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ROCKETRY AND ASTRONAUTICS

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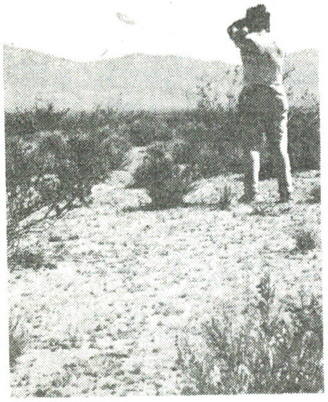
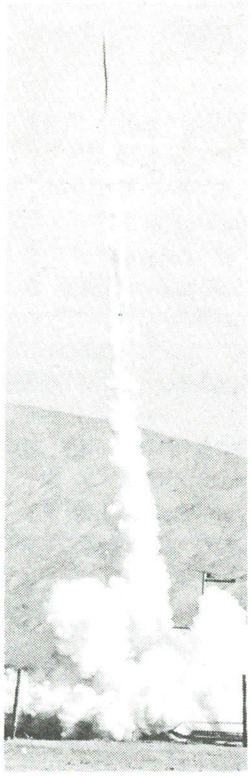
FROM THE EDITOR

The events you are about to read actually happened. Only the dates have been changed to protect the innocent.



"Publish or perish!" threatened the sign at RRS headquarters. "Hah!" I threatened back. "I see I'm going to have company with me after I die!" And I began to recite the tale that you have begun to read.

Lorenz to Girard with thought on article. Girard to Lorenz with oh, man, yes, man, it's the only one we got. Butterfield to staff with publish or perish. Staff to . . . well, never mind. Pooley to Girard with article (something wrong there, I think). Claybaugh to Sacramento to James for firing and good cheer, back to RRS with book on teamwork in rocketry. Girard to Teebken with review it. Teebken to Girard with . . . well, never mind.



Butterfield to staff with P.O.P. (Indeed, that might be Pay One Price.) Dosa to Girard with article (something wrong there, too.) Girard and Claybaugh both to Sacramento to research static stands, to Bennett to consult, to NASA for background, to the professional libraries in Los Angeles for information.

It took a year. But communication did pay off, and today we are quite proud to present to you our version of RRS NEWS 102.

RRS NEWS

A magazine of comment on the amateur field today.

RRS NEWS NO. 102 ISSUE ONE, 1967

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MANAGING EDITOR

Don Girard

THE RRS NEWS, No. 102. Published quarterly for the advancement of rocketry and astronautics by the Reaction Research Society, Inc., P.O. Box 1101, Glendale, California 91209.
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POST FIRING ▮▮▮▮▮▮▮▮▮▮▮▮▮▮▮▮▮▮

By Don Girard and George Dosa,
Reaction Research Society

At last writing, zinc-sulfur rockets were reported leaving the Mojave Test Area in orderly fashion. Little has happened to change that. What has happened, and what we are compelled to take up here, is the extraordinary frequency of the commonplace.

Thirty-six rockets, from the two Societies and from service and various educational groups, fired in the space of a year, provide a curious insight into amateur rockets and rocketeers. The full record about these missiles is in tabular form on pages 4 and 5, published with numbers alone in the hopes of establishing empirically a pattern for zinc-sulfur rockets. This quaint notion met with little success, but we will talk more about that later.

Several experiments were begun in these series of firings, but conclusions are wanting as of this publishing date (that is, for all time). One experiment, the comparison of capsulated zinc-sulfur to semi-packed zinc-sulfur, was concluded. The firing operations were smooth, expedited by experience, the telephone hook-up, the adjustable launch racks, the motor driven fuel mixer. Craftsmanship in the rockets was, generally, lacking: most of the rockets fired were for the owner's education.

Follow along, though, and we shall attempt to walk this trail of low-level activity and point out features of the landscape where we can.

The May 30 firing was a service by the RRS for the Northrop Institute Chapter of the Pacific Rocket Society. Seven "Goddard" rockets, built by various students at Northrop, were fired using capsulated fuel. The particular experimental has been written up in NEWS 100. We repeat here that the capsulated vehicles burned out from 0.094 seconds to 0.188 seconds. The same design rockets, filled with loosely packed fuel, burned out from 2.3 seconds to 3.5 seconds, a result that indicates the importance of inertia effects on the fuel column of an unnozzled vehicle.

