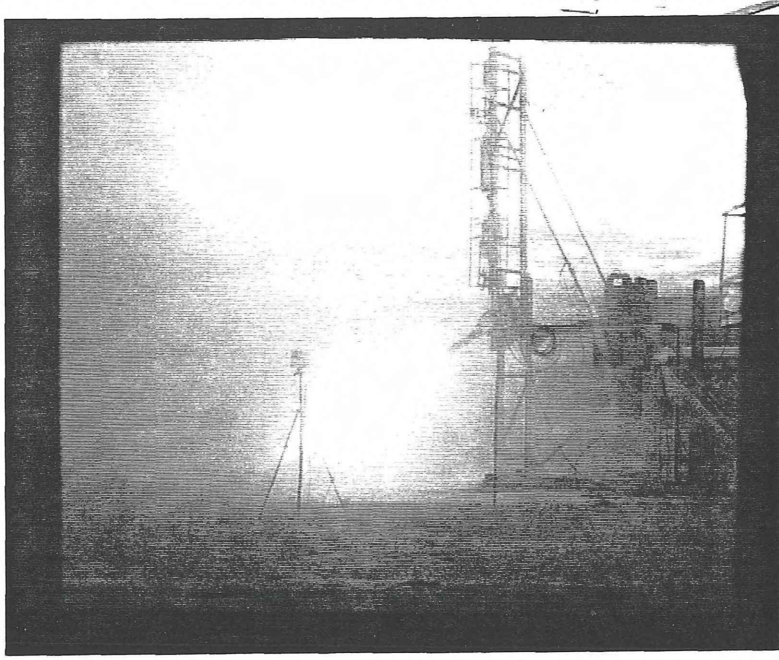

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RRS Memorial Day Work Party

May 23-26, 1996

by Brian Wherley

The year of 1996 will be remembered as the most ambitious year to date for development of the facilities at the Mojave Test Area and this past Memorial Day weekend was perhaps the most effective work party of all time. Several major facility improvements are well underway with their completion finally in sight. Many thanks to all who donated the time and money required to make it a complete success, especially George Garboden and Chip Bassett. Thank God George loves to build things because we would have a real problem if he preferred taking things apart.

As most members know, the need to upgrade the Mojave Test Area to support the Solid Propellant Rocket Motor Design course has forced us to accelerate our planned improvements. Prior to the Memorial Day weekend, the blockhouse was repainted and its floor leveled. A small concrete porch was added around the blockhouse as well. The Quonset hut was straightened up. The new solid propellant fueling area was extended to provide room for a shower stall, the existing water tower, and a sink. The test stand, instrumentation, data acquisition system and presentation materials for the solid propellant course have all been assembled. The solid propellant fueling area, which was a very flat and empty 20 x 20-foot slab for over a year, now has four-foot-high walls that form four separate bays. Each bay has pedestals for bench tops....and bench tops. The shower stall is in place complete with a drain and the April solid propellant course has come and gone. Come to think of it, the June solid propellant course has come and gone also. Now for current events.

The following accomplishments were made possible by the miracle of 5 sack concrete and hard work. No thanks to Cal City Concrete who, after overcharging us in the past, decided to overcharge us even more this time and in so doing nearly brought a calamitous halt to the weekends planned construction activities and more preparatory work than you could shake a stick at. Many thanks to Ridgecrest Concrete who ended up supplying the concrete, to Peter Saueracker (RRS member) for the supplier information he provided and Dave Crisalli (RRS president) for tracking them down. These folks delivered to the job site at 8:59:30 a.m. PDT (actually scheduled for 9:00 a.m.) on Saturday morning, May 25, exactly 20 yards of concrete and dropped it right where it was needed in about 15 minutes; a perfectly executed plan. All that were present knelt and gave thanks. They were either giving thanks or they were exhausted. Present at one time or another were, and forgive me if I have omitted anyone:

George Garboden
Chip Bassett
Brian Wherley
Scott Claflin
Dave Crisalli
Mark Ventura
Doug Caldwell
Niels Anderson
Charles Pooley
Jim Gross and family
Unknown previous member

Item 1: Our friendly contractor, Brian Melka, has completed the slab for the new building. The next step is to take delivery of the 25 x 30-foot building kit and erect it. This will be labor intensive and eager hands will be needed. The new building will have roughly three times the floor space of the old Quonset hut and none of the bugs, rodents or filth. UNBELIEVABLE! Do not miss this upcoming work party or you will never forgive yourself. A bulletin will be sent out announcing the date of this work party.

Item 2: The new entrance gate to the MTA was begun this past weekend. It will consist of an exceptionally large arch and sign that will greet visitors to the site. The arches are salvaged tollway structure and will be fixed to subterranean concrete piers interlaced with 3/4-inch rebar on 18-inch centers. The forms are courtesy of George Garboden with help from Chip Bassett, Brian Wherley and Mark Ventura. Honors for delivery and installation of these forms goes to Chip and his John Deere 510 backhoe. When finished, anyone happening across the MTA will know exactly where they are. In keeping with the definitive new entrance over range road, the compound itself has been physically doubled in size. Removal of debris, fence posts and the like has expanded the boundaries and reduced the danger of fire.

Item 3: Also completed were the 10K pad extensions which will clear the way for erecting the new Vertical Test Stand (VTS). The pad extensions consist of two concrete piers measuring 3 feet wide, 9 feet long and 5 feet deep matrixed with 3/4-inch rebar welded on 12-inch centers. The forms were assembled at George Garboden's shop and delivered to the MTA via flat bed truck. The forms were massive and solidly built, dare I say "Georgebuilt"? Each pier contains four 1.5-inch diameter studs welded into the rebar to permit the mounting of the two forward vertical steel pylons of the VTS. Each pier contains 5 yards of concrete or half a truck load (20,000 pounds worth). The concrete was poured into each form and subsequently vibrated with a rented gadget that helps to remove air and minimize voids. The piers are aligned with the existing 12 x12-foot pad and separated by a six-foot-wide flame trench in which will eventually reside the flame deflector. From 5 feet below grade, the trench will be ramped up with a concrete slab and retaining walls to ground level facing south. In a word, or two, this test stand will be world class.

Item 4: Four sets of four 1.5-inch diameter holes were hammer drilled 12 inches deep in each corner of the existing 10K pad. After drilling (an exhausting, bone jarring, teeth rattling evolution), 18 inch long, 1.5-inch x 6 pitch B7 alloy steel studs were glued into the holes using commercial epoxy masonry adhesive. This will permit installation of the main pylons for the VTS primary structure which will consist of six 8-inch schedule 40 galvanized steel pipe verticals rising to a minimum of 16 feet above the concrete slab. These verticals will be tied together with 7 inch square tube cross beams at 8 feet (level 2) and 16 feet (level 3). The VTS will be complete with catwalks, jib crane, hydraulic lift, thrust mount, electric power, lighting and water deluge cooling system when completed. This may be the largest amateur rocket engine test stand in the world.

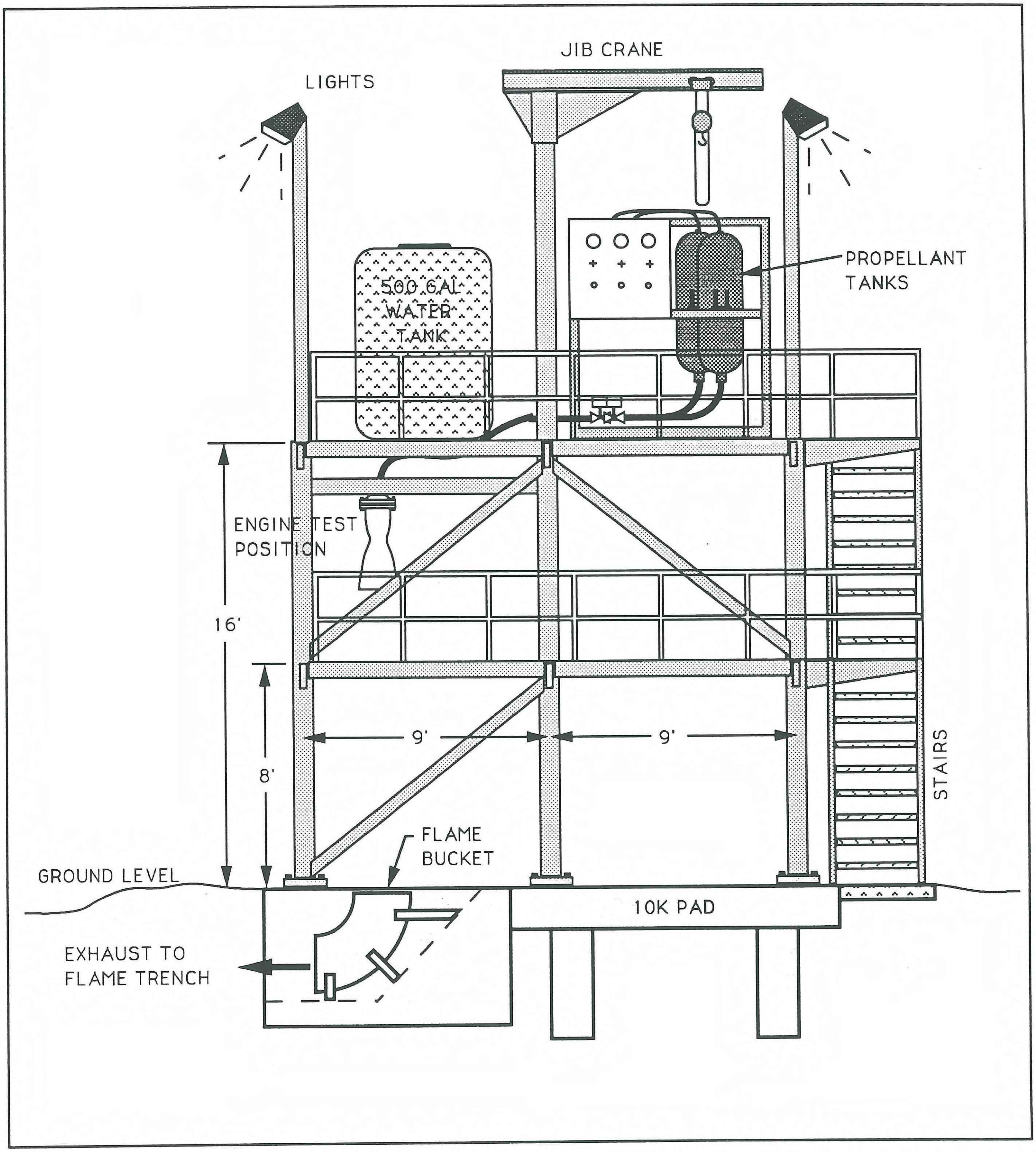
Item 5: The digging, forming, pouring and finishing of a 6 x 6-foot pad for the Beta short launch rack was completed. The rack itself will be relocated after the concrete has cured.

Item 6: The removal and relocation of the old water tower to the Solid Propellant Processing Area (SPPA) was undertaken. This tower will provide water to the shower, sink and fueling bays, but will require some improvement and a coat of paint before it can be affixed to its final resting place.

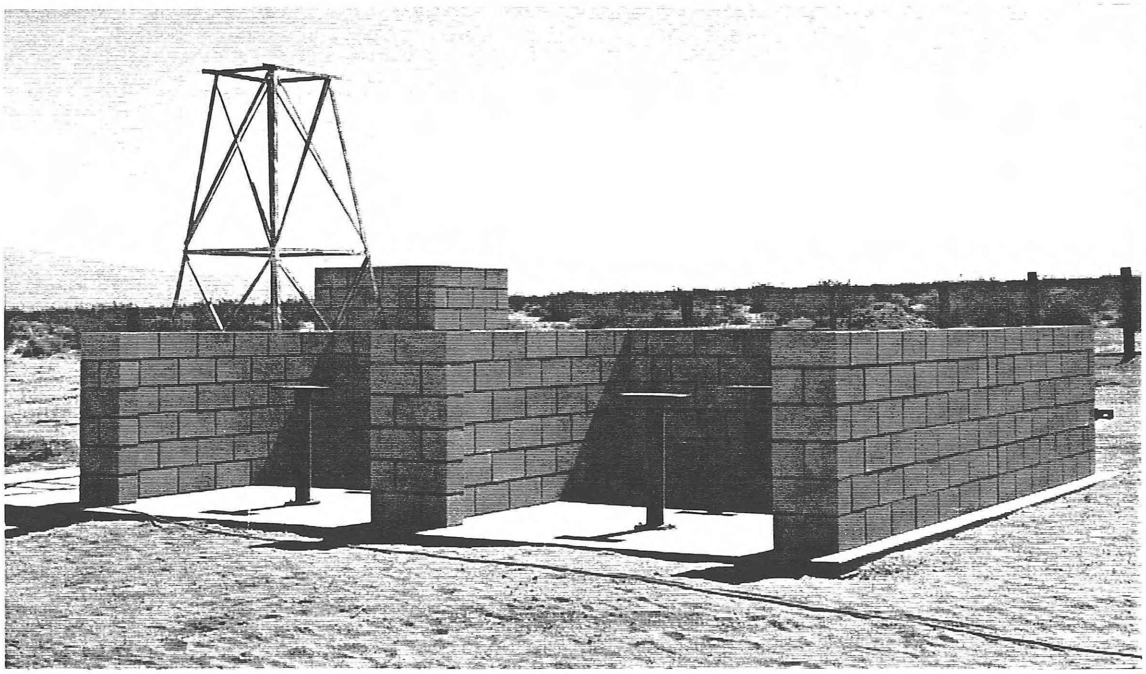
Item 7: One of the Beta long launch racks was relocated to one of the 12 x 12-foot pads cast over a year previously. This will be a much more secure and clean installation for Beta launches than has previously been possible.

Item 8: The last achievement, and certainly far from the least, was the bang-up job done by Mark Ventura and Doug Caldwell in locating and drilling twelve 1.5-inch diameter holes in the other 12 x 12-foot launch pad to accommodate two vertical pylons for the new, pivoting, 40-foot tall, large rocket launch tower. These pylons are heavily armored and the completed launch tower will be spectacular and extremely functional. In the words of the quotable Niels Anderson, **"OUTRAGEOUS!"**

I would like to take this opportunity to ask anyone who has ever considered a life membership in the past but shined it on, to make the donation at this time. Funds are needed and will be put to good use building facilities that many members will use and appreciate each time he/she visits the MTA. Take the plunge, it only hurts when you write the check.

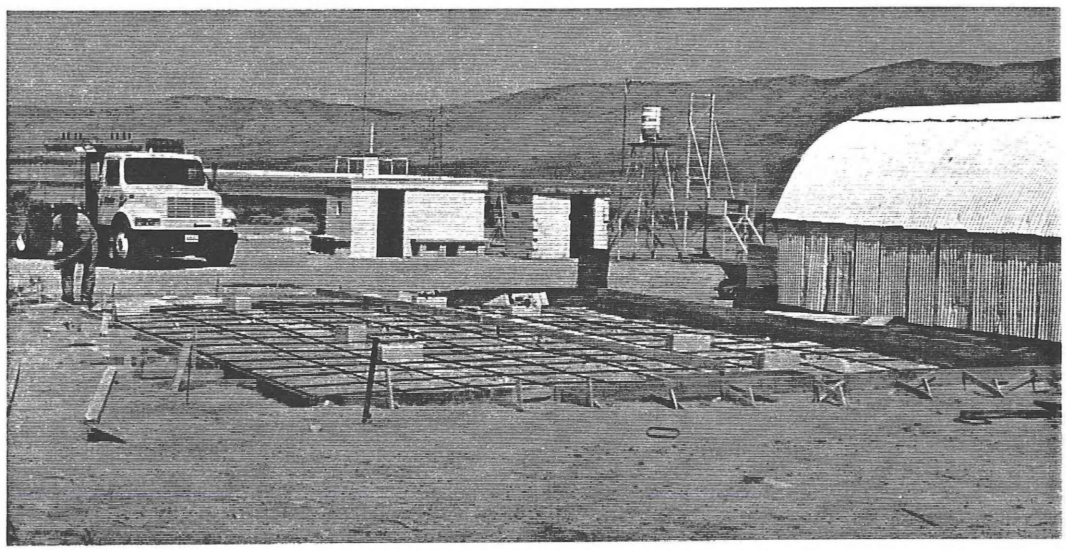


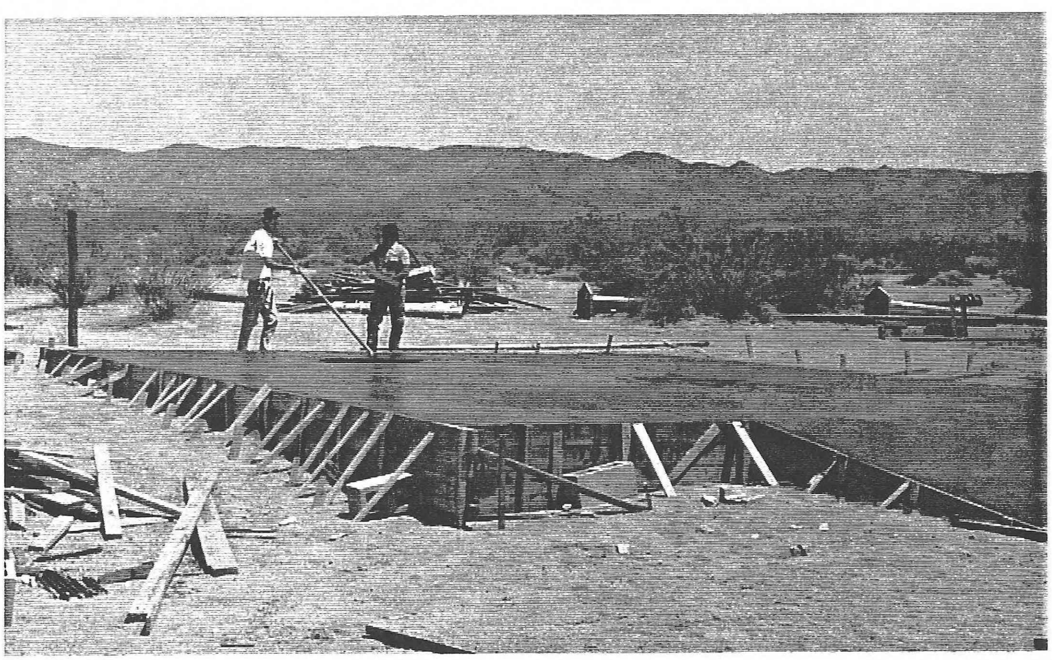
The new RRS Vertical Test Stand (VTS)



The Solid Propellant Processing Area (SPPA) is now being used for the solid propulsion classes. The four bays will eventually be covered by a steel roof and the water tower will supply water pressure to the shower and deep sink to be installed on the north side fo the SPPA. The four 10 foot square bays provide protection, separation and an excellent work area for solid propellant mixing and loading.

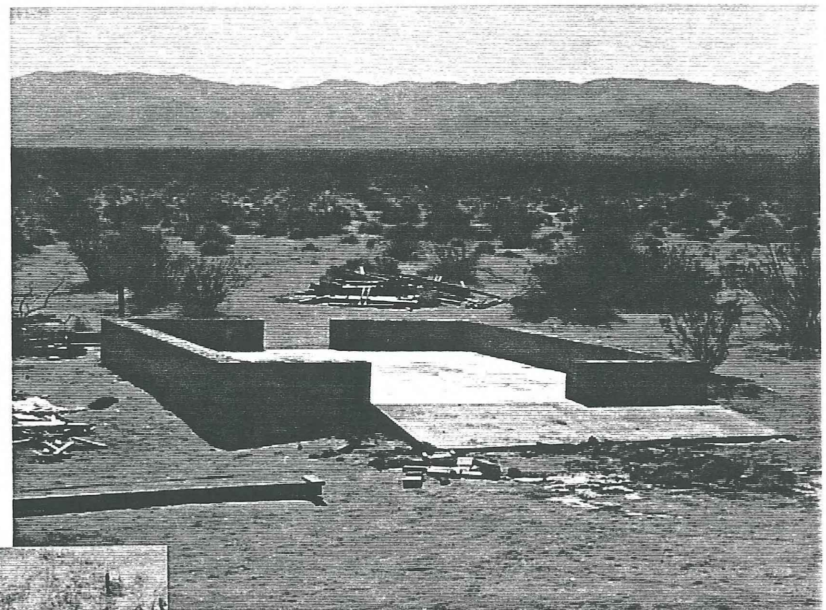
The new steel building foundation was placed next to the old Quonset hut. Requiring 30 yards of concrete, the 30 x 25 foot foundation has been the largest single construction project at the MTA to date. Here the rebar is being completed prior to the first concrete pour.