Two two-stagers, by John Jaakkola and by Carlos Beer, similar except for the second stage length, tested a method of clustering and parachute ejection mechanisms. Jaakkola's, due to premature parachute ejection (fuse actuated) and burnthrough in the first stage, broke up. Beer, who also had first stage burnthrough, was successful in deploying one of three parachutes.

Two other vehicles were fired: one night fired, with a strobe light for later film analysis and a timer actuated parachute, the other a $KClO_4$ and resin static test. The strobe was not observed (though some owl-eyed individuals insist the strobe was visible) or recorded on film. Indications are that the instrument section separated, as the nose cone and motor only were recovered. The static test rocket exploded.

On July 4, six rockets were fired, two of which were cast by Bill Claybaugh and the others two-inch vehicles fitted with Beta-type nozzles (30 convergent, 15 divergent). The first of the cast grains consisted of $NaNO_3$, aluminum powder and a polyester resin.

The advantage to this grain includes a performance at least five times that of micrograin, an ability to be cast into any shape, and relative ease of handling. Disadvantages include high exhaust temperature, the need to transport the grain, the need for chamber insulation, the need for high strength metals for the chamber, and difficulties in grain design. The test blew up as the rocket was unable to build pressure quickly, and not because the propellant detonated.

The second grain was of zinc and sulfur in acetone. Acetone was chosen since it dissolves sulfur, and transports it throughout the grain structure. It has a low vapor pressure, and leaves behind a strong, integral cast mixture of zinc and sulfur. The cast micrograin failed to ignite, which we note here as a consistent problem with cast micrograin.

The Butterfield rocket had an early burnout, a good maximum velocity and a slow rise, indicating that the rocket was too short. The La Habra rocket, fired three times, deteriorated from fair performance on the initial shot to very poor performance on the third. Nozzle erosion was considerable.

On July 18, a single vehicle was fired, in experiment of the notorious photoelectric peak sensor. The experiment failed (as reported in the Featured Articles section of this issue), and the rocket itself burned erratically, with flame-out and re-ignition occuring. In the firing of October 31, we note that the Goddard-type rocket of David Crisalli performed poorly, and the Girard-Schreiner vehicle hung fired. The sulfur used was old, and probably water saturated: the performances were not typical.

The Thanksgiving firing saw Greg Stewart's first vehicle fired, with a hand-formed ceramic nozzle reminiscent of the John Mariano days of explosions. Stewart's rocket did not explode, but came quite close, as it had a very short burn time, and a short but high velocity peak in the burn phase curves. The rocket has not been recovered. The two La Habra vehicles performed well, showing good improvement from the first rocket.

John Novak made his debut into the Society by constructing an RRS Beta, firing it for an excellent performance record, and modifying the fiberglass cones of George Dosa design into a molded epoxy shell. John Novak nearly made his exit from the Society during Live Fire II, but that story will wait until NEWS 103.

The January 28 launch was a service to Chaminade Preparatory,

DATE	NO.	TOTAL LENGTH (Inches)	O.D. (Inches)	PROPELLANT	MASS RATIO	OWNER
5-30-66	1	38	1.00	80% Zn, 20% S	?	PRS
	2	38	1.00	80% Zn, 20% S	?	PRS
	3	38	1.00	80% Zn, 20% S	?	PRS
	4	38	1.00	80% Zn, 20% S	?	PRS
	5	38	1.00	80% Zn, 20% S	?	PRS
	6	38	1.00	80% Zn, 20% S	?	PRS
	7	38	1.00	80% Zn, 20% S	?	PRS
	8A	96 (1st stage)	1.25*	80% Zn, 20% S	?	Jaakkola
	8B	96 (2nd stage)	1.25	80% Zn, 20% S	?	
	9	84	2.50	80% Zn, 20% S	?	PRS
	10	48	2.00	$KClO_4$ & resin	?	Weige, Sorencino, Porter Beer
	11A	96 (1st stage)	1.25*	80% Zn, 20% S	?	
	11B	72 (2nd stage)	1.25	80% Zn, 20% S	?	
7-4-66	1	12	1.00	68% $NaNO_3$, 20% Al, & 12% resin	?	Claybaugh
	2	36	2.00	80% Zn, 20% S	1.98	Butterfield
	3	23	2.00	80% Zn, 20% S	1.78	La Habra Jr. High
	4	23	2.00	80% Zn, 20% S	1.63	La Habra
	5	23	2.00	80% Zn, 20% S	?	La Habra
	6	12	1.00	82% Zn, 18% S in acetone	?	Claybaugh
7-17-66	1	20	2.00	80% Zn, 20% S	1.58	Girard, Schreiner
10-31-66	1	31	1.25	80% Zn, 20% S	?	Crisalli
	2	31	1.25	80% Zn, 20% S	?	Crisalli
	3	20	2.00	80% Zn, 20% S	?	RRS
11-26-66	1	38	1.00	80% Zn, 20% S	1.91	Stewart
	2	48	1.87	80% Zn, 20% S	3 (?)	La Habra
	3	24	1.87	80% Zn, 20% S	1.76	La Habra
	4	56	2.00	80% Zn, 20% S	2.22	Novak
	5	50	3.00	80% Zn, 20% S in acetone	3.41	Claybaugh
1-28-67	1	38 (?)	2.00 (?)	80% Zn, 20% S	2.23	Kirchner
	2	60	2.00	80% Zn, 20% S	2.98	Thomas
	3	48	1.50	80% Zn, 20% S	2.25	Crisalli
	4	12	1.00	80% Zn, 20% S	3.80	Crisalli
	5	12	1.00	80% Zn, 20% S	3.96	Crisalli
	6	12	1.00	80% Zn, 20% S	?	Vito
	7	12	1.00	80% Zn, 20% S	?	Vito
	8	12	1.00	80% Zn, 20% S	?	Thomas
3-18-67	1	20	2.00	80% Zn, 20% S	?	RRS
	2	24	2.00	80% Zn, 20% S	?	Claybaugh

*Cluster of three rockets, each 1.25 inches O.D.

NO.	HEIGHT AT BURNOUT (Feet)	TIME TO BURNOUT (Seconds)	MAX. VEL. (Feet Per Second)	MAX. ACC. (Feet Per Second^2)	ALTITUDE (Feet)	RANGE (Feet)	COMMENTS
1	47	0.141	Data in raw form	Data in raw form.	Lumped, 500 feet average	Lumped, 500 feet average	Goddard-type
2	63	0.156					
3	24	0.094					
4	46	0.156					
5	55	0.188					
6	53	0.156					
7	48	0.141					
8A	292 (2nd stage)	1.147 (Both stages)	600	1220	?	?	Nozzle-less, aluminum tubing, capsulated fuel
8B							
9	?	?	?	?	?	?	Night fired with strobe light
10	-	-	-	-	-	-	Static, exploded
11A	276 (2nd stage)	0.765 (Both stages)	430	1152	?	?	Similar to 8A-8B
11B							
1	-	-	-	-	-	-	Static, exploded
2	55	0.203	525	12,096	1640	2300	Moderate steel nozzle erosion
3	?	?	?	?	930	800	Not filmed
4	180	0.656	338	2,750	520	800	2nd firing
5	69	0.094	960	Indeterminate	1190	?	3rd firing
6	-	-	-	-	-	-	Static, no ignition
1	76	0.281	460	(3,000)	1500	1100	Photo exp't
1	59	0.469	415	5,950	150	?	Goddard type
2	37	0.375	212	1,985	150	?	2nd firing
3	-	-	-	-	-	-	Hung-fired
1	61	0.083	1,514	51,920	?	?	Ceramic nozzle
2	110	0.167	1,057	8,850	900	?	
3	59	0.125	523	19,250	1600	?	Unstable flight
4	124	0.208	1,164	8,650	7000	?	RRS Beta
5	-	-	-	-	-	-	Static, no ignition
1	?	?	?	?	?	?	Not filmed
2	198	0.266	1,526	12,920	?	?	
3	?	?	?	?	1100	3000	Filmed from bunker
4	-	-	-	-	-	-	Exploded
5	-	-	-	-	-	-	Exploded
6	?	?	?	?	?	?	Filmed from bunker
7	?	?	?	?	?	?	Filmed from bunker
8	?	?	?	?	?	?	Filmed from bunker
1	-	-	-	-	-	-	Fired from balloon; erratic
2	-	-	-	-	-	-	Static; graphite nozzle

and many of the rockets were not altogether taken seriously by the students. The data records were compiled months after the firing: as a result, little information was gained that is proper to report.