Finishing the building slab was not an easy task in the very hot, dusty and windy conditions.

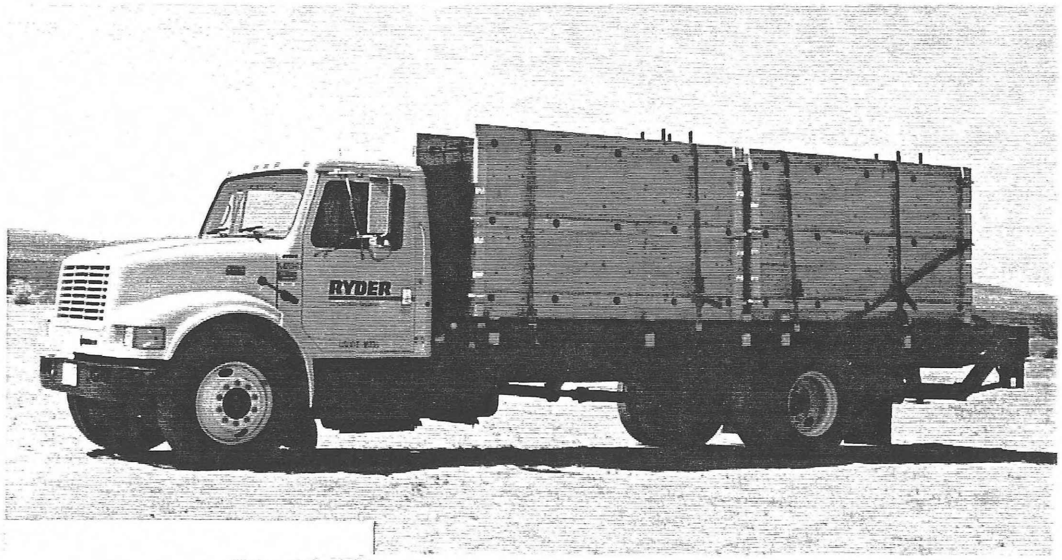
The 16-inch thick, 2-foot high stub walls completed the preparations for setting up the steel structure. By raising the building an additional 24 inches, it will be possible to build an internal partial mezzanine providing additional living and working space. The building will be erected during a work party in August. We are all looking forward to the pleasant Mojave weather conditions in the middle of summer!



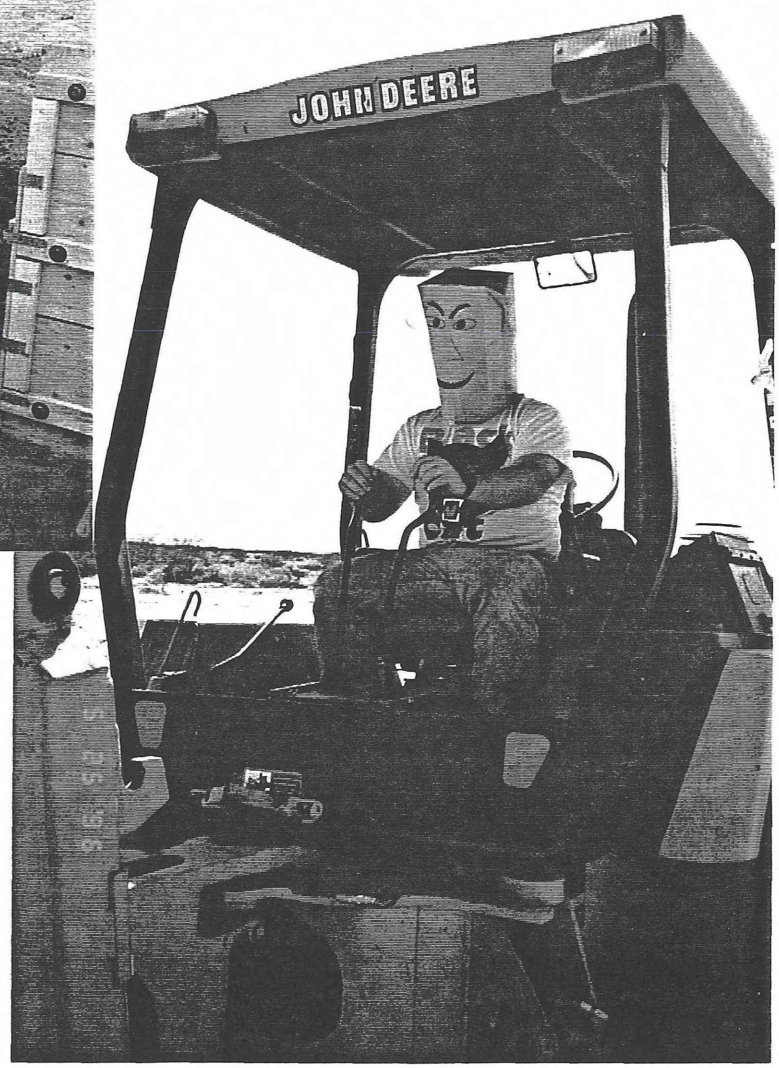
One of the prefabricated concrete forms for the new RRS facility sign is being leveled here at the bottom of a six foot deep hole. Each of these forms took 20,000 pounds of concrete to fill.

Chip Bassett starts to dig the forward abutment footings for the Vertical Test Stand. When completed, VTS-1 will rise almost twenty feet above the slab and the flame trench will run from between these abutments some 20 feet to the south.

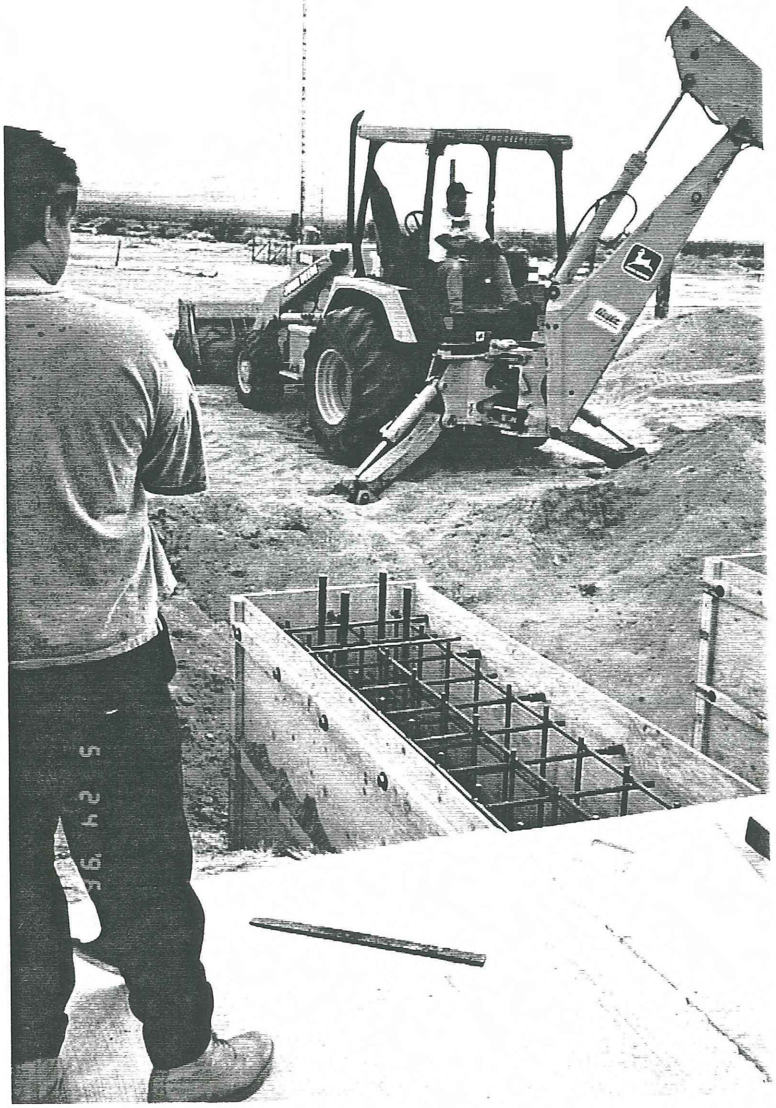
George Garboden had to rent a flat bed truck to transport the four large prefabricated concrete forms out to the MTA. As is apparent from these photos, this type of work requires a tremendous amount of planning, preparation work, logistic support (and money) to complete successfully.



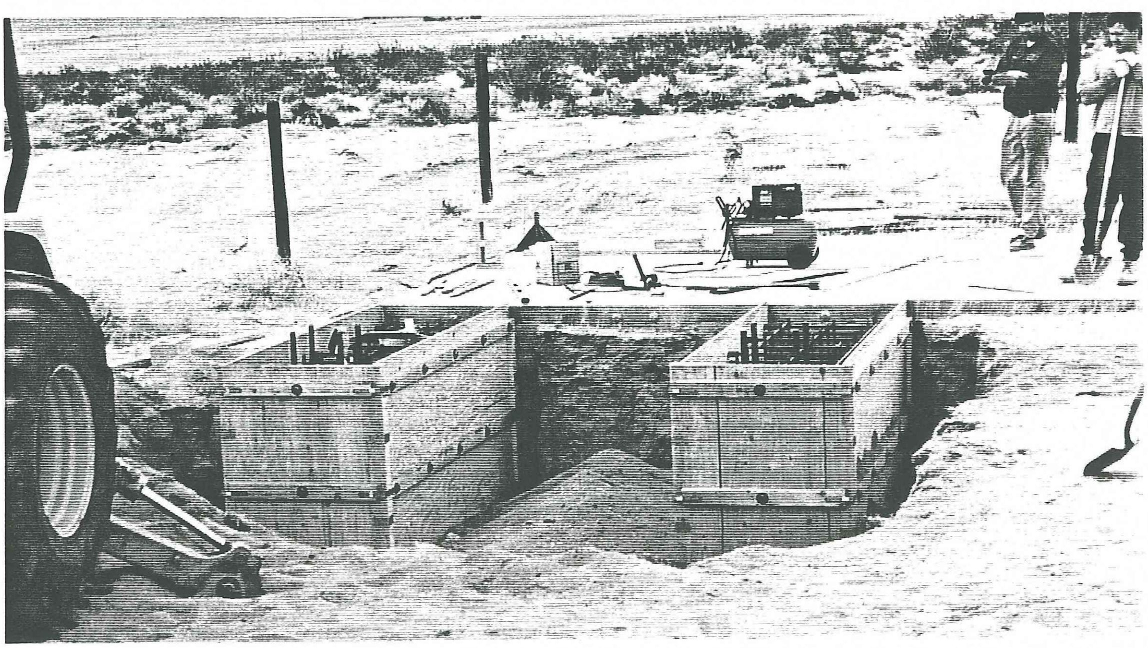
Scott Claflin is installing steel dowel pins in the edge of the existing slab to tie in the new abutments. These were the easy holes. The one and a half inch diameter ones to follow rattled several people's teeth loose as they spelled one another on the drill.



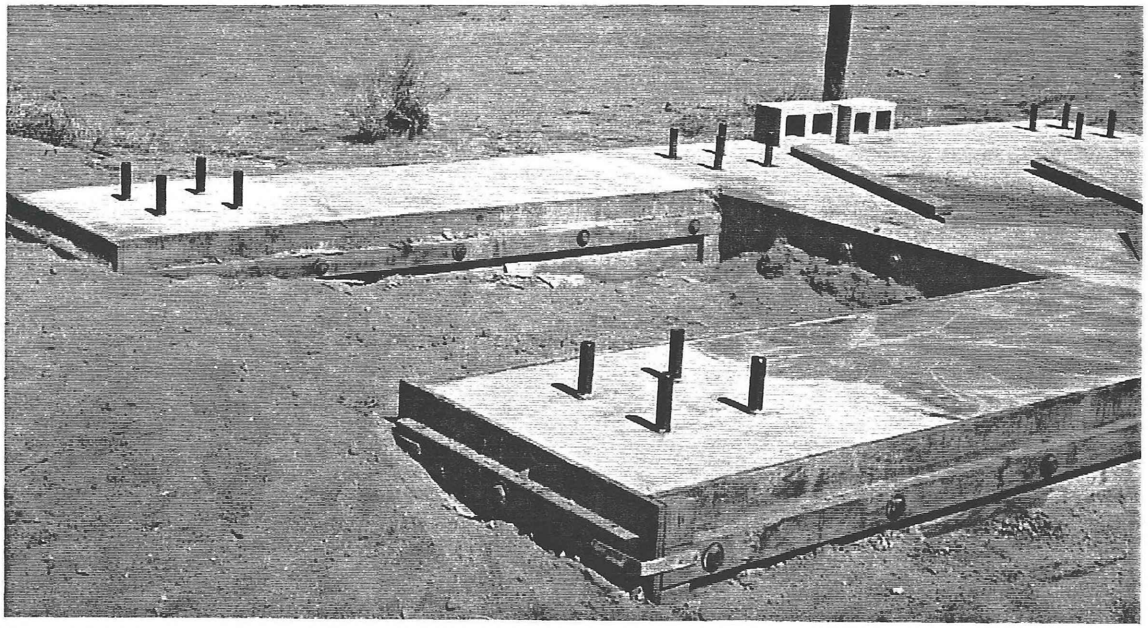
The Unknown Back Hoe Operator (Chip Bassett) works incognito to avoid prosecution if he inadvertently runs over a kangaroo rat or other environmentally protected species. As it turned out, the only species dumb enough to be out there in that weather was "homo RRS erectus."



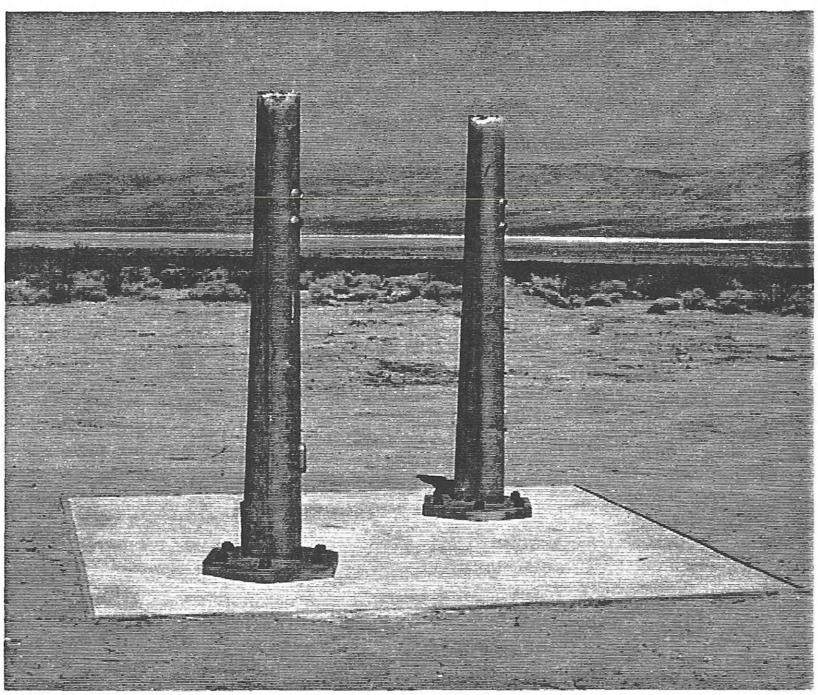
After installation and leveling, the VTS-1 abutments are being backfilled in preparation for the concrete pour.



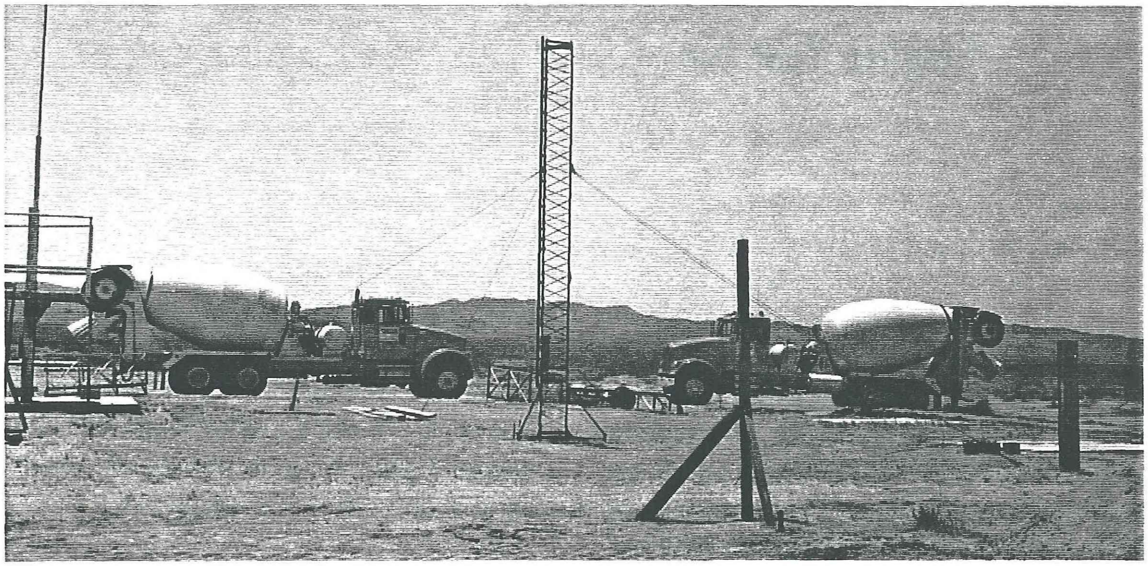
Waiting for 40,000 pounds of concrete to arrive.



The VTS-1 abutments completed. The fill dirt between them and the wooden forms will be removed to pour the concrete for the flame trench.



The vertical pylons for the new 40 foot large rocket launch tower. These are really heavy duty and would probably take a direct nuclear hit. The tower will be pivoted and counter balanced. This will allow rockets to be loaded on the rail horizontally and then rotated to the firing position.



This work party was a first for the RRS - here an empty cement truck is leaving the compound and a full one arriving. We almost had a traffic jam of cement trucks. Two hundred thousand pounds of concrete (50 yards) were delivered in a three day period.

George has been thinking about trading in his pickup truck for something a little larger. This model caught his eye at the rental yard where we got the back hoe. The trick is finding a gas station with a big enough tank to fill this baby!

Engine Test Number 4 - "Desert Thunder"

by Jim McKinnon

Liquid rocket engine ground testing is an exhuasting way to spend a Saturday. It is especially so when it's your countless hours of effort on the line. Each test requires a high attention to detail to ensure that all parts were fabricated and assembled correctly before they are all committed to producing 1000 pounds of thrust for a precious few seconds. During the minutes just before the test, while the tension is high, I am sure I would be having more fun having beer and pizza with my poker buddies. Once the test is over, however, a sense of accomplishment overcomes you that you don't get drawing to an inside straight (a straight flush...maybe).

After three tests of my old thrust chamber injector were less than successful, I designed a new injector based on one that others were having success with. For added insurance, I increased the boundary layer coolant (BLC) that cools the combustion chamber wall from 20% to 25% of the total fuel flow (see Figure 1). Also, I decided that a regeneratively cooled thrust chamber would have the best chance of surviving the 15 seconds or so of burn time needed for my rocket. It would also allow me to use the same engine in a larger rocket if I ever get crazy enough to do so.

After David Crisalli and I fabricated the new injector, we modified another Atlas rocket vernier thrust chamber like I had used previously (see HPR, December, 1994). The thrust chamber was provided courtesy of Brian Wherley who had purchased it from a scrap dealer when these things were still cheap (thanks for not gouging me, Brian!). I treated the coolant passage of the decades old thrust chamber with a heavy duty derusting solution. A rust layer would insulate the liner wall causing the combustion chamber liner to overheat and burn out. The treatment worked like a charm acheiving a 15% reduction in flow resistance through the chamber coolant passage. The reduction provided me with added confidence it would work as designed.

To prepare for the engine test, oxygen components were disassembled, inspected, cleaned and reassembled. After the usual last minute hardware fabrication Friday morning, the entire propulsion system and a truck load of instrumentation, wiring, control boxes, cameras and the like were packed up and again hauled to the desert.

When we arrived at the Mojave Test Area (MTA), the test stand was on its side and had to be erected and put into position. Fortunately for Dave and I, Keith Batt and Richard Butterfield were there already and gave us a hand. It was now dark so we decided to head into town (Mojave) for a good nights sleep and get an early start assembling the propulsion system to the stand. Keith stayed with the hardware and braved the elements that night (cold, wind, and the constant threat of rain).

We arrived back at the MTA at dawn Saturday, February 3 and Dave, Keith and I started to get everything set up. Tom Mueller, who provided the digital data acquisition system, arrived with a few parts that we discovered were missing the night before. As the engine mount was assembled to the stand, we discovered the the engine mount plate and thrust bar were still missing. Tom realized it was still at his house, over three hours away! Fortunately, another RRS member Brian Haack was able to find the missing parts in Tom's garage and bring them to the MTA (thanks Brian!). To add to the turmoil, the 35 mm camera box for close-up pictures was brought, but without the camera! Again, Keith Batt helped out with the only camera that could be made to fit in the box with a bit of ingenuity by Brian Wherley. Scott Claflin brought the liquid oxygen and analog instrumentation. Brian and Scott also helped assemble the instrumentation to the hardware. Thanks to everyone for all your help.

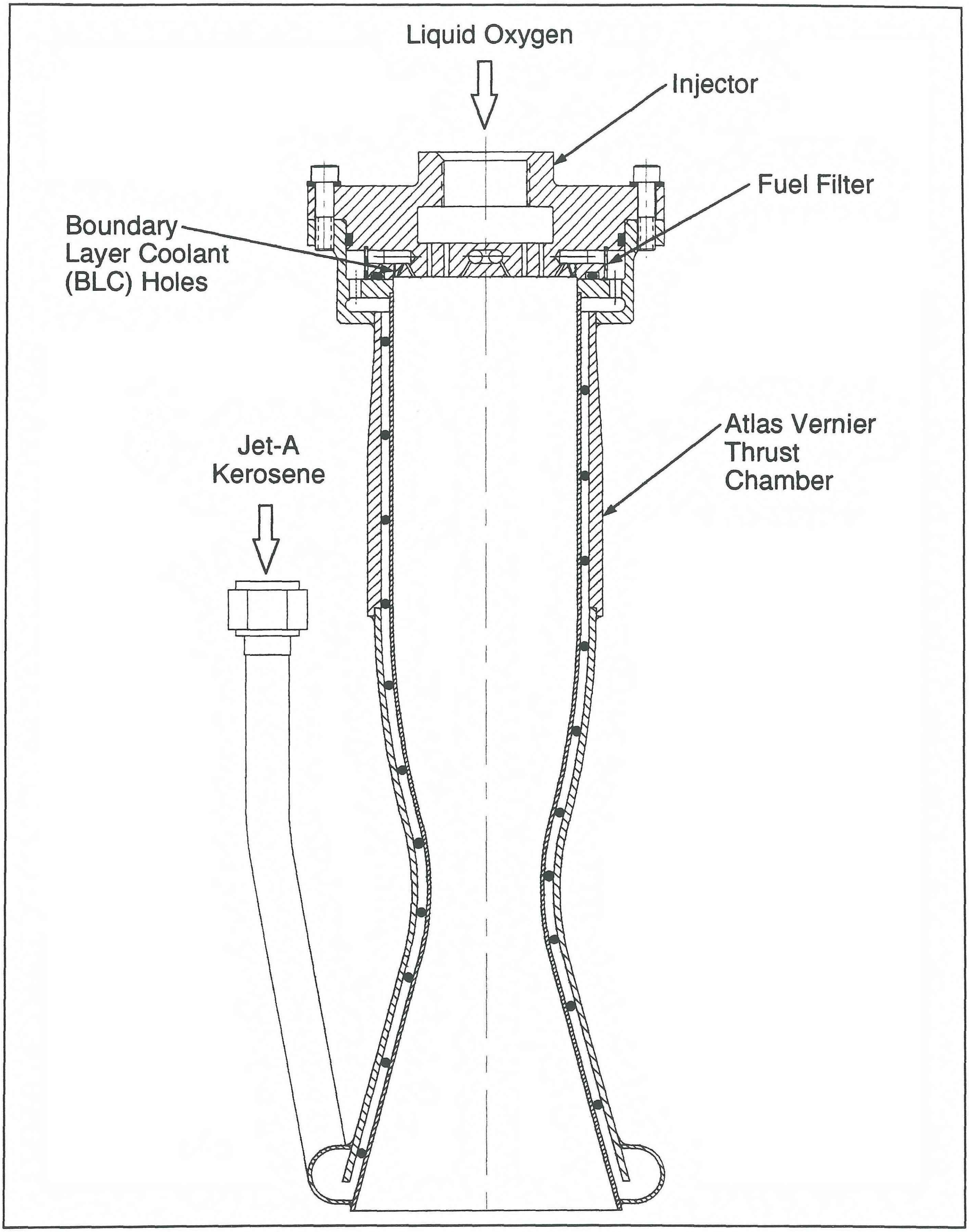


Figure 1 - Cross section of vernier engine.

While we were getting the liquid system ready, my wife Robin successfully flew her first model rocket that she built herself. Now she has the rocket bug! On the high power side, Alan Risse was preparing a PML Quantum Leap upper stage for flight. Alan and I built the rocket together to test out the Adept altimeter and chute deployment circuit that I eventually wanted to use on my liquid rocket. We purchased a Kosdon J270-1050 reloadable motor to give the rocket a good kick to near sonic speed. With a J450-1050 in the first stage, the rocket should go supersonic and provide a good test for the Adept electronics. This was our first venture into high power (solid) rocketry, so we only wanted to fly the upper stage on this outing to get some experience. We also used an Adept sonic beeper to increase our chances of retrieving the rocket.

Once the rocket was ready, it was inserted into the launch tower. Keith Batt provided the firing electronics (thanks again, Keith!) and we wired the Thermalite ignitor. Alan had the honor of firing the rocket while I watched from the viewing bunker. The countdown progressed and at zero...nothing! (Does this happen often?) So Dave Crisalli (our licensed pyro operator) added an electric match and a little black powder to the equation. It was all we needed because at the next count, the motor came roaring to life, hurling the rocket straight and true into the sky, disappearing into a cloud. Those J motors are really impressive! Unfortunately, that was the last we saw of the rocket. Multiple search parties couldn't locate it. The best we can figure, the chute must have deployed OK and the rocket drifted a good distance away. Maybe we'll find it the next time we go out.

After Brian Haack arrived with the engine mount parts, we calibrated the thrust load cell and completed final assembly of the engine to the test stand. After we loaded the fuel, everyone but the test crew was cleared from the test area to the observation bunkers so we could start loading LOX.

Once the LOX tank was full, helium was loaded into the propulsion system and video cameras were started (except mine because both of my batteries failed to hold a charge). Tom Mueller, Scott Claflin, Dave Crisalli and myself were in the block house operating the data acquisition and control equipment and video camera. Dave initiated the countdown, flipped on the ignitor, and at T=0, I switched the main propellant valves on. Nothing. I flipped the switch on and off again, and nothing. The valves were not opening. After depressurizing the tanks, we went out and replaced the ignitor with the backup and increased the pneumatic pressure supplied to the valve actuator.

Everything was ready once again and Dave started the countdown. This time right on cue the valves opened and the engine roared to life. The sound of the continuous thunder of a rocket engine firing still amazes me. Almost immediately, Scott yelled "blow-down!", meaning the propellant tanks were slowly depressurizing due to a low helium bottle pressure. I let the engine run for a few seconds longer since the exhaust flame looked good, and then shut the propellant valves. I looked on in shock as, after shutdown, small flames erupted around the end of the engine nozzle! After a moment I realized it was just the wooden ring burning that the ignitor was attached to (which was harmless) and the flames only lasted a few moments.

After the tanks were vented to safe the test stand, we dumped the remaining LOX and checked the engine for damage. Inspection of the engine revealed a smooth coating of carbon soot typical of LOX/kerosene engines with no erosion at all. The engine worked great!

With this successful test, I now have a proven propulsion system for use in my rocket (Figure 2). The vehicle design is nearly complete and is currently under construction. Most of the structure is already fabricated including custom 10-inch I.D. paper phenolic tubing. Utilizing the test data (Figure 3) to calculate the rocket's flight perfor-

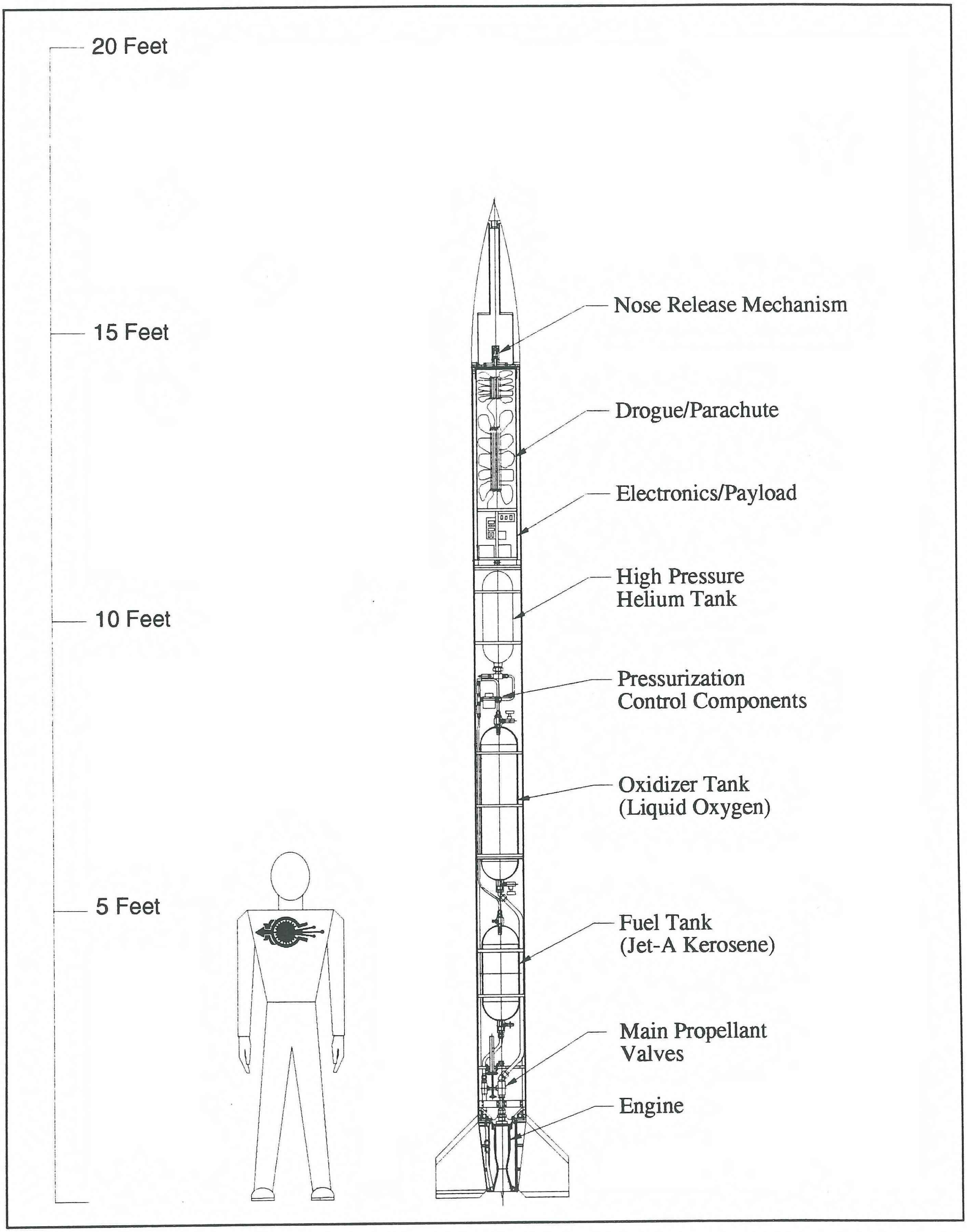


Figure 2 - Vehicle layout

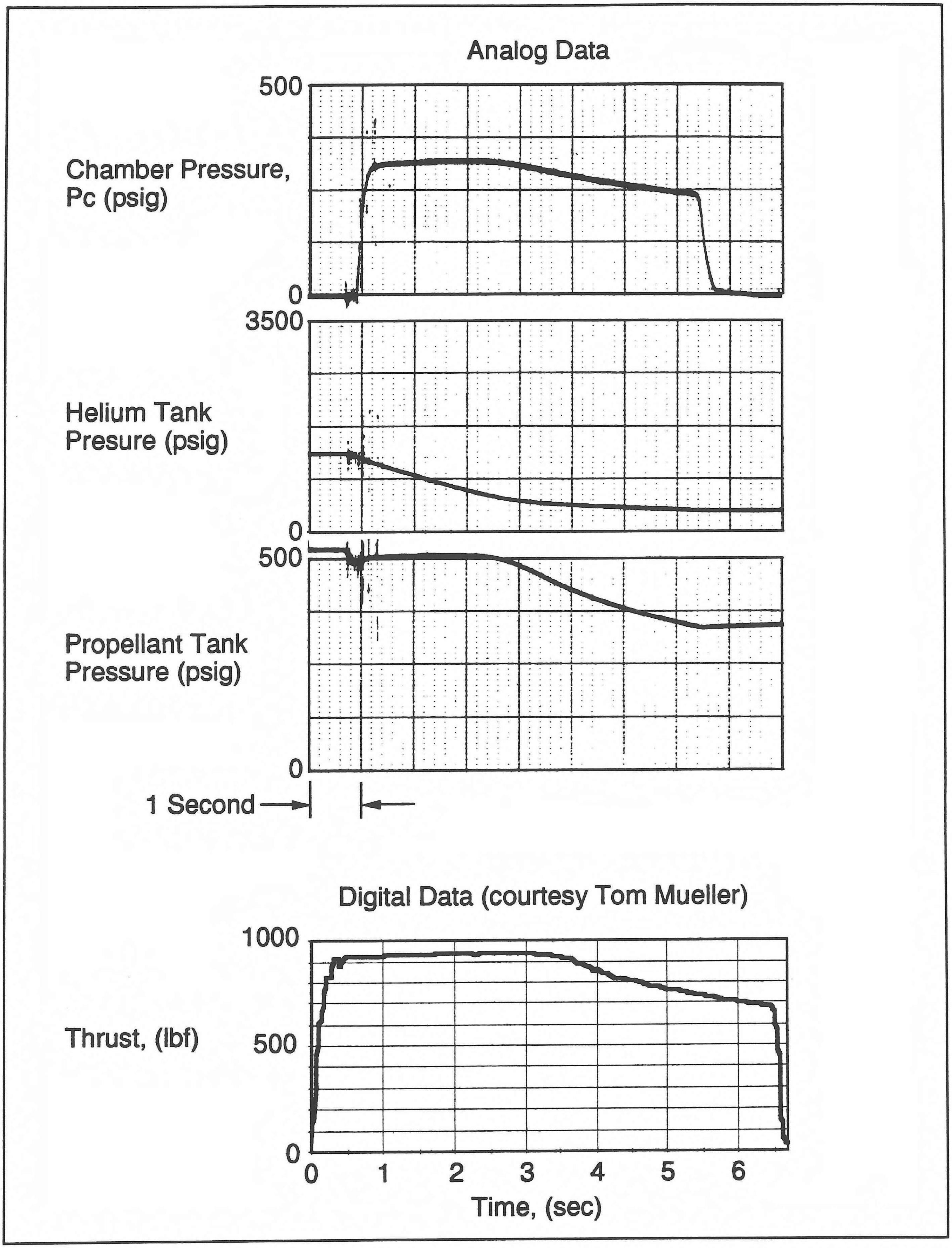


Figure 3 - Test data from Jim McKinnon's fourth LOX/Jet-A engine test.

mance, the actual burn time is expected to be about 15 seconds during the flight. With my predicted vehicle weight, this would provide a theoretical maximum altitude of about 40,000 feet. Depending on my motivation, I will be launching out at the MTA as early as the summer of '96, but hopefully no later than spring of '97. I would like to extend special thanks to David Crisalli, Eric Stangland and Troy Thomason who all contributed countless hours in making this project happen. With team work and lots of luck we might even get the rocket back in one piece!

Figure 4 - In the usual endless tangle of wires, pipes, hoses and cables, set-up for the static test proceeds into the early evening on 2 February 1996.

Figure 5 - Jim and Alan work to complete final preparations on the high power rocket to test an Adept Electronics recording altimter and parachute deployment system.

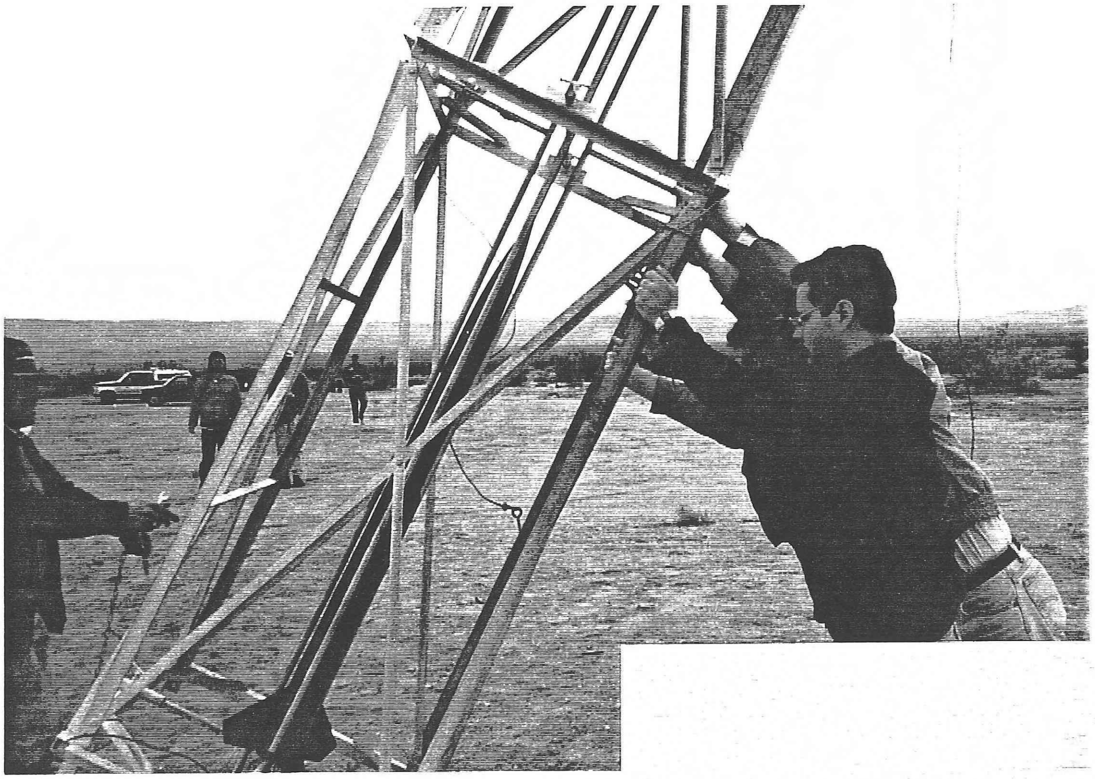


Figure 6 - Standing up the twelve-foot launch tower for the flight.