The March 18 launch saw only two vehicles fired, but the first requires some comment.

It started with a suggestion by John Mariano, RRS member on leave to the Air Force, on a way to promote Project Live Fire I of last year. We simply launch a rocket from a balloon over the City Hall, and let the publicity take care of itself. Fortunately, reason itself prevailed, and the stunt was shelved, but the idea remained.

It was fueled when word came from New Jersey of a successful amateur orbital launch (their judgment, not ours) that was accomplished through the use of high altitude balloon launching techniques.

And it commenced when Bill Claybaugh and Margery Hills teamed together to attempt the first RRS balloon-held rocket launch. The total project called for a high rise balloon to carry an extremely light rocket casing, in all likelihood fiberglass, to extreme altitudes (60,000 to 80,000 feet), at which point the rocket would be barometrically ignited for high altitude research. It must have been the vision of a pragmatist that compelled Bill and Margery to conduct the project in a series of experiments.

The first test was held in December of 1966: the object was to ignite a rocket from beneath a tethered balloon. This would give the two experience in handling the balloon, and would also point out the problems that might be caused by balloon oscillation.

That test ended rather abruptly when the balloon escaped its collar while still under inflation. It was shot down immediately to avoid any possibility of air hazard.

The second test, in early March, was far happier. The balloon was tethered from three ground points, inflated with hydrogen, and allowed to rise about sixty feet while carrying a seven pound rocket. At the appointed time, the rocket ignited quite readily, but glanced slightly against a tether line, causing a deviation that was magnified by the violent thrusting of the vehicle. The rocket shot to the ground, bounced downrange, and died.

The second vehicle of March 18 was also constructed by Bill Claybaugh, using thin-walled tubing, and a graphite nozzle (without a steel skeleton strengthening it). A picture of that test appears in the Yearbook Pictorial of this issue. The test was considered highly successful, even though the tubing burned through after some time.

And we've come to the end of the trail, as far as this series of rockets is concerned. We started this project hoping to take a random number of zinc-sulfur flights and arrive at some firm qualitative conclusions. We end by saying that we are not able to do that, at least not with this grouping. Goddard vehicles climbed from 100 feet to 1000 feet depending on the day, and just as likely on the prayer used while mixing the fuel. Beta-type nozzles caused performance differences in acceleration that makes prediction impossible. Data is missing on too many of the smaller vehicles to make any judgment about them.

The one rocket consistent with past experience was John Novak's RRS Beta in that the performance curves compare favorably with the curves considered typical in NEWS 99 and NEWS 101. Unfortunately, in the grouping under discussion, no other RRS Beta rocket was fired.

The approach to gathering experimental data on zinc-sulfur that seems to be emerging is this: use vehicles of a proper length to diameter ratio (that ratio itself is subject to question); modify the nozzle to eliminate erosion, thereby keeping the throat area constant; and static test vehicles to produce thrust curves directly. The last two of these suggestions will be considered again in NEWS 103

TECHNICAL REPORTING

This is an interim progress report on the 7-inch by 12-foot hydrogen peroxide-methyl alcohol rocket on an RRS Research Contract. The design of the motor, less the injector assembly, has been finalized and the chamber body and flange have been machined. Procurement of the stock for the nozzle and the finalized design of the injector assembly are next on the schedule.

The fuel and oxidizer tanks have been mounted and secured in place. However, because of space limitations, the plan now is to obtain a shorter and fatter nitrogen tank. Calculations indicate that although the present tank has the proper capacity, the new tank would shift the center of gravity forward, increase the space available for controls, and provide some savings in weight.

An investigation of the multiple solenoid valve fuel/oxidizer controls indicate that there might be difficulties in obtaining the desired configuration and it is possible that independent solenoid controls would not only be feasible but desirable for fuel-rich starts and programmed control.