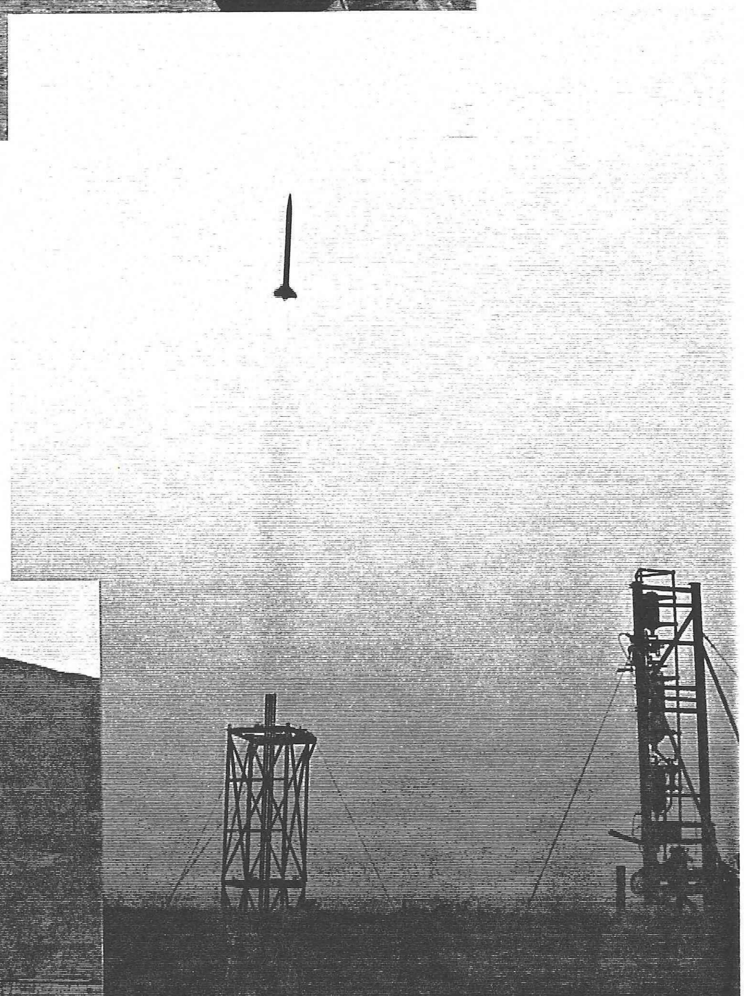


Figure 7 - The last known photograph of this several hundred dollar test rocket. Alas, the best lessons are oft expensive ones.

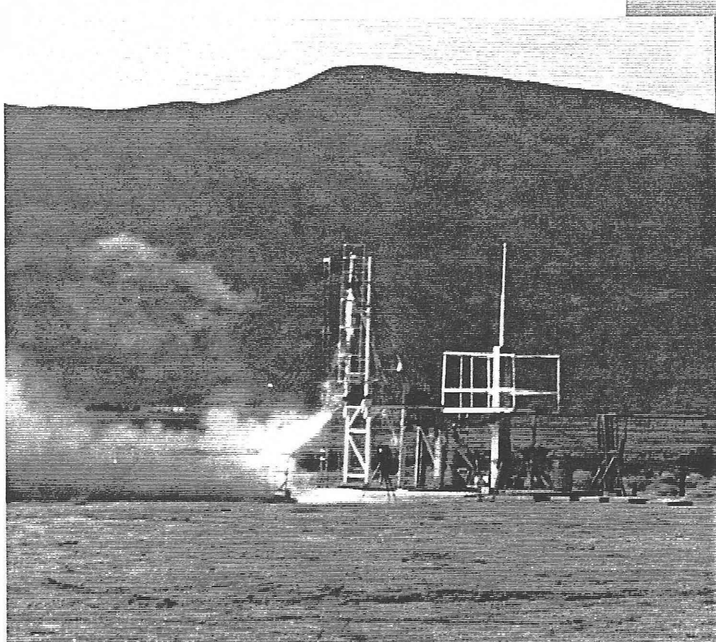
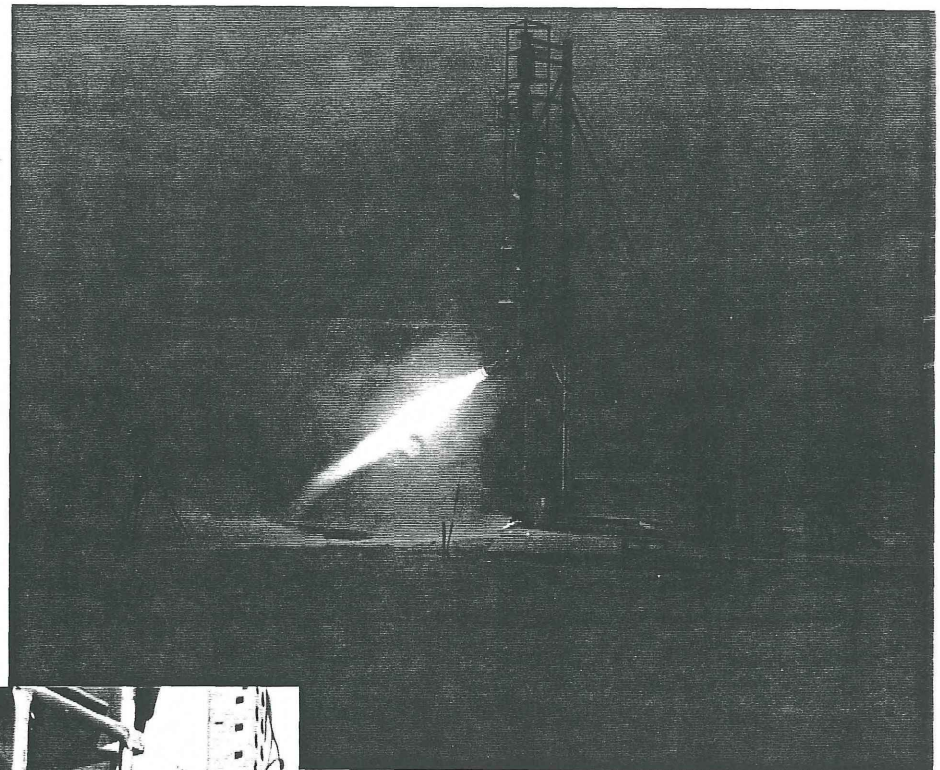


Figure 8 - The engine firing as observed from the bunkers.

Figure 9 - The view of the engine through the blockhouse windows.



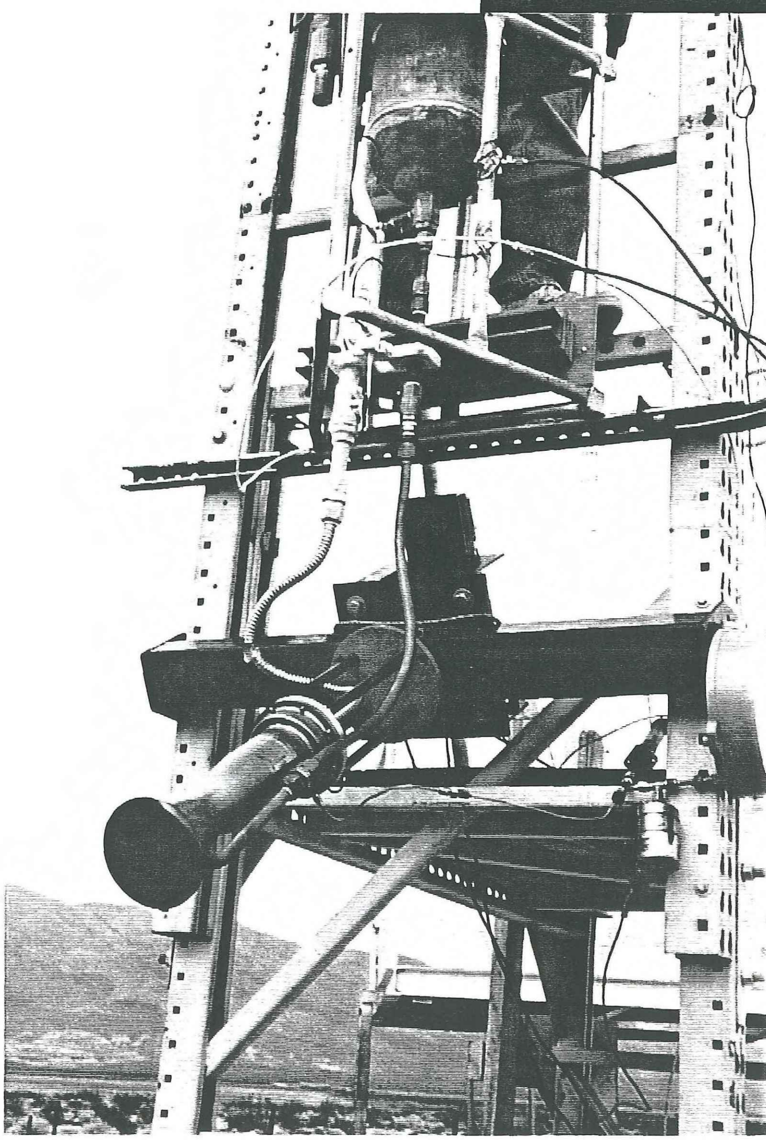


Figure 10 - Just to prove Jim's engine worked well this time, here is photographic evidence that the engine was still intact post-test. (Compare this to all previous post-test pictures of Jim's engine!)

Figure 11 - Stephen McKinnon, age three, appeared to be the smallest and youngest amateur rocketeer on site that day. Stephen poses here with his Estes rocket just before a successful launch.

Figure 12 - Not to be outdone, Kevin McKinnon prepares to take the record for the smallest and youngest amateur rocketeer away from his elder three year old brother. Kevin is wearing the very stylish inflatable blast suit expressly designed for miniature rocket guys.

Editor's Note: The following article was written in its entirety by my 11 year old daughter. But before I am accused of nepotism, let me say that, as the editor of the RRS News trying to meet deadlines, I will browbeat even my own children into writing articles whenever I can. All that aside, the science project documented here represents something that the Society has partially lost over the years. That is the involvement of younger students. I first joined the RRS and fired my first two zinc/sulfur rockets when I was in eighth grade. At that time, many members of the Society were in high school. These days we do not have many younger people involved and that is a shame since one of our main goals is to provide a unique educational experience to students. I would encourage the membership to try to interest high school and college students in what the Society does. This article is just an example of what can be learned and accomplished at even the grade school level.

Land Rockets: An Experiment in Rocket Propulsion

By Katie Crisalli (Fifth Grade)

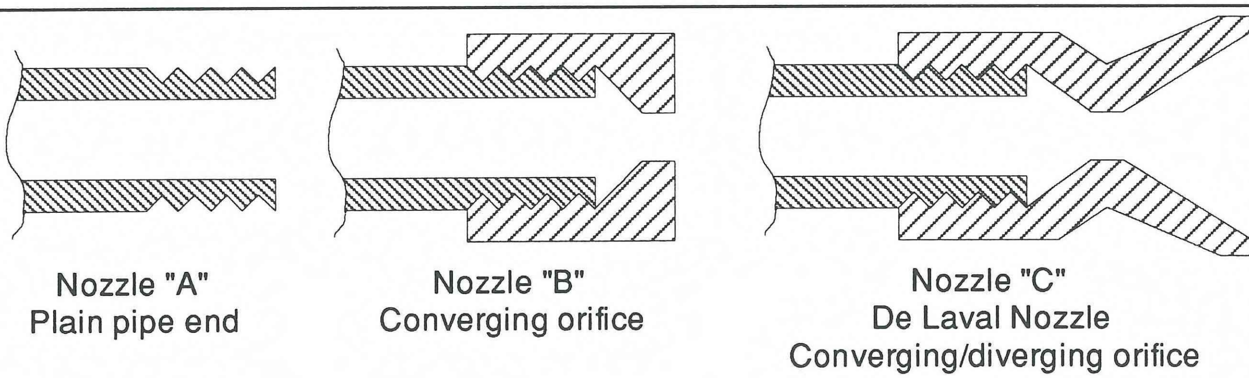
Every year, at Sierra Canyon School in Chatsworth, California, row after row after row of science projects line the walls of several rooms. They are displayed on three-fold cardboard display boards, with reports, procedures and data charts. There are projects on animals, chemicals, electricity and hundreds of other topics, done by students in grades third through eighth.

My father has been involved with rocketry for quite some time. I enjoy watching him work with the rockets and helping him to build and launch them. When thumbing through one of his books one day, I found information on how to build a go-cart powered by pressurized cylinders of carbon dioxide. I thought it would be fun to build one of these as my fifth grade science project. I could test different types of nozzles on it to see which one worked the best.

Although the entire study of rockets and rocket propulsion is very complicated, for the purposes of this project it was possible to reduce everything required to a few fairly simplistic principles.

I chose this science project because I was interested in learning what effect the shape of a nozzle had on the speed of a rocket. To test this question, instead of using a real rocket, I decided on a type of go-cart which was propelled by cold gas (like the ones I had seen in my father's book). I would also use carbon dioxide for propellant to make the experiment safer and less expensive to test.

The "Big Question" (this was a required feature of the science project format) was, which type of nozzle would make the go-cart go the fastest. I machined three different types of nozzles out of brass bar stock on a lathe, labeling them nozzles "A", "B", and "C." (See figure below)



Three different nozzle configurations were tested

My hypothesis was that nozzle "A" would work the best. This is because it was the only nozzle that would allow the gas a larger opening to get through without constricting the flow. Nozzle "C" also allowed a larger opening, but it narrowed the gas flow and thus, I thought, slowed the go-cart down.

With my father's help, I built the go-cart using an ordinary *Radio Flyer* wagon, attaching a pressurized cylinder of carbon dioxide to each side. (Carbon dioxide is a colorless, odorless gas, identified in the 1750's by Scottish chemist and physician Joseph Black. Also, it is non-toxic and not dangerous if inhaled.) One cylinder would be used to propel the wagon forward, and the other was to be used as a braking device. When the main valve on the right-hand side was opened, carbon dioxide was discharged out the back through the test nozzle, propelling the go-cart forward. When a second valve on the left-hand side was opened, a nozzle pointing to the front retro-fired, to stop the wagon. I tested each nozzle by running the go-cart across a known distance, using a stopwatch to record the time it took to cross the finish line with each different nozzle. For each test run, a fresh bottle of carbon dioxide was used. The wagon was also equipped with a seat and a steering bar so that I could control it (well, sort of) as it traveled down the test track.

The experiment was conducted in the parking lot of Rocketdyne's De Soto facility, under adult supervision. In the interest of safety, I wore long pants, a long-sleeved shirt, goggles, and a crash helmet to protect me if the go-cart flipped or tipped over.

For each of the test nozzles, the go-cart was allowed to accelerate for 100 feet. Then a stopwatch was used to time how long it took to cover the next 120 feet. The distances were marked with lines of tape placed on the ground. Between every test, I dismantled all the piping to insert a fresh gas bottle. I then checked to assure that everything was connected again properly.

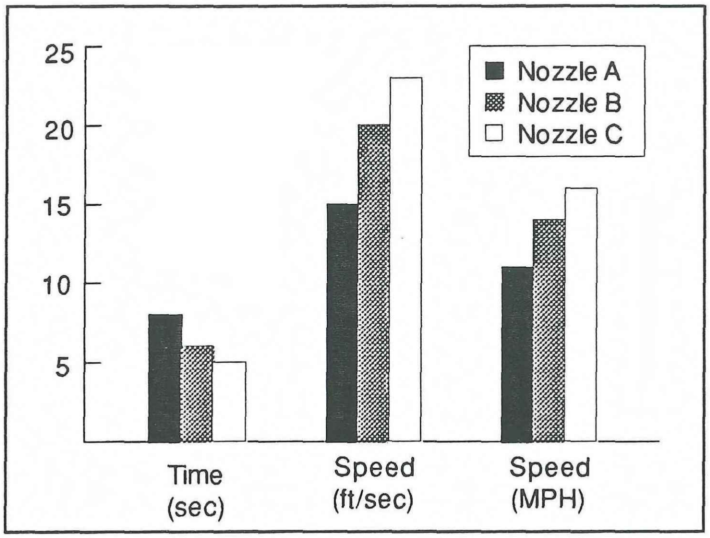
Looking at the data I collected, I determined that my hypothesis was incorrect. After testing my rocket-powered go-cart several times, the conclusion that I reached was that nozzle "C" worked the best. Nozzle "A" was the slowest of the three designs tested, and nozzle "B" was in between.

In studying to complete this experiment, I learned that one of a rocket's most important features is the De Laval nozzle. Invented by a French engineer, named De Laval, it is based on a simple law of physics which effects both liquids and gases. This law states that as a tube diameter decreases, the velocity of the substance flowing through the tube will increase. Thus, the De Laval nozzle is designed so that it first closes down to a narrow tube, (called the *throat* of the nozzle) then flares out to a wider neck. (called the *port* of the nozzle) When used with a gas, this flare allows the gas to expand rapidly, achieving the maximum speed.

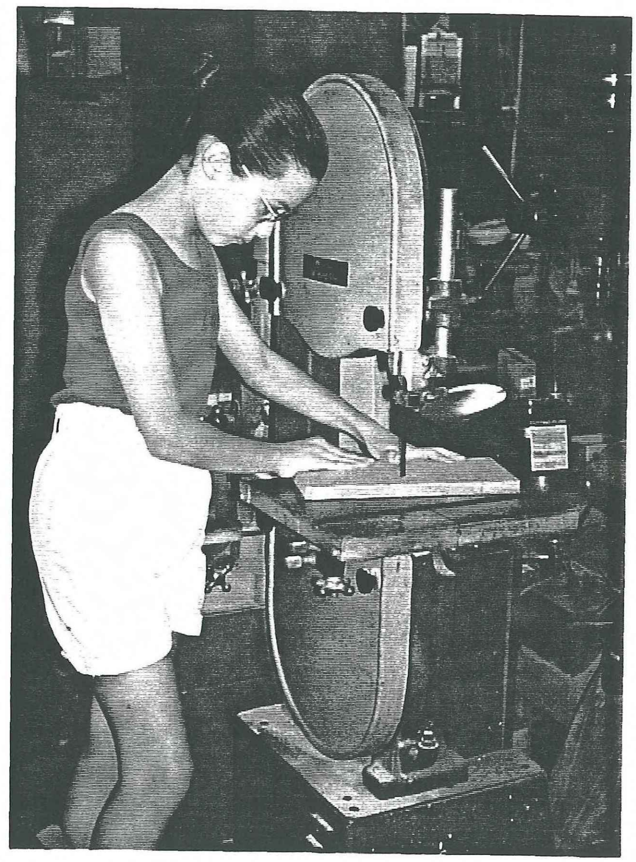
As I learned after having conducted my experiment, the De Laval is the best type of working nozzle. A nozzle which only necks down to a narrow throat works at a mediocre rate, but without the ending flare, maximum velocity cannot be achieved. A simple tube with no nozzle is the least effective, because nothing is done to make the gas flowing through the tube go faster.

There are also two different categories of propellants that can be used in a real rocket. The first of these is a liquid fuel rocket. In this system, the fuel and an oxidizer are stored in two separate tanks. Using either a turbo pump or the pressure of another gas, (such as nitrogen) the two liquids are pushed through the fuel feed lines into the combustion chamber. When these two substances meet, they burn and provide the necessary thrust.

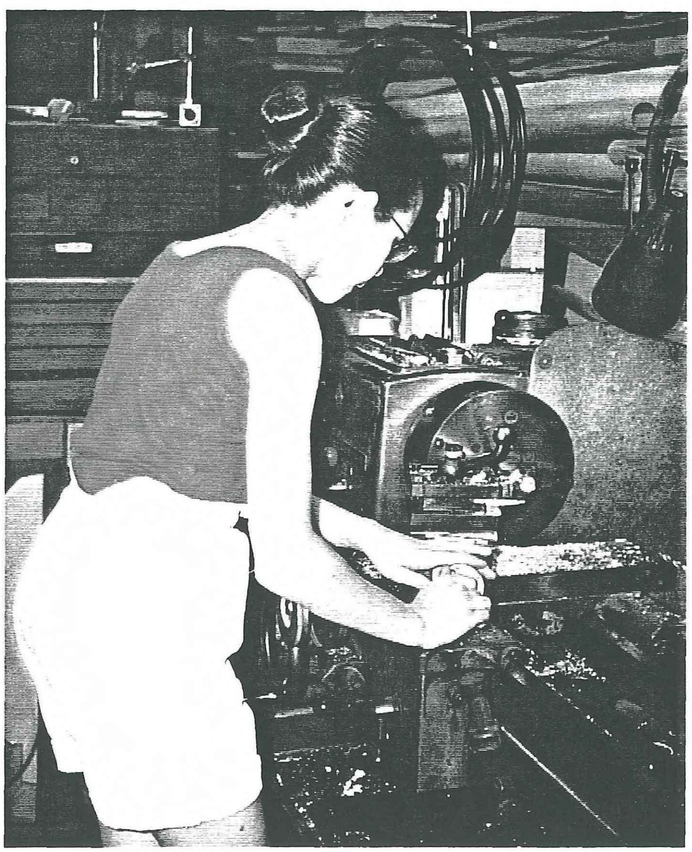
The second type is a solid fuel rocket. With this design, all the solid propellant chemicals are mixed together and formed into a solid, shaped mass. When lit by a spark, the propellant burns and gives off hot gases which flow out the nozzle and create thrust. The De Laval nozzle can be used on either one of these two types of rockets.



Results from the experiment proved that the De Laval nozzle (Nozzle "C") worked the best.



First, to begin my project, I used a bandsaw to cut the pieces of wood to be used to clamp the bottles of carbon dioxide in place. Afterwards, I used wood glue and an air nailer to fasten two wood pieces together, in order to make the clamps stronger and more durable.



I used a lathe and various cutting tools next, to machine the nozzles used in my experiment. I also used a tap (internal threading tool) to create the threads necessary to screw the nozzle onto the wagon. The nozzles were machined out of hexagonal brass bar stock of varied lengths.

Finally, I used assorted size open end wrenches and a crescent wrench to tighten the fittings on the wagon and prepare it for a test run before the actual experiment.

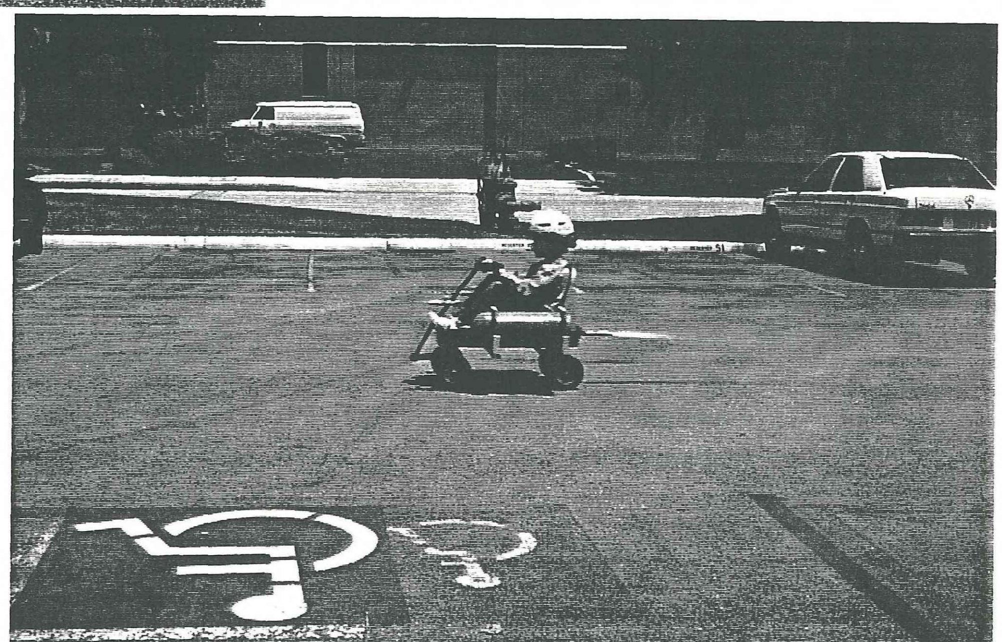
The nearly completed rocket go-cart.

On May 11, I tested my experiment in the parking lot of Rocketdyne's De Soto facility. Here, my grandfather (Emanuel Crisalli) checks to make sure I tighten the fittings properly. He was also the official timer for the experiment. We tested the experiment five times, with three different nozzles. After each test, we had to remove all the fittings and piping to install a fresh bottle of carbon dioxide.

At right is a rear view of the go-cart. Pressurized cylinders of carbon dioxide are on either side. At the bottom is the nozzle where the gas is ejected.

For testing, I wore long pants, a jacket, gloves, crash helmet and goggles, (not shown here) to protect me if the go-cart crashed. At right is the test nozzle, and at left is the retro-fire nozzle, or braking device.

We started the testing by marking lines on the ground. The first two lines were 100 feet apart, for acceleration. The distance between the second to the third lines was 120 feet, where I was timed with each nozzle. Here the go-cart is accelerating for the final test run.



Many people use the words "rocket" and "jet" interchangeably. This, however, is incorrect. Rockets and jets are two entirely different propulsion systems, each having their own distinguishing characteristics. A rocket carries a fuel and an oxidizer, in order to be able to function outside of Earth's atmosphere. This complete independence of its surroundings also makes the rocket the only type of propulsion system able to function in a vacuum. Both jets and rockets work based on one of Sir Isaac Newton's principles: for every action there is an equal and opposite reaction. In a rocket or jet, burning the fuel and ejecting it from the nozzle is the action, and movement of the unit is the reaction.

A jet, on the other hand, uses oxygen from the surrounding air and cannot function in space. Jets run by taking in air from their surroundings, burning it with fuel and expanding it in a turbine. Finally, the air is pushed out through an exhaust pipe, producing thrust. For my project, however, the pressurized cylinders of carbon dioxide were ideal for this purpose because they were safe, very common, and inexpensive.

This project was interesting and fun. I learned a great deal by reading the several references I needed to understand the principles involved. I also learned to use several tools I had not used before to make the go-cart parts and to assemble everything. (Machining on the lathe was the most fun of all). And, finally, I got to ride my science project around a parking lot at high speed. If I had done a project using gold fish or growing mold, I would not have been able to do that!

Materials List

Materials

1. 1 *Radio Flyer* wagon
2. 3/4" plywood
3. 4 ball bearing wheels
4. assorted fasteners
5. assorted pipe fittings
6. 1/2" copper pipe
7. 2 ball valves (1/4 inch)
8. square steel tubing
9. threaded rod
10. 20 lb. carbon dioxide bottles
11. brass bar stock
12. steel strutting
13. wood glue
14. sandpaper
15. flux
16. solder

Tools & Machinery

1. lathe (assorted lathe bits)
2. drill press (drill bits)
3. bandsaw
4. table saw
5. electric drill (drill bits)
6. square drive screwdriver
7. assorted size crescent wrenches
8. assorted size open end wrenches
9. ratchet and socket set
10. assorted hand tools (hammer, etc.)
11. tap (internal threading tool)
12. air nailer
13. vice

Resistor-Initiated Igniters

by Bob Dahlquist

Safe and very reliable igniters can be made from ordinary resistors, such as are used in electronic circuits. These igniters require substantially more voltage and current than electric matches to fire, which is a safety feature. The resistor igniter, when correctly made, is not sensitive to static electricity or electrostatic discharge.

The higher wattage used in firing the resistor igniter translates into more heat released in the initiation of ignition, which makes ignition more reliable. Even with no pyrogen dip or other pyrotechnic compound, the resistor igniter will emit a burst of flame.

When coated with an appropriate pyrotechnic compound, the resistor igniter will reliably produce a ball of fire and ignite the rocket motor. It can also be used with a powdered pyrotechnic mixture such as AlClO, but in this case, the powder may still be sensitive to electrostatic discharge although the resistor igniter itself is not.

The heart of the resistor igniter is a quarter-watt, carbon-film 5% resistor. Its value in ohms is chosen so that it will draw enough current to produce a 200x overload in the resistor. For a quarter-watt resistor, this means that when the firing button is pushed, 50 watts or more will be dissipated in the resistor. This overload converts the resistor's coating to flames within a fraction of a second.

Experiments show that the energy required to produce these flames amounted to about 14 Joules (14 Watt-seconds). The time required for flames to appear varied inversely with the average power dissipation.

$$t = (14 \text{ Watt-sec})/P_{avg} \qquad (1)$$

where t = time delay in seconds for flames to appear
P_{avg} = average power dissipation in Watts

When the resistors were immersed in black powder or coated with a pyrogen composition, the time delay for ignition was substantially less.

Carbon composition resistors were also tested, and had much longer delays. This is because the carbon, where the heat is released, is covered by a thick layer of insulating material (See Figure 1), which delays the release of heat to the exterior.

Carbon composition resistors also often broke in half without producing flame. Carbon film resistors have a ceramic substrate which holds the resistor together during and after firing. Conceivably they could be re-coated with carbon black and used again as resistors (though not as igniters).

Flameproof resistors, holding true to their name, produced no flame at all, even at extreme overloads. These are colored blue. The carbon resistors are brown.

Because carbon has a negative temperature coefficient (its resistance decreases with increasing temperature and vice versa), the resistance of the carbon film resistor igniter will decrease to about half of its initial value during firing. Average power must be used in equation 1 because the power dissipation varies during firing.

When computing power dissipation, all the other resistances in the circuit must be taken into account. This includes the internal resistance of the battery or other power source, the resistance of the wires, and the contact resistance of all the connections and relay and switch contacts; and last, but not least, the contact resistance of the igniter clips.

To achieve the most reliable ignition and shortest delay, when using carbon resistor igniters, the other resistances in the circuit should not add up to more than half of the igniter resistor's initial value. Then when the igniter's resistance decreases during firing, the other resistances in the circuit will not be greater than the igniter.

In choosing what value of resistor to use, then, the criteria are:

(1) The resistor must draw enough current so that it dissipates at least 200 times its power rating initially.

(2) The value of the igniter resistor, in ohms, must be at least twice the total of all other resistances in the circuit.

(3) You must use a standard value of resistance (see Table 2) unless you are making your own resistors.

(4) For shorter ignition delay, the resistor should draw 400 times its power rating when hot (assume its hot resistance is half the initial resistance).

Table 1 gives a range of values that will meet these criteria for a 12.6 volt system.

The resistor igniter works by converting a substantial amount of electrical energy into heat in a small area. The surface area of the carbon film in a 1/4 watt resistor is roughly 5 mm^2 or 0.05 cm^2.
The rate of heat release at 100 watts dissipation is 23.9 (gram) calories per second. The heat flux in the 1/4 watt resistor igniter at 100 watts is thus approximately

$$\text{Heat flux} = (23.9\ \text{cal/sec})/(0.05\ \text{cm}^2) = 478\ \text{cal/cm}^2\text{- sec.}$$

In theory, this is almost 16 times the heat flux required to ignite HTPB propellant directly (see note 3), if the resistor were cast into the propellant or inserted into a close-fitting hole or slot; and it has been verified by experiment that the resistor will indeed ignite the propellant directly. But, to have a short ignition delay within the motor as a whole, a faster burning pyrotechnic compound is usually needed as a booster.

The flame from the resistor lasts longer than the flame produced by an electric match, giving time for more heat energy to transfer to the pyrotechnic booster compound. This makes the ignition

Table 1: Resistance values for 12.6 volt system

To Function Reliably			For Shorter Ignition Delay		
R_i	Max. R_c	Max. R_t	R_i	Max R_c	Max. R_t
1.0	0.50	1.50	1.0	0.391	1.391
1.1	0.55	1.65	1.1	0.384	1.484
1.2	0.60	1.80	1.2	0.376	1.576
1.3	0.65	1.95	1.3	0.366	1.666
1.5	0.68	2.18	1.5	0.340	1.840
1.8	0.59	2.39	1.8	0.295	2.095
2.0	0.52	2.52	2.0	0.260	2.260
2.2	0.44	2.64	2.2	0.220	2.420

All values are in ohms.
R_i higher than 2.2 is not recommended for 12.6 volts.
Left columns are for $P_i = 200 * P_r = 50$ Watts minimum.
Right columns are for $P_h = 400 * P_r = 100$ Watts. (1/4 Ohm Resistor)

R_i = Resistor initial value
P_i = Initial dissipation
P_r = Resistor power rating
R_c = Circuit resistance
P_h = Hot dissipation
R_t = Total resistance

Table 2: Standard 5% resistor values useful for ignition (ohms)

1.0	2.7	6.8	18	47
1.1	3.0	7.5	20	51
1.2	3.3	8.2	22	56
1.3	3.6	9.1	24	62
1.5	3.9	10	27	68
1.6	4.3	11	30	75
1.8	4.7	12	33	82
2.0	5.1	13	36	91
2.2	5.6	15	39	100
2.4	6.2	16	43	110

sequence more foolproof and allows less sensitive booster compounds to be used.

The disadvantage is that the energy source required for the resistor igniter is much larger and heavier. Thus, the resistor igniter is not practical for second-stage ignition, parachute deployment, etc, except in rather large rockets. For such purposes, more sensitive igniters are still needed.

For short ignition delay using resistor igniters, the power source must have low internal resistance.

Note that R_C in Table 1 includes the internal resistance of the power source in addition to the resistance of igniter leads, system wiring, and contacts.

When R_C is low, the resistor undergoes a thermal runaway effect during firing. As the resistor initially conducts electricity and begins to heat up, its resistance decreases due to carbon's negative temperature coefficient. This causes more current to flow, which generates more heat, which causes the resistance to decrease further, which causes more current to flow, and so on.

The thermal runaway effect shortens the ignition delay of the carbon resistor igniter. If R_C is not low, then R_C tends to limit the current increase, thus preventing the thermal runaway. To avoid this, R_C should be no greater than the values shown on the right side of Table 1. With lower values of R_C the ignition delay will be shorter.

The maximum allowable R_C in keeping with this consideration can be calculated for any given voltage, as follows:

For short ignition delay the resistor should dissi-

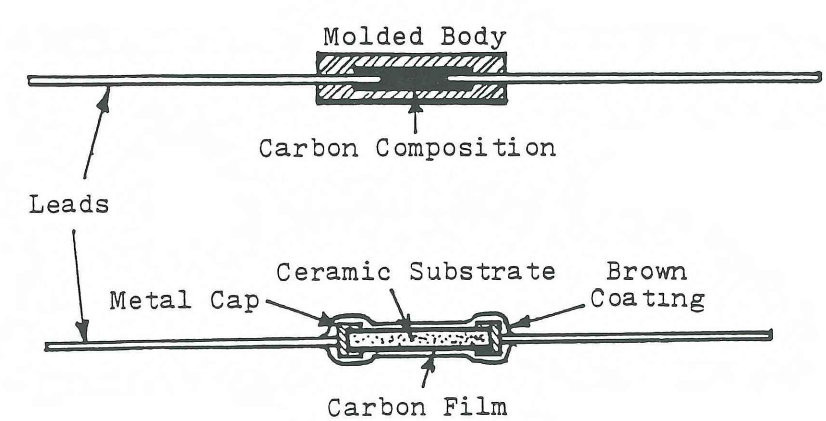


Figure 1 - Types of carbon resistors (cross sections)

pate at least 400 * P_r when hot. We want the hot resistance R_h to be 1 to 2 times R_c. Therefore, begin by assuming $R_h = R_c$ and $R_t = R_h + R_c = 2*R_h$.

Then, the total circuit power must be 2*(400 * P_r), or 800 * P_r based on the hot resistance. Half of the power will be dissipated in the circuitry and half in the resistor.

The maximum R_t is given by

$$R_t = E^2 / P_t \qquad (2)$$

If P_r is 1/4 watt, then

$$R_t = E/200, \qquad (3)$$

where E is the open-circuit voltage and R_t is total resistance and the maximum R_c is:

$$R_c = E^2/400 = R_h \qquad (4)$$

For less ignition delay, limit R_c to half the value given by Equation 4, or use:

$$R_c = E^2/800 = (1/2) * R_h \qquad (5)$$

Now, the value of R_h from Equation 4 must be doubled to find R_i and then R_i (the initial resistor value) must be rounded off to a standard value (see Table 2).

After rounding off, a new maximum value for R_c should be calculated based on the new values of R_i and R_h, as follows.

Calculate a value of current that will cause 400 * P_r to be dissipated in the new value of R_h (which is 1/2 the new value of R_i).

$$I = (P/R_h)^{0.5}$$
$$= (400 * P_r / R_h)^{0.5} \qquad (6)$$

where I = Current (amps) required (minimum)
P = Power dissipated in the resistor, watts
P_r= Power rating of the resistor (1/4 watt)
R_h = Hot resistance of the resistor, ohms

Now, use Ohm's Law to calculate total resistance R_t such that the desired current will flow:

$$R_t = E/I \qquad (7)$$

The new value of R_c is then found by subtraction:

$$R_c = R_t - R_h \qquad (8)$$

This is a maximum value for R_c; using a lower value will result in a shorter ignition delay.

Example 1: The power source for this example is a 9.6 volt Nicad battery pack.

Assume: $R_h = R_c = E^2/400 \qquad (4)$

$$R_h = R_c = 92.16/400 = 0.23 \text{ ohm}$$

$$R_i = 2 * R_h = 0.46 \text{ ohm}$$

Since the lowest standard value is 1.0 ohm, R_i must be rounded off to 1.0 ohm. The new R_h is half of that or 0.5 ohm.

The minimum current required for 400 * P_r is:

$$I = (400 * P_r/R_h)^{0.5}$$
$$= (400 * (1/4) / 0.5)^{0.5}$$
$$= (200)^{0.5} = 14.14 \text{ amps} \qquad (6)$$

The maximum total resistance R_t for this current to flow is:

$$R_t = E/I = 9.6 \text{ volts}/14.14 \text{ amps}$$
$$= 0.6788 \text{ ohm} \qquad (7)$$

The new value of R_c is:

$$R_c = R_t - R_h = 0.6788 - 0.500$$
$$= 0.1788 \text{ ohm (max.)} \qquad (8)$$

Note that R_c includes the internal resistance of the battery pack. Note that 0.1788 ohm is a maximum; a lower value will result in a shorter ignition delay.

What is the absolute minimum voltage to be used with a resistor igniter? Assume R_c is zero and R_i is the minimum standard value, 1.0 ohm. Then,

$P_i = 200 * P_r$, based on R_i, and $P_r = 0.1$ watt. Then, $P_i = 50$ and

$$E = (P_i * R_i)^{0.5} = (50)^{0.5} = 7.07 \text{ volts}$$

or, $P_h = 400 * P_r$ and $R_h = 0.5$ ohm. Then, $P_h =$ 100 watts and

$$E = (P_h * R_h)^{0.5} = (50)^{0.5} = 7.07 \text{ volts.}$$

In practice, this voltage is too low because R_c will never be zero except in a laboratory situation with a regulated power supply and a four-wire connection to the igniter resistor. But it is useful to know what the lower limit is. To find the practical lower limit, multiply the absolute lower limit by $(2)^{0.5}$ to allow for circuit resistance, and round off to the nearest available battery voltage.

$7.07 \times (2)^{0.5} = 10$ volts (9.6 volts is close)

The following example involves the highest practical voltage for use of a resistor igniter. The power source for this example is a portable generator producing 120 volts AC at 1,000 feet from the rocket, on a very large dry lake bed.

Example 2: Assume E is 120 volts and P is 1 watt. What value of resistor should be used, and what gauge wire is required for a cable length of 1000 feet?

Assume: $R_h = R_c = E^2/400$ (4)

$$R_h = R_c = 14400/400 = 36 \text{ ohms}$$

$$R_i = 2\,R_h = 72 \text{ ohms}$$

Round this off to 75 ohms, the nearest standard value (Table 2).

The new R_h is 75/2, or, 37.5 ohms.The minimum current required for $400 * P_r$ watts is

$I = (400 * P_r/R_h)^{0.5}$
$= (400 * 0.25/37.5)^{0.5} = 1.633$ ohms (6)

The maximum total resistance R_t for this current to flow is

$R_t = E/I$ (7)
$= 120$ volts/1.633 amps $= 73.48$ ohms

The new value of Rc is then

$R_c = R_t - R_h$ (8)
$= 73.48 - 37.5 = 35.98$ ohms

Round off to 36 ohms in this case. Normally, you would round down, not up.