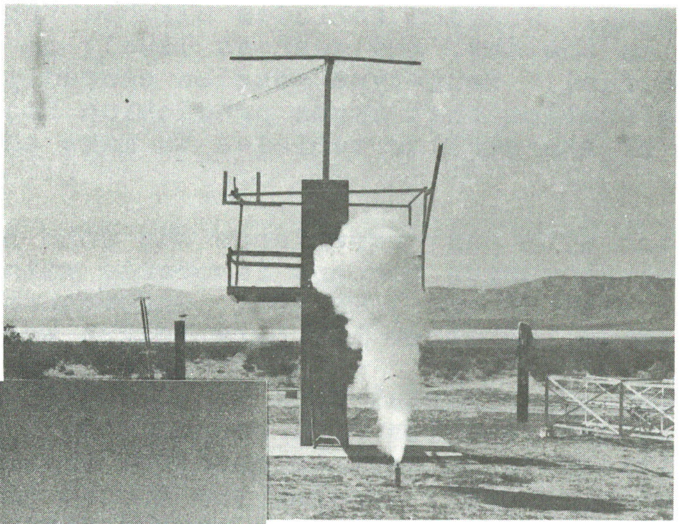
Bulkheads, damaged during exhibits, have been replaced and the skins for the motor section have been fabricated. A mold was made for the fiberglass boattail, the shell halves made, and the tailpiece has been completed.

From a $\frac{1}{4}$ scale model, the center of pressure was determined and wooden mockups of the tail fins have been made. It is hoped to have these precision milled from magnesium.

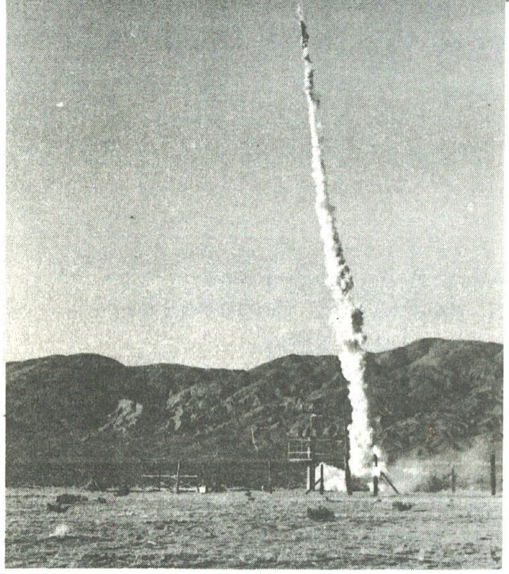
Additional small details have been attended to including the design and fabrication of the umbilical cord disconnect. Further details will be reported as the work progresses.

YEARBOOK

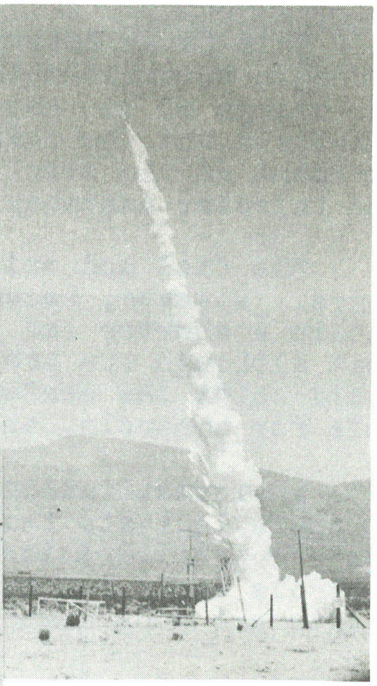
pictorial



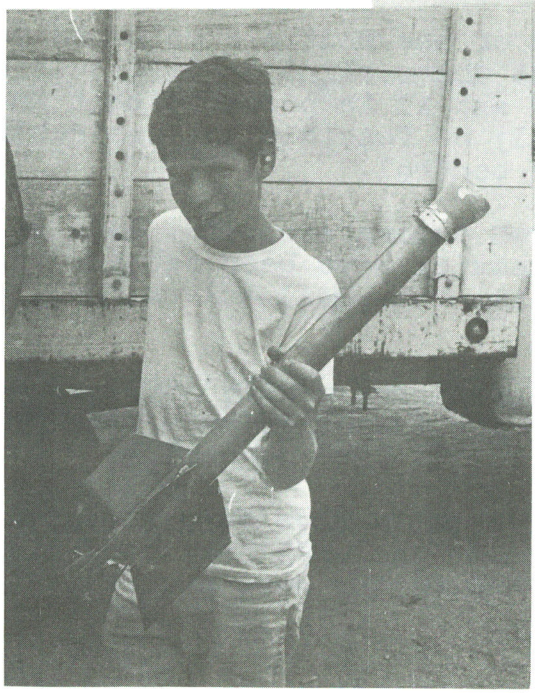
Test firing of Bill Claybaugh's graphite nozzle vehicle