Check the copper wire table to see what size wire has low enough resistance (Table 3). Remember that there are 2000 feet of wire in a 1000 foot pair. Also don't forget to allow for the internal resistance or droop of the power source.

Because the total length of wire is 2 x 1000 feet, its resistance per 1000 ft. must be no more than 36/2, or 18 ohms/1000 feet. According to the Table 3, #22 has 16.46 ohms/1000 feet and will carry 8 amps. A #22 pair would have about 33 ohms of resistance, and will work if the internal resistance power source is 3 ohms or less. A shorter ignition delay would result if #20 is used and would have 20.7 ohms resistance.

Note that when using 120 volts AC, the insulation of both the cable and the igniter leads must be able to withstand the peak voltage. With a square wave source such as a cheap inverter, the peak voltage is 120 volts. With a sine wave source such as a generator, it is $(2)^{0.5} * 120$, or 170 volts.

When using voltage above about 40, it is possible to have an arc in the igniter or between the igniter leads after ignition. It is also possible for the igniter leads to weld themselves together. An arc has relatively low resistance, and of course a weld has essentially no resistance. Thus the current would be limited by the R_c alone.

Table 3 - Resistance for copper wires

Gauge (AWG #)	Milliohms Per Foot or Ohms Per 1000 Feet of Single Wire	Current Carrying Capacity, Amps Continuous
10	1.018	55
12	1.610	41
14	2.575	32
16	4.094	22
18	6.510	16
20	10.35	11
22	16.46	8
24	26.17	5.5
26	41.62	4
28	66.17	2.75
30	105.2	2

For a pair of wires, multiply the length of the pair by 2.
At 1 amp, each milliohm causes one millivolt of voltage drop.
At 10 amps, 100 milliohms would produce a voltage drop of 1 volt.

In this case our R_C is somewhat greater than 33 ohms. Then, the short circuit current will be limited to:

$$I = E/R = 120 \text{ volts}/33 \text{ ohms} = 3.64 \text{ amps}$$
(with #22 cable)

When using voltages over 40, make sure your R_C is not too low; add a ballast resistor or current limiting fuse, if necessary.

If other things such as fuel and LOX valves and computers are running off the same power source, you do not want shorted igniter leads to trip the main circuit breaker. If you want to see some very nervous people, just attend a launch where this happens and leaves a fully loaded and pressurized liquid fuel rocket sitting on the pad with no way to vent the LOX tank until someone goes out and gets the power source on line again.

The 120 volt igniter circuit should have its own properly sized magnetic circuit breaker or current limiting, fast acting fuse, or its own separate power source.

In addition, the white wire should not be grounded except through a 1-megohm resistor, unless a ground fault circuit interrupter (GFCI) is used, for personnel safety.

Internal Resistance

The internal resistance or effective series resistance of any power source can be calculated after first measuring the voltage droop under load:

$$Res = \Delta E / I$$

where ΔE = voltage droop
I = current at which ΔE is measured
Res = effective series resistance, or internal resistance of the power source being tested.

Assembly

Once you have chosen the right value of resistor, you can assemble your resistor igniters as shown in Figure 2.

You must choose the appropriate igniter lead wire gauge for the length of leads that you need. The igniter leads are part of R_c, so don't forget to include their resistance in your calculations. The drawing shows #24 wire 18 to 36 inches long, but you can use whatever you need. (Refer to Table 3.)

Notes

1. The temperature coefficient of resistivity for graphite varies with temperature, but on average it is about - 2.7×10^{-4} ohms/ohm-°C, that is, the resistivity decreases as the temperature increases.

To find the hot resistance, R_h, you can use the following formula.

$$R_h = R_i + R_i * (T_h - T_i) * (-2.7 \times 10^{-4}) \text{ ohms}$$

where R_i = the cold resistance in ohms
T_i = the initial temperature in °C
T_h = the hot temperature in °C

2. For a given value of EMF and R_c, maximum power to the load resistance occurs when $R_L = R_c$. When R_L is less than R_c, most of the power is dissipated in R_c (defining R_L as the load resistance or igniter resistor, and R_c as all the other resistance in the circuit combined).

3. The approximate threshold heat flux is given as 30 cal/cm2-sec in Ignition by Lawrence G. Teebken.

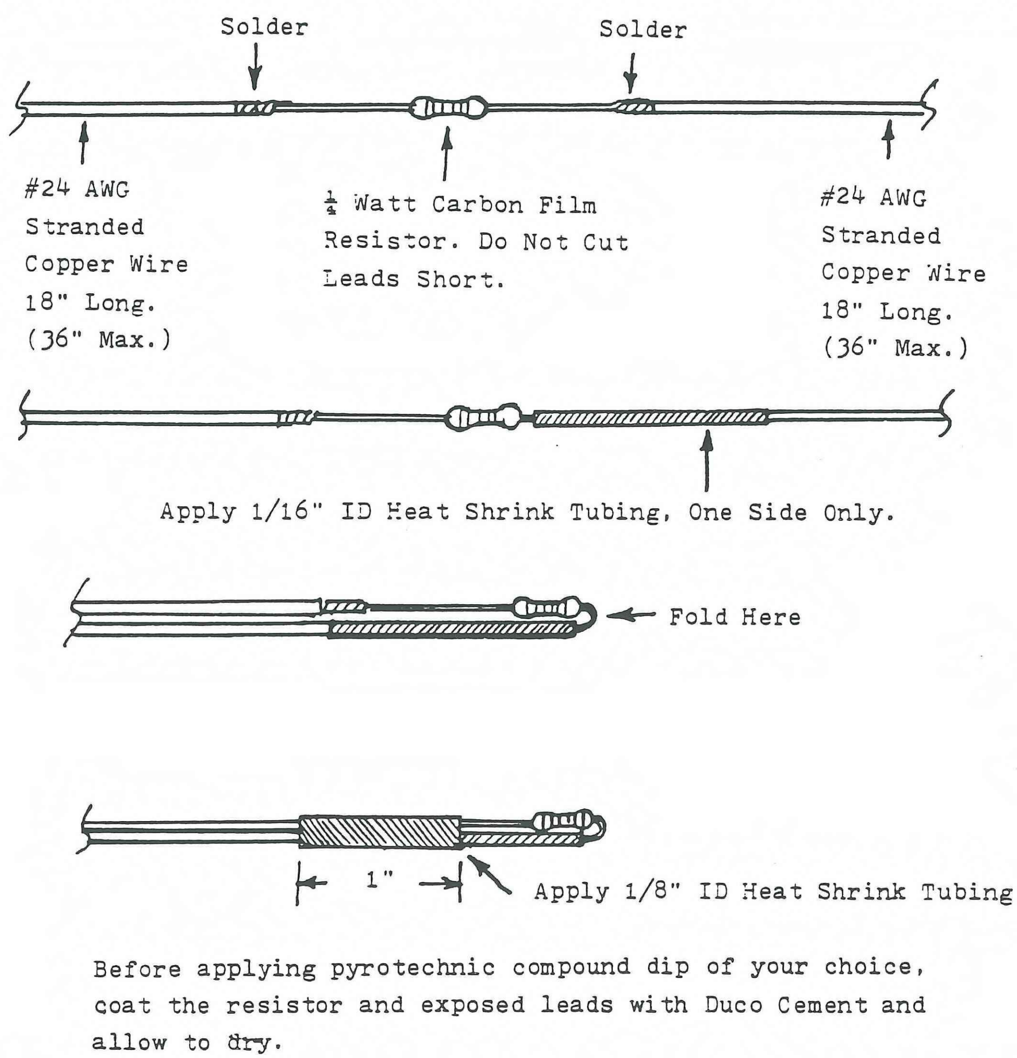


Figure 2 - Assembly of a resistor igniter

[The following article is an adaptation of a letter written by a group of amateur rocketeers in Denmark explaining their activities in liquid rocketry. We have sent them a few of our last newsletters and a note inviting them to write us a longer article on their progress. When I received this letter, I was struck by the fact that the author did a much better job of writing to us in English than I could respond in Danish! -Ed.]

Amateur Rocketry in Denmark

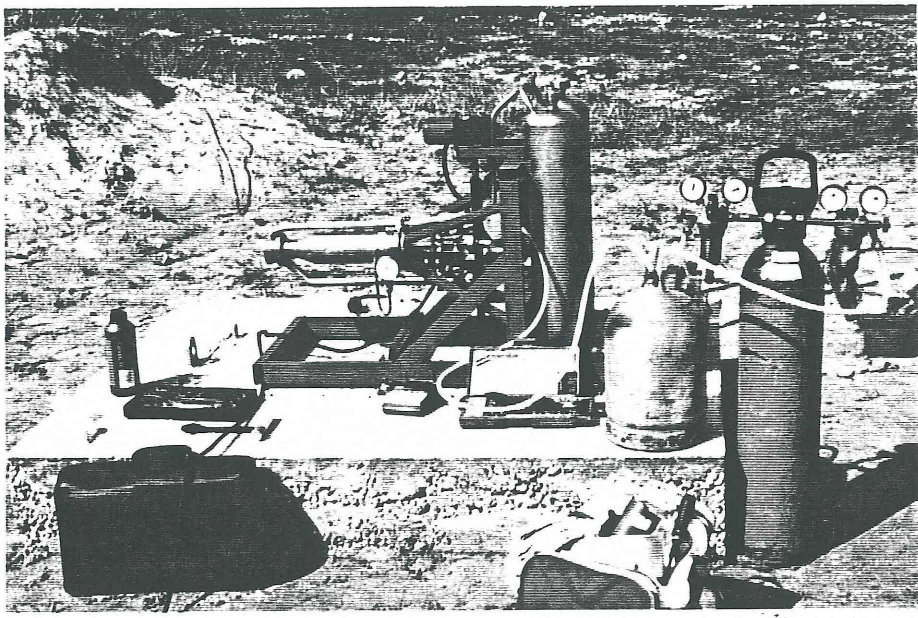
My name is Peter Madsen. By 1990 I was assigned the job of designing propellant tanks for the Tune Volunteer Missile group. Since May 1993, the TVM group has been testing liquid fuel rockets statically on an army artillery proving ground and in an abandoned gravel pit. Today, this gravel pit, its 4000 lb concrete test stand and LOX storage, is the center of our activity. We started out with storable fuels, WFNA/turpentine, in May 1993 and had the first completely successful test by April 22, 1995. I have included some photos of the EM-3 engine used. By December 10, 1995, we tested with LOX/75% ethanol and again by February 11 with LOX/kerosene. Our engine is film and regen. cooled and has a special heat exchanger for the helium pressurization gas near the nozzle exit.

We are, of course, very interested in the activity of you and Mr. Blair of Australia *[Mark Blair, founder of Australian Space Research Institute]*. I was hoping to get some contact to the U.S. rocket community.

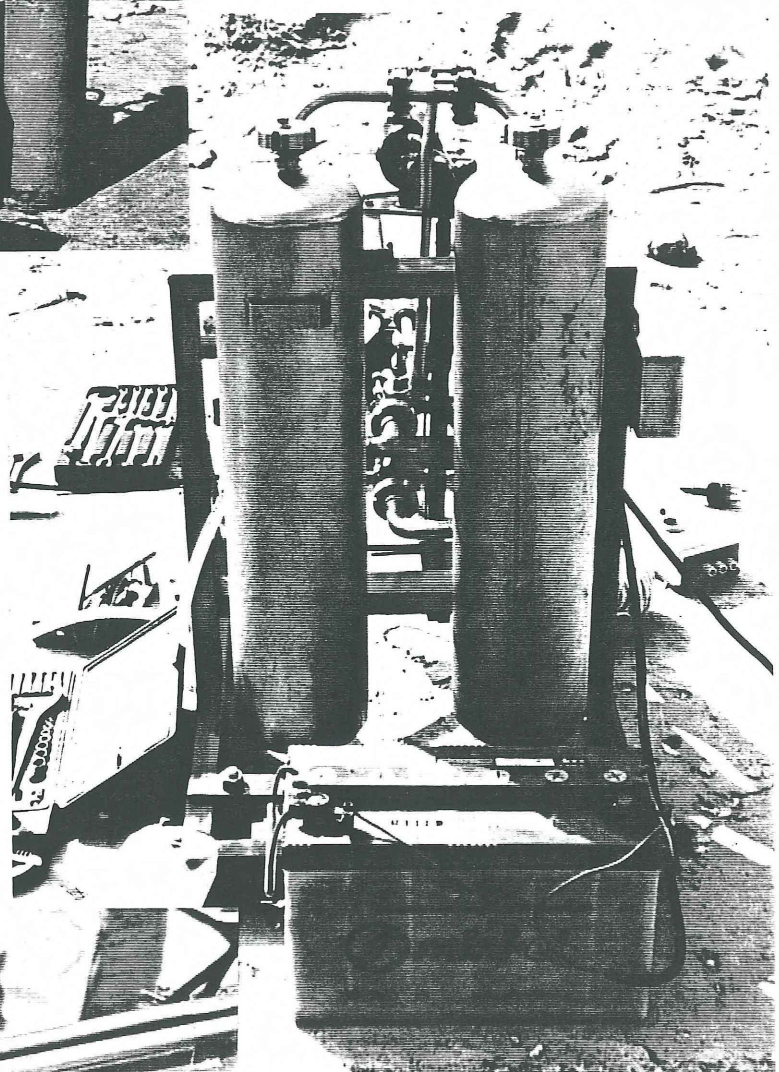
We have a special group for tank design. We have developed a very useful method for explosive forging of end cap material. We can produce in stainless steel, AISI 4301, or 4316 ellipsoidal end caps measuring 154, 204 and 380 mm in diameter. In Europe, stainless tubes are available in these dimensions. This means we can produce specified tanks in these dimensions. The 154 mm tank is tested for use at up to 450 psi, the 204 mm tank is tested to 360 psi and 380 mm diameter tank (designed for our experimental turbopump engine) to 90 psi. We use a special welding technique, WIG, where the tank is filled with a nitrogen/hydrogen 90/10 mixture during the welding process to prevent inside oxidation. This gives a very clean and strong weld seam. I don't know about shipment cost, but we would be very honored if you would use a TVM tank in your next project. About the weight, it depends on the length you may specify, but the material density is 7.9 gm/cc and is 2 mm thick. In the photos of the EM-3, you can see the type of tanks.

Just now, by February 1996, we have two projects underway. The first is the fabrication of a flight version of our LOX/kerosene engine. The other is the design of a turbopump engine. Last summer we started to produce 80% hydrogen peroxide and by February 4 we made the first test of the monopropellant gas generator to power our single stage impulse turbine. This turbine, its two pumps, tanks and engine are mounted on a steel frame to be bolted to the concrete in the gravel pit. We expect 25 to 30 second burn time and to consume around 600 lbs of LOX and kerosene. Then there is the flight rocket. It is really very simple. I just finished the last end cap for the LOX tank, and welding is well underway at the workshop. It uses 204 mm tanks for 50 lbs of kerosene and 95 lbs of LOX. The tanks are also the outside of the rocket to provide a better mass ratio and simpler design. We use heated helium pressurization and the tank pressure is 290 psi. The engine will be ablative cooled and of course we are therefore very interested in your ablative experience. If you have some good advice, I will be very happy to hear from you.

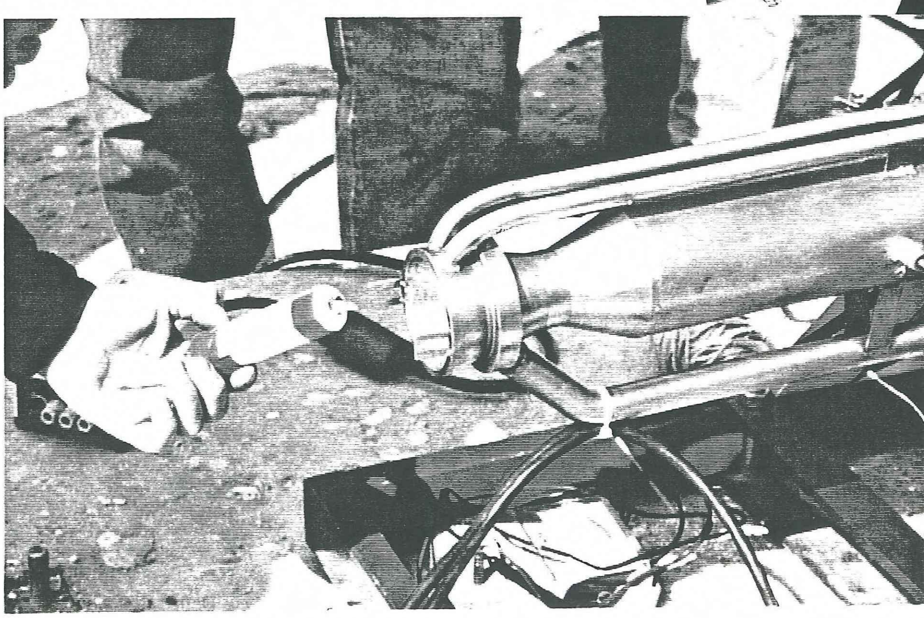
Our plan is to finish this flight design, test it statically of number of times and then find a place to fly it. The problem is that the largest Danish army proving ground in Jutland may not be large enough. We may have to travel very far to find a safe place to launch. If no other possibility comes up would it be thinkable that Mojave could be the place. I believe we will find something closer; I hope so.



[These photos came with Peter's article but without captions, so what we are including here is our best guess.] This photo shows the test stand and engine being set up for a run.

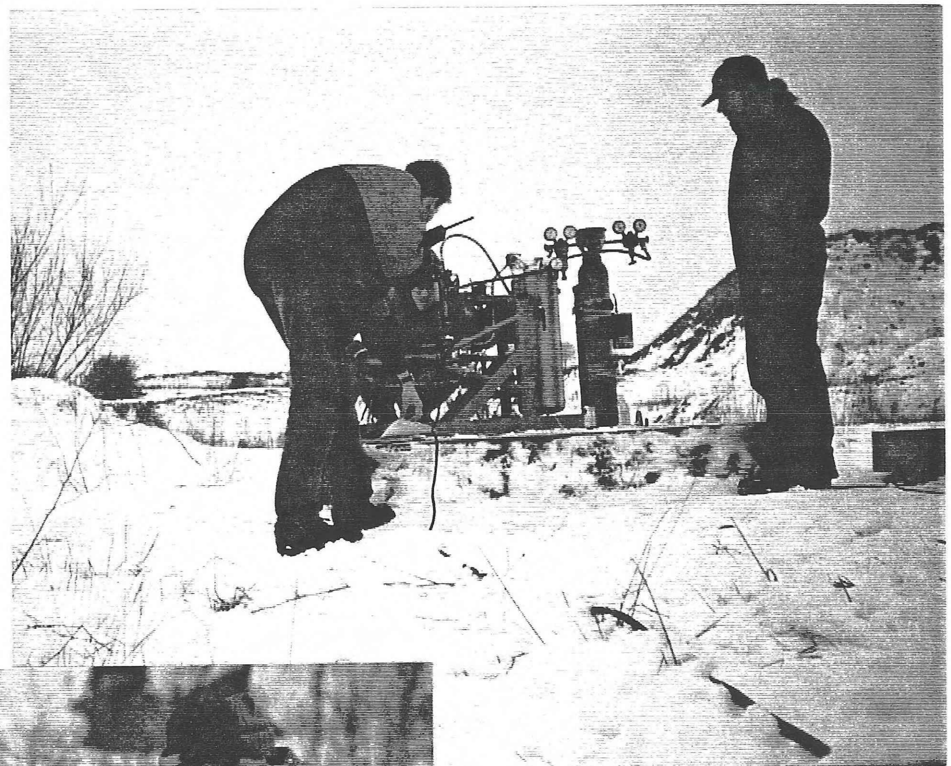


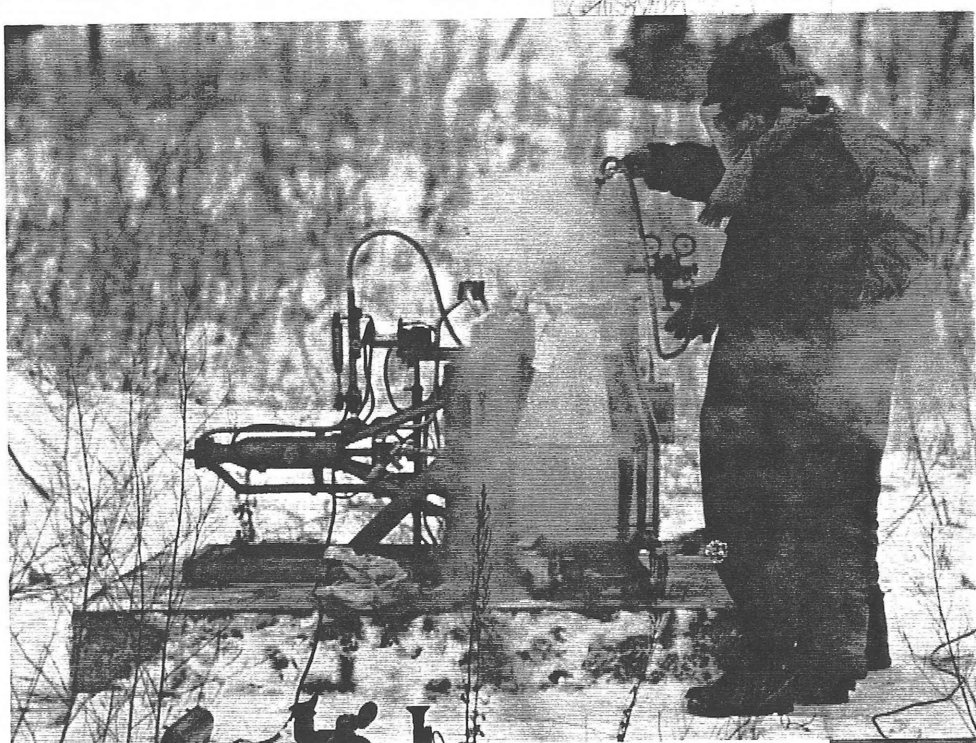
These look to be two of the tanks Peter describes in his letter. The explosive formed ellipsiodal ends look to very nicely made.



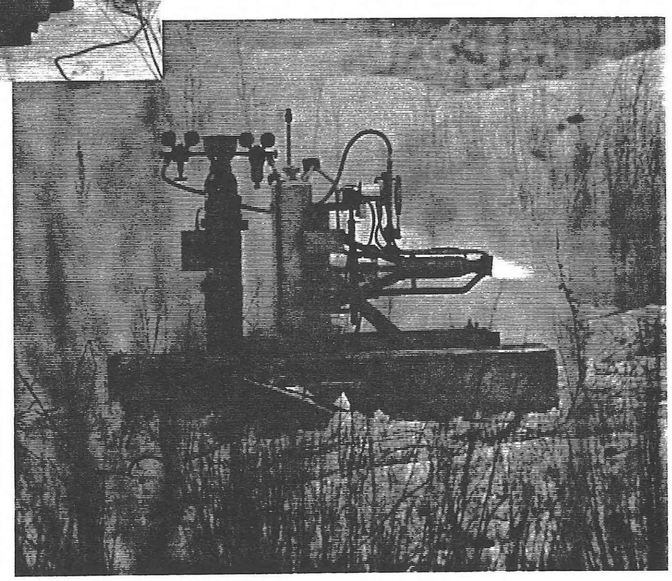
I presume this close-up of the engine shows a pyrotechnic igniter being installed. The engine looks to be beautifully made. The large tube connected to the ring around the nozzle is the fuel inlet to the regen jacket. The two smaller tubes are the inlet and outlet of the helium heat exchanger.

Testing in the dead of winter in Denmark. While we usually worry about the rate of LOX boil-off, they might have to melt it to get it into the LOX tank.





This photo looks like propellant loading operations. Either that or they are steam cleaning the hardware.



This was the only photo of hot fire testing and it looks as if the picture was taken just at start or shutdown.

The Micro Hybrid

By Rene Caldera

Reading through the May 95 issue of High Power Rocketry, I came across an article stating that, with the weight considerations of hybrid hardware, it would be interesting to see someone build one in the E, F, and G range. Wanting to build a rocket motor of my own design, this was my cue.

My first task was to obtain a small oxidizer tank and design around that. Not looking at the time, as it sometimes seems to work out, I came across a small oxygen/butane torch at my local Radio Shack. The cylinders used are about the size of a CO2 cartridge. Checking on a replacement pack of oxidizer cylinders I found a label that said "Micronox". A safety data sheet from the Radio Shack faxback service confirmed that these are indeed nitrous oxide cylinders. Recently, I have found a new source for these cylinders at the cooking store in the mall. I can now get them in bulk for less than a dollar a piece.

With this information in hand, next came the selection of the fuel. Well as hybrid fuels go, you name it and it's probably been tried. Anything from wood to plastic to tar paper and even a salami or two. Trying to keep this as simple as possible, I first opted for an acrylic grain (see Figure 1), but I didn't like the burnt smell it gave off so I decided on a rolled paper fuel grain instead (see Figure 2). To make it, I simply took a paper grocery bag, cut it up, and rolled it around a 1/4" inch rod while brushing it with glue.

To test this fuel grain, I made a simple injector from a Radio Shack butane torch frame. With a little bit of "micro pluming", I was able to attach it to the fuel grain. For a nozzle I simply peeled some of the paper from the other end and constricted the opening with a small hose clamp. Very high tech! In order to get oxygen from nitrous oxide it has to be heated above 500 degrees F. To accomplish this I used a fuse and a little piece of composite propellant with a hole hand-drilled in it and placed at the top of the motor. Once the propellant started burning, the nitrous was released from the cylinder, passed through the burning propellant, heated, and started the combustion in the core of the fuel grain.

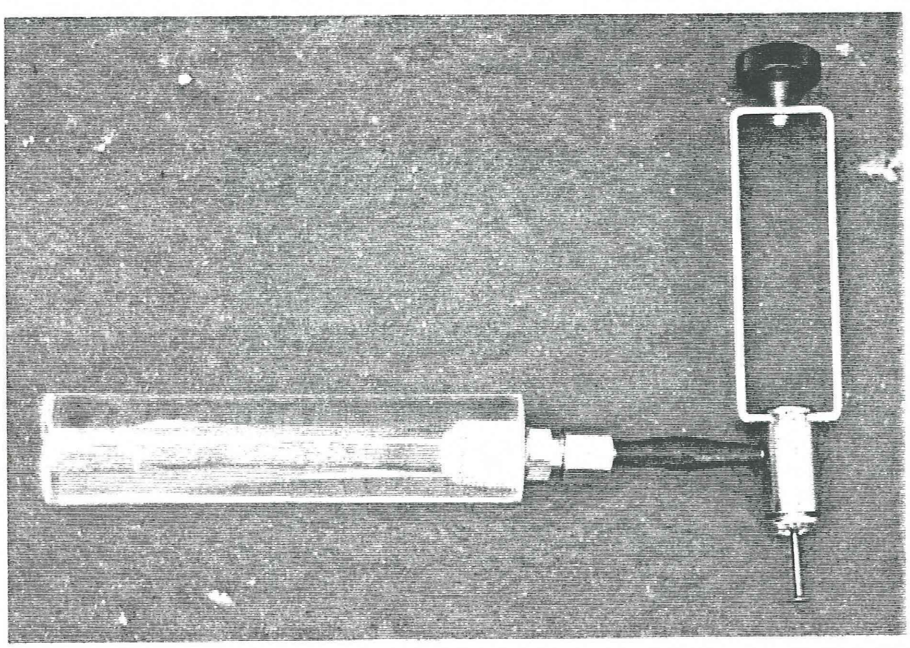


Figure 1 - Acrylic fuel grain with nitrous oxide cartridge holder

To release the nitrous I took out the needle valve/knob from the torch and inserted a pencil eraser into the hole. I then put a nail into the eraser which resulted in a very simple piercing mechanism (another high tech item!). So the whole thing works like this: The frame is held in a vise with the fuel grain attached to the side port of the torch body. The nail head is sticking out the bottom. The vise is

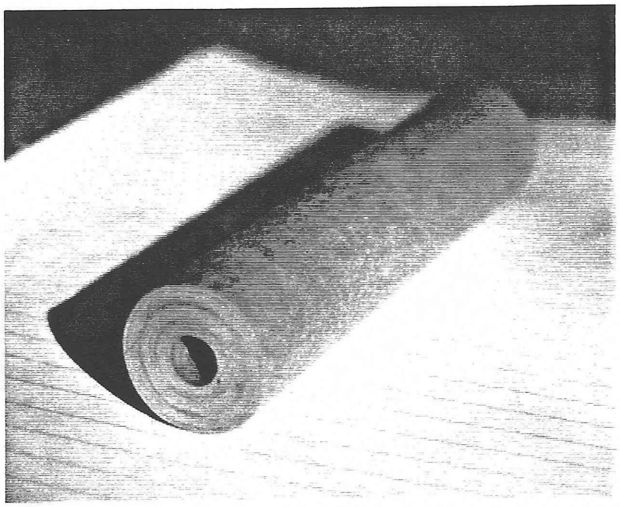


Figure 2 - A rolled paper fuel grain

then tilted off-balance and held in that position with a clothespin (first thing I saw when I turned around to look for a stick). Once the fuse is lit and the composite propellant starts burning, the clothespin is removed via a tug on a string and the vise falls, piercing the cylinder and releasing the N2O.

The test resulted in a nice bright flame about 2 inches long and a sound level about the same as an Estes "D" motor. Total burn time was less than two seconds. The fuel grain was later cut in two lengthwise, revealing a typical hybrid burn pattern (see Figure 3). No measurements were taken as this was just a functionality test.

I am now working on the motor hardware which will use an aluminum injector/piercing unit, a 1" diameter motor tube and a graphite nozzle (Figure 5 shows some of that hardware). I hope to get some thrust measurements and final grain dimensions from these firing tests so I can optimize the size and be able to fly it in a small rocket.

To be continued...

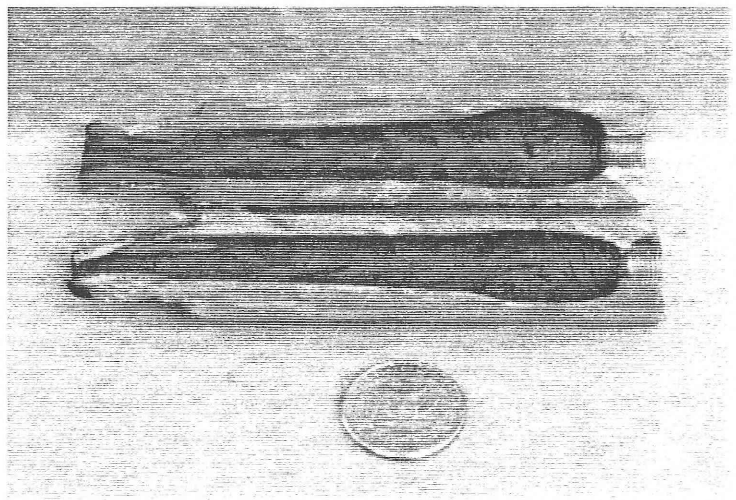


Figure 3 - The paper fuel grain, cut in half, after the first test.

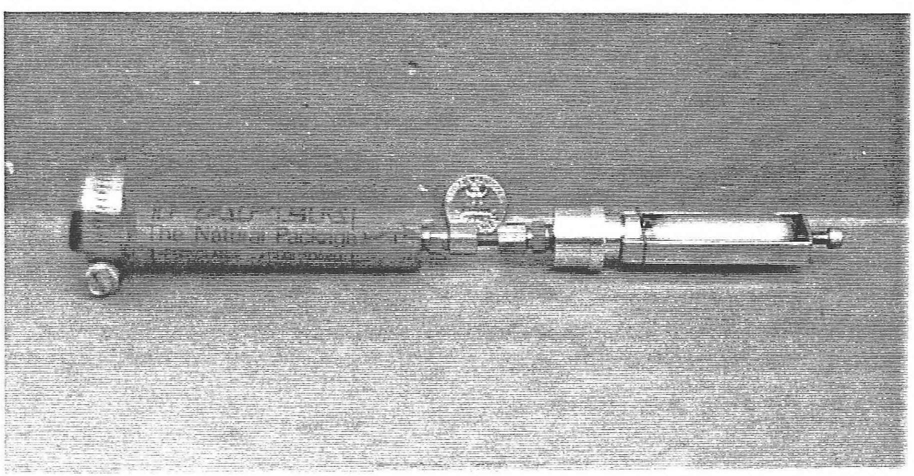


Figure 4 - The second generation micro hybrid

Section 8

[Former section number of the U.S. Army regulations governing discharge from the service due to psychological unfitness. It was often used to refer to someone discharged for being crazy, i.e. "Watch out for that amateur rocket guy, I'm sure he's a Section 8!"]

Sometime around the publication of RRS News issue number 99 in the Summer of 1965, then editor (and now honorary RRS member) Don Girard started a feature article called "Section 8". It was to be a collection of editorials, book reviews, comments, and letters. The section was always informative, well written, and very entertaining. In the last issue, we restarted this feature. Here is round two. If you have anything to contribute to this section, please send it along to Scott Claflin or Dave Crisalli.

Younger Members Sought

Over the course of time, the membership of the RRS shifts somewhat as the average age, backgrounds, and total numbers of people interested in rocketry change. As I mentioned in the editor's note leading into the article on the rocket powered go cart in this issue, I started in the RRS when I was in eighth grade. At that time, many members of the Society were in high school. There was a great deal of excitement and enthusiasm in the RRS as a result of the energy these younger students brought with them to meetings and firings. It was a wonderful time for learning, designing, building, flying, and going on to bigger and more elaborate projects. The RRS provided these youngsters with an unbelievable opportunity to do something utterly fantastic and out of the ordinary - launch big, powerful rockets - and do it safely.

The Society still offers those same opportunities today. The pursuit of rocketry almost always leads to individual study in a plethora of related fields. Electronics, mechanical engineering, chemical engineering, metallurgy, photography, optics, physics, aerodynamics, thermodynamics, and even journalism, to name a very few, often become secondary aspects of a given rocket project. And the learning is not boring. The end result, launching a rocket in a thundering cloud of fire and smoke, generates great enthusiasm for the next lesson or next project. I can say without a doubt, that in my own case, my experience in the RRS while I was in grade school and high school was the greatest educational motivation of my life. I learned more engineering, science, and practical information from other RRS members (and from designing and building my own rockets) than from any classroom study I ever experienced.

For these reasons, I would ask members of the Society that have an opportunity to encourage any younger students, who may be interested, to come take a look at the RRS and what we do. Sponsor some student you know and bring them to a meeting, let them read your latest copy of the RRS News, or better yet, bring them to a firing. We have such a unique opportunity to teach and motivate younger students, that we should actively try to share it with those it might benefit greatly. The Executive Council has authorized a $15 discount on Associate membership to any bona fide junior high, high school, or college student who wishes to join or renew his or her membership. At $20 a year for a student membership, I don't think you could beat the educational value anywhere.

Now go out and find some unsuspecting student and drag them out to the MTA !

Solid Propulsion Course

The Society has begun teaching a class in beginning composite solid propellant motor fabrication and testing. For more information, see the June Bulletin Summary at the end of this issue.

Books

There is a new book out on the market published by the AIAA. It is called, "Spacecraft Propulsion" and is written by Charles D. Brown. In my review of the text, the author seems to do very well at sticking to the following points made in his Preface;

"This book is a product of my spacecraft design course at Colorado University. Its primary purpose is to teach. To that end, the subjects are explained as clearly as possible with worked examples, so that you can teach yourself if need be......This book is different from other books in this field in three ways. First, the book includes PRO.AIAA Propulsion Design Software, as well as an appendix that serves as a users manual for the software...Second, this book emphasizes spacecraft propulsion (small engines, monopropellant, solid rockets, pulse performance, etc.) The big launch vehicle systems are touched on, but they are not the focus....Third, this book takes a system level view. Rocket engines are discussed, but so are pressurization systems, propellant systems, thrust vector control systems, safe and arm systems....After deliberation, I prepared the book in the English system of units. These are the units of early propulsion development and the units in which professionals in the field still think and talk..."

The last couple of sentences were enough to convince me this guy knows what he is talking about. There has been nothing quite so stupid in recent years as the governmentally forced shift to metric units. Speaking professionally, and as an irate taxpayer, we have wasted millions of dollars starting out programs in metric and then being forced by practicality (since every machine tool, measurement instrument, data system, and standard material size is in English units) to convert back. I have not tried the software yet, but the text seems to be well written, practical, well illustrated, and coherent. It really looks like the author tried to write a text to teach rather than to confuse and impress everyone with his fundamental grasp of paranormal existential propulsion derived, using LaPlace transforms of imaginary numbers, from fundamental, but as yet undiscovered, physical phenomenon. (You know, the guys who prove that single stage to Pluto is possible in a vehicle constructed of frozen mesons and burning paradichlorobenzine and Old Spice after shave as propellants!) This looks like a good text. It is available from the AIAA for around $60.

Jim Gross wrote in to pass along some information about a two volume set of books recounting the history of the propulsion work done over the years at the Naval Ordnance Test Station (NOTS), China Lake. Both volumes are now available in paperback. Volume I, Sailors, Scientists, and Rockets (303 pages), is $15.00 plus $2.95 shipping and handling. Volume II, The Grand Experiment at Inyokern (425 pages), is $18.00 plus $2.95 shipping and handling. Jim told us he hasn't read Volume I, but he said Volume II was great. These books can be ordered directly by writing to:

Commander, 474500D
NAWCWPNS
1 ADMINISTRATION CIRCLE
CHINA LAKE, CA 93555-6001

Make checks payable to "DFAS-CL, China Lake" Allow 3 to 4 weeks for delivery.

Comments

The Environmental Impact of the RRS (a letter to the membership)

by Douglas W. Caldwell

Something was amiss. I am not often disoriented, but there it was — a sense that my memory of the MTA was somehow wrong. I was almost to the compound, not quite out of the creosote brush, and could discern a large truck, a back hoe and a large pile of dirt. They were too close. The relation between them and the I-beam pad was wrong. Suddenly, I emerged from the brush, some 150 feet sooner than I expected. What had happened to my little corner of the desert?!! A great swath of land lay denuded, the MTA "compound" which I knew seemingly shrinking to insignificance next to this newly bared earth. Why? Why? Why?

Over the next three days, I absorbed a number of emotions and opinions from myself and others, some unsettling, some contradictory. "Don't worry, it will come back really fast." [Bull, my heart says; creosote will not come back anytime soon!] "I really liked the coziness of the MTA the way it was." "We needed to clear it for safety." "Who has the right to change the MTA this radically?" "Why didn't we talk about this before?" "Anyone who wants to complain should be out here working."

That it took me a couple of weeks to come to peace with this indicates, I think, that this is not a simple black-and-white issue. And I don't think that I would have been as happy had another event not also happened that weekend: we finally cleaned up most of the more visible environmental abuse which has smitten the MTA for far longer than I have been an RRS member. Mark Ventura, Charles Pooley and I spent more than three hours raking the desert (including a large amount on the BLM land to the east) to collect the various trash that has been discarded by the inconsiderate and then dispersed by Nature. The mattress entrails are gone; you can now look to the east without having your eyes drawn to the incessant cacophony of white cotton ticking. And the same back hoe which cleared so much brush helped bury some 100 cu. ft. of broken glass, plastic bags, rotting plywood, rusting bedsprings, and so forth.