RRS rocket in motion

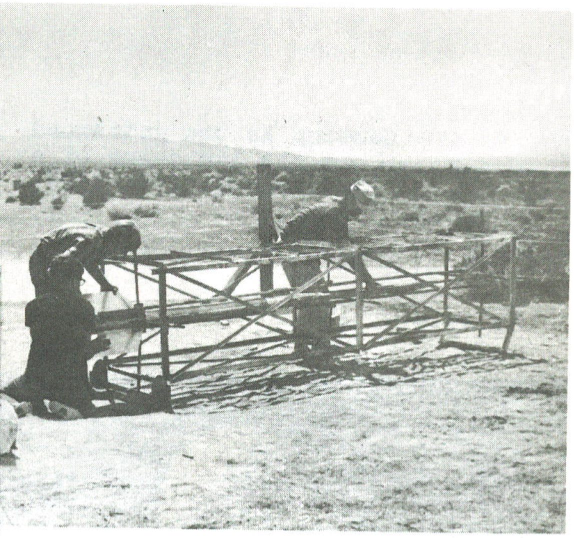


Carlos Beer's two-stager moves out slowly



Young Novak displays his rocket after the fact

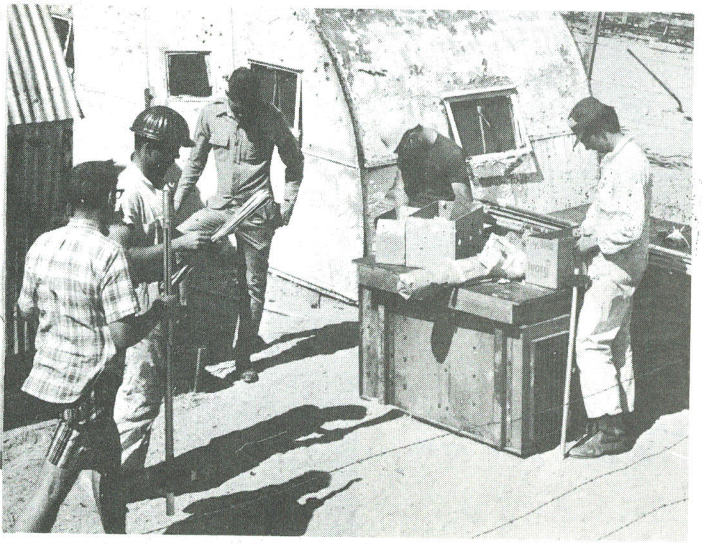
The rocket is carefully inserted in the guide railing



"V" is for explosion

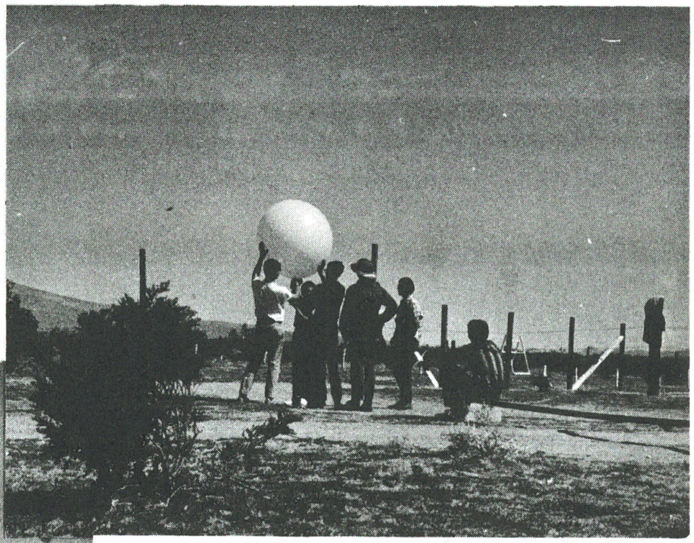
Rick Bennett and John Jaakkola prepare a PRS two-staged vehicle for flight