As I reflect on the various facets of the problem, I conclude that: No, the desert will not heal itself anytime soon and I remain saddened by this. I think we can expect to see the cleared area covered with the thin grass that covers the parking area but the creosote will not return. Even if it could, we would routinely quash its ability to do so because we really do need a larger area around the test stands and launch pads. The RRS is growing both in the number of activities and in the size of individual activities. It is not reasonable to expect that a site which was "designed" for 500 lbf tests can support 20,000 lbf tests. A rocket-initiated brush fire could cause far more environmental damage than our precautionary clearing (not to mention the high likelihood of ending the relatively lax oversight of the RRS by various bureaucrats). This, unfortunately, is the price of progress.

Besides, the absolute magnitude of what we have done pales in comparison to that which was done not 1/4 mile to our north. While I am certain that many outside the RRS may disagree, I feel that our small clearing is potentially of far more long-term value than the 160 acres originally cleared for farming but which now serve as a final resting place for tons of LA's waste.

But while that plot has become a dump, we can and should become better caretakers of our small piece of the desert. There is no justification whatsoever for simply polluting our environs. Everyone should take more care to pack out garbage, to keep plastic bags from blowing away (suggestion: don't bring them; you know the wind will steal them from you), to keep fires confined to fire pits, to pick up the various byproducts of rocket launches and static tests. By doing this we can demonstrate that we are responsible custodians. For those who consider the concerns discussed herein to be so much leftist eco-babble, think instead of the benefits this could have if ever we are faced with some bureaucrat who feels that the tortoise preserve must be expanded or that our activities are otherwise injurious to the environment. If we have voluntarily done our best to minimize our environmental impacts, we stand a much better chance of being left alone or, failing that, of defending ourselves in whatever forum we are being attacked.

There is, alas, no perfect answer. Progress has a price and I, for one, am not willing to go back to stone knives and bearskins. However, we should consider the ramifications of our actions. Moreover, significant actions should be discussed in advance with others rather than becoming apparently spur-of-the-moment decisions which affect us all.

[Editor's Note: The clearing we did at the MTA apparently caused Douglas to do some soul searching. I personally didn't have any problem with clearing the rather scrubby brush west of the

compound until later that afternoon when I became down right irritated about it. Doug was not "at one" with the clearing on aesthetic and/or environmental grounds. I was perturbed because I had to walk so much further to find a bush of sufficient size to use as a relief station ! It was difficult to "weedle in the bushes" when there weren't any damn bushes to "weedle" in. Alas, my sympathies go out to Doug, for some of his beloved creosote is lost to us. My problem, on the other hand, can be corrected with another outhouse.

By the by, an extract from the creosote bush was long used to prevent insect attack and rot of wooden fence posts, telephone poles, and wooden building foundations. This excellent preservative is now illegal to use and is considered environmentally hazardous and a carcinogen. Some time ago, the RRS asked the telephone company for more of the used telephone poles they had taken down and replaced. We wanted to refurbish the bunkers that had been built originally out of used, donated poles. The telephone company informed us that they could no longer donate the poles. Under recently enacted environmental laws, the poles were now considered to be hazardous waste because they had been treated with creosote. Go figure! Boy, was that a close call. Now I know, because of this new information, that I really must stop eating telephone poles and I will never get close enough to another Mojave creosote bush to "weedle" on it again.]

Construction Corner

If your looking for another great mail order surplus place, the Surplus Center is an outstanding candidate. Their excellent catalog lists all manner of equipment including hydraulics, pneumatics, pressure gages, hoists, gear boxes, motors, pumps, valves, etc. There are too many categories to mention here, so just send for a catalog by calling or writing to:

Surplus Center
(800)-488-3407
1015 West "O" street
P.O. Box 82209
Lincoln, NE 68501-2209

Dennis Feucht, RRS member from Pennsylvania, is building some hardware that will be of special interest to liquid propellant rocket types. Dennis has designed and built an electrically actuated ball valve controller that mates with available Grainger gear motors. He is also building an electronics package, called an RFC1 (Rocket Flight Controller). The unit is an on board system of sensors, actuators, and a flight computer that can be used for launch sequencing, data acquisition, data recording, flight control, and recovery. For more information, get in touch with Dennis at the following address:

Innovatia Laboratories
(814)-789-2100
14554 Maplewood Rd.
Townville, PA 16360

Review of Parker o-ring software "INPHORM"
by Jim Gross

Parker O-ring company is selling a computer program called "INPHORM" that aids in the selection of an o-ring and determines the gland dimensions. "INPHORM" sells for $39.95 and is available from

Valley Seal Company
6430 Variel Ave., Suite 106
Woodland Hills, CA 91367
(818) 883-3505
(213) 873-3630

I used some design calculations from a recent project. This included three design iterations. The same dimensions were entered in "INPHORM" and the results compared. In the first and third iterations, the amount of squeeze "INPHORM" calculated matched the squeeze calculated by hand.

"INPHORM" did not calculate the o-ring stretch and squeeze for my second design iteration, so a comparison could not be made. However, it did reject my second design iteration. I suppose this is some form of "idiot proofing." At least it came up with the same conclusion I did.

The program is very useful and accurate. It comes with three 3-1/2" floppy disks, a roughly 40 page manual, and contains the Parker o-ring manual on disk (I have not used that module). It runs under Windows 3.1. They do not have a MAC version.

Bits and Pieces

Last Call - Requiescat in Pace - As this issue of the RRS News was being prepared, we received some very sad information. Leonard Olive, a long time RRS member and a good friend passed away from a heart attack on May 4, 1996 while he was running in the Manhattan Marathon. He had completed 23 miles of the course when he colapsed. He died a short time later at a local hospital. Leonard was quiet, a hard worker, and a joy to know. He always had a kind word or some interesting story for those around him. He will be missed by all his friends in the Society.

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.

Back Issues of the RRS Newsletter - For those members who may be interested, copies of the last several RRS Newsletter issues are available for $6.00 each. 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 lb thust hydrogen peroxide engine, 1995 in review, electric matches, legal transportation of propellants, robust nose cone)

• Volume 53, No. 2, June 1996 (This issue)

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

The following excerpts from recent local bulletins are reprinted here for the benefit of those members who live outside the southern California area and do not receve these meeting notices on a monthly basis.

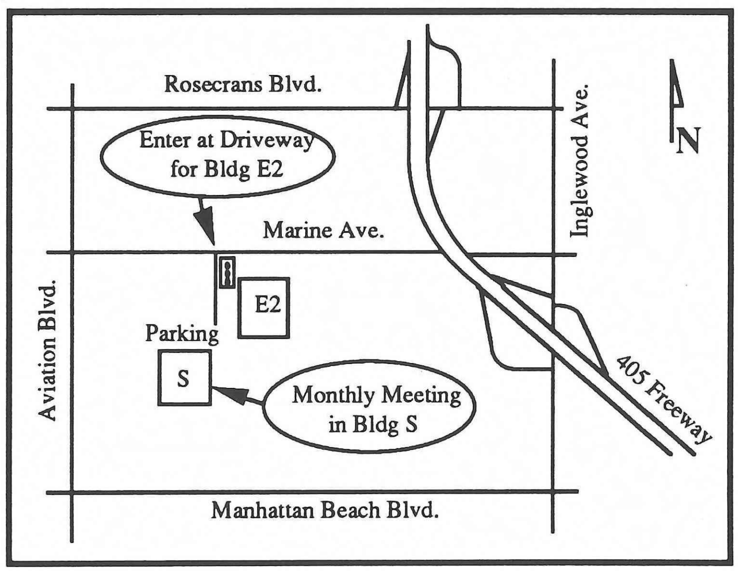
RRS Bulletin April 1996

Reaction Research Society, Inc., P.O. Box 90306 World Way Postal Center, Los Angeles, CA 90009

April Meeting Agenda - The main topic of this meeting will be discussions of the upcoming work and schedule for facility improvements at the MTA for 1996. Mr. William Bissell will also give a beginning lecture on rocket turbopumps. Bill spent many years working professionally designing turbo machinery for all the major liquid rocket propulsion systems built by Rocketdyne. This lecture is the first in a series and will cover the basics of turbopump theory. The Society relies on the active participation of its members to continue to grow and improve. Please make every effort to attend meetings when you can. Thanks.

April Meeting

Date: Friday, April 12 (second Friday of every month).
Place: (see map): TRW, Bldg. S (cafeteria), Redondo Beach, CA.
Time: 8:00 PM



Beginning Solid Propulsion Course - The trial run of the basic solid propulsion course was completed over the March 22 to 24 weekend. The course materials were refined during lectures on Friday in Mojave, and composite propellant was mixed, cured, and processed for 12 motors on Saturday. On Sunday, all 12 motors were assembled and fired successfully by the individual builders. The digital data collected showed that the motors were very repeatable (within ~ 1%) and all delivered a specific impulse around 232 seconds. The entire effort went extremely well and was an excellent rehearsal for the first course to be run in April. The motor used for this class was initially designed by George Garboden and Niels Anderson to be the Society's standard composite rocket much as the Beta is the standard zinc/sulfur rocket. Based on the success of this first class, this motor design will more than adequately serve as a basic, relatively easy to build, composite rocket.

Facility Improvements - The recent efforts to improve the MTA have been documented in the RRS News. Most of the work accomplished thus far has been preparation for the major construction efforts yet to come. This year the Society would like to really step out and make the major improvements that have been planned. In order to stretch our meager resources as far as we can, we may need to hold a couple of "all hands" work parties. When the word comes out, please make every effort to get out to the MTA and lend a hand. We will need all the help we can get. In addition, if any members know anyone in the construction, electrical contracting, heavy equipment, fencing, or plumbing business that would be willing to donate a day of their time or materials (or both), please let me know as soon as possible. Thanks. (The Ed)

RRS Bulletin May 1996

Reaction Research Society, Inc., P.O. Box 90306 World Way Postal Center, Los Angeles, CA 90009

May Meeting Agenda - The main topic of this meeting will be discussions of the upcoming work and schedule for facility improvements at the MTA for 1996. Dr. Thomas Flynn will also be the guest speaker at this month's meeting. Internationally recognized as one of the leading authorities on cryogenic engineering, Dr. Flynn will address the meeting on the topics of double density hydrogen and other cryogenic fuels for hypersonic aircraft and rocket propulsion. He is the author of the only university level textbook currently in print on the subject of cryogenic engineering and has lectured extensively on cryogenics world-wide. This promises to be an excellent lecture. The Society relies heavily on the active participation of its members to continue to grow and improve. Please make every effort to attend meetings when you can. Thanks.

Beginning Solid Propulsion Course - The first class on beginning composite solid propulsion was completed over the April 19th weekend. A day (Friday) of classroom work was held at a hotel in Lancaster followed by composite propellant mixing, curing, and processing for 16 motors on Saturday. On Sunday, all 16 motors were assembled and fired successfully by the individual builders. The digital data collected showed that the motors were very repeatable (within ~ 1%) and all delivered a specific impulse around 232 seconds. The entire effort went extremely well. The motor used for this class was initially designed by George Garboden and Niels Anderson to be the Society's standard composite rocket much as the Beta is the standard zinc/sulfur rocket. Based on the success of this first class, this motor design will more than adequately serve as a basic, relatively easy to build, composite rocket.

Membership Dues are Due! - This is just a gentle reminder that membership dues come up for renewal next month. We usually have to spend a couple of hundred dollars in postage sending notices out to people to remind them about this subject. This year we thought we would ask for the cooperation of the membership and see if we could get everyone to send in their annual dues just with a note in the monthly bulletin. As of January 1, 1996 corresponding membership is $30.00, associate membership is $35.00, and administrative membership is $40.00. For those really dedicated types (such as Paul Montgomery), lifetime membership is $500.00. Congratulations and thanks to Paul for his lifetime membership status. Please send your dues to the official RRS address and to the attention of Mr. Frank Miuccio.

Web Page - The RRS now has its own web page. The preliminary copy is now out at the following address;

http://www.cerfnet.com/~tolson/rrs/

George Dosa - For any members who may not know, George Dosa has been ill and hospitalized since early March with a gastro-intestinal condition. George has been, without question, the backbone of the RRS for over 35 years and was the first licensed rocket pyrotechnic operator in the state if California. We are all trying desperately to keep up with the mail (and everything else George routinely handles for the Society) while he is recuperating. However, none of us are as good at this as George is, so please be patient with us until George gets back. Meanwhile, please also keep George in your thoughts and prayers and drop him a note of encouragement if you get a chance.

RRS Bulletin June 1996

Reaction Research Society, Inc., P.O. Box 90306 World Way Postal Center, Los Angeles, CA 90009

June Meeting Agenda - The main topic of this meeting will be plans for the next rocket firings and propulsion courses. The Society relies heavily on the active participation of its members to continue to grow and improve. Please make every effort to attend meetings when you can. Thanks.

Work Parties - For those members who have not been out to the MTA lately, a tremendous amount of work has been going on to improve the test facilities. A very intensive work party was held from 22 May through 26 May over the Memorial day weekend. Fifty yards of concrete were poured over these few days completing the new building foundation, the forward abutments for the 15k test stand, and placing the footings for the new MTA entry sign. Since our ambitions for the facility improvements are always bigger than our assets, we have entered into some new lease agreements with individuals who have sponsored the building of additional structures. The bottom line is that the Society is greatly indebted to a very few members who are always there with both monetary resources and the back breaking physical labor required to improve the MTA. However, for the past three years, it has always been the same six or eight members (out of over 200!) who have braved the heat, and cold, and grueling days at hard labor.

I would ask that more of the membership get involved in the work that needs to be done. We have more than enough arm chair quarterbacks - we need people who are dedicated enough to show up at the MTA and lend a hand. We need people to dig footings, paint structures, clean up, repair bunkers, hammer nails, set fence posts, lay down conduit, and repair roofing. Don't wait to be called. Find out what needs to be done next and pitch in. And for all those members who cannot make it to the MTA to help out, please consider sending a donation. It is doubly unfair for those same few who are dedicated enough to the Society to go out and do all the hard work to also wind up footing the bill for much of the materials, tools, and supplies needed to do the job. Twenty five dollars will buy a sheet of 3/4" plywood and $80 will buy a yard of readymix concrete. (As an example, 4 yards of concrete will put a new concrete roof on the larger existing blockhouse and 8 yards will complete the footings and slab for 20 feet of new concrete observation bunker.) To do what we have planned and to make the MTA a really top notch test facility will take many thousands of dollars. Please send what you can to help us along the way. Every donation is a help. Or consider becoming a lifetime member for $500. This will save you money on dues (if you live long enough) and will help us with working capital right now.

All of the recent improvements and activities reported in the RRS News that members constantly send me congratulatory notes about were not completed in the night by elves. This progress is the result of a few members expending Herculean effort, blood, sweat, concrete, and steel. From a morale standpoint, it would be a great boost to those of us who go out to work and sweat if we knew the rest of the membership was behind us and was at least rooting us on by sending monetary support. As it stands, some of us are starting to feel like we are the only ones putting any effort into improving the RRS. Please lend us a hand one way or the other. Thanks.

Membership Dues are Due! - This is just a gentle reminder that membership dues come up for renewal this month. We usually have to spend a couple of hundred dollars in postage sending notices out to people to remind them about this subject. This year we thought we would ask for the cooperation of the membership and see if we could get everyone to send in their annual dues just with a note in the monthly bulletin. As of January 1, 1996 corresponding membership is $30.00, associate membership is $35.00, and administrative membership is $40.00. For those really dedicated types (such as Paul Montgomery), lifetime membership is $500.00. Congratulations and thanks to Paul for his lifetime membership status. Please send your dues to the official RRS address and to the attention of Mr. Frank Miuccio.

Solid Propulsion Course - The Society has now completed the first two beginning composite propellant classes. Twenty five students have been given a day of classroom instruction and two days of field work mixing propellant and firing motors producing over 300 pounds of thrust at a specific impulse of over 230 seconds. The next course will be held on 21, 22, and 23 June. These classes are offered for $475.00. This may sound a little steep, but compare the following; the reloadable motor you build is approximately an "L" size (as the high power guys rate them). A commercially available reloadable motor of this size can run from $500 to $700. For less than the price of a commercial motor, you get three days of "hands on" personalized instruction, use of the Society's mixing and curing equipment, an opportunity to static test your motor, a copy of the test data, and you get to keep the motor hardware. For those interested in composite propellant work, this is a great deal. We have had students from as far away as the east coast and Canada attend so far, so don't think this is just for the local guys. If you are interested in receiving some detailed information on the class, please write to Niels Anderson at 440 20th St., Santa Monica, CA 90402.

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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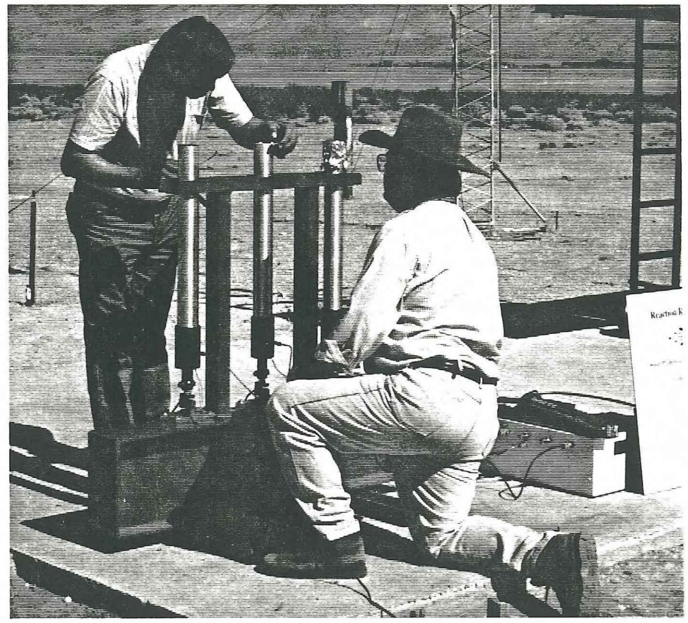
The Reaction Research Society

ROCKET PROPULSION COURSE

The Reaction Research Society, founded in 1943, is the oldest continuously operating amateur experimental rocketry group in the United States. With a membership active in all areas of the propulsion sciences, the Society maintains the largest privately owned rocket test facility in the country and has, among its membership, many experienced, state licensed First and Second class rocket pyrotechnic operators. Utilizing these facilities and expertise, the RRS is now offering the first in a series of dedicated rocket propulsion classes for the serious rocketry enthusiast.

Planned courses will eventually cover beginning and advanced levels of solid, hybrid and liquid rocket propulsion. However, the first to be offered is a unique "hands on" three day class in beginning composite solid propellant motor technology. Students will spend the first day in classroom work covering theory, materials, procedures, and safety. The second and third days of instruction will be held in the field at the Society's Mojave Test Area. The second day will involve the student in propellant mixing, casting, and curing. Each student will be provided with all necessary materials to assemble and load a 300 pound thrust motor. All the required propellant mixing / handling equipment, and motor assembly tooling will be available for the use of the students . The course will culminate on the third day with each student static testing his or her own motor in the Society's instrumented, state of the art test stand under the guidance of a Society pyrotechnic operator.

In addition to the knowledge and experience gained, the student will take away from the course all instructional handouts, test data, and the reusable motor hardware.



Three student motors being prepared for static test.

These classes are offered for $475.00. The reloadable motor you build is approximately an "L" size (as the high power guys rate them). A commercially available reloadable motor of this size can run from $500 to $700. For less than the price of a commercial motor, you get three days of "hands on" personalized instruction, use of the Society's mixing and curing equipment, an opportunity to static test your motor, a copy of the test data, and you get to keep the reusable motor hardware. For those interested in composite propellant work, this is a great deal.

Although designed to thoroughly cover all required technical information, this class is not just for "rocket scientists". The course materials have been carefully prepared to be useful and instructive to a wide range of students from professional propulsion engineers to the amateur experimentalist. If you are interested in receiving a free brochure with complete course information, please send a self addressed, stamped long envelope to the Reaction Research Society. Class space is limited, so write today.

Reaction Research Society, Inc.
c/o Mr. Niels Anderson
440 20th Street
Santa Monica, CA 90402

Name ____________________

Address ____________________

City __________ State ______ Zip ______

Please send me your free information brochure on the Reaction Research Society Beginning Composite Solid Propulsion Course in the enclosed self addressed, stamped envelope.

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c/o Mr. Niels Anderson
440 20th Street
Santa Monica, CA 90402