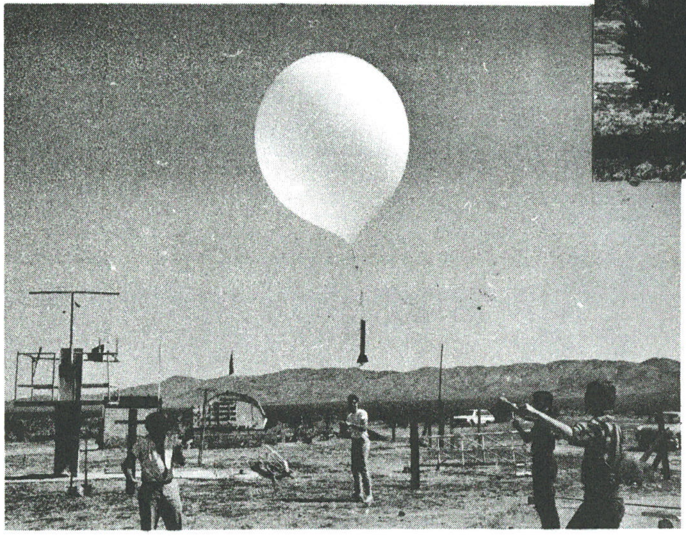
Richard Butterfield, pyro-op, pauses for a picture



Loading commences for a PRS two-stager

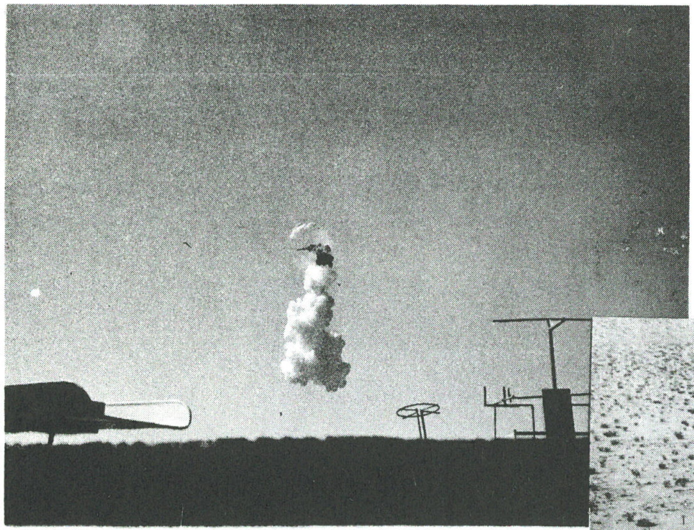
Caution is the guideword in the launching of a balloon-hoisted rocket





Balloon-launch experiment rises on three mooring lines

Photograph shows rocket penetrating the balloon at ignition

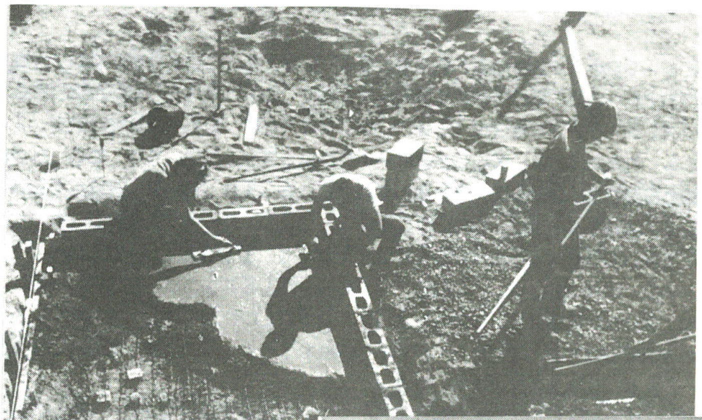


Aerial view of the Mojave Test Area

Preparation begins for
the fueling of the
Goddard series experiment

Young Butterfield, just
prior to his arrest for
speeding

The floor of the
new blockhouse
facility takes
shape



The first load of
cement is readied
for the blockhouse

Gary Lorenz,
photographer

FEATURED ARTICLES

PRACTICAL ROCKET TELEMETRY: Part 1

By Gary Lorenz,
Reaction Research Society

One of the things most wanted by the amateur rocketeer is some form of on-board flight instrumentation for his rocket. In this, the first part of a two-part article, we will bring out the basic considerations that must be kept in mind for the design of an on-board rocket telemetry system. In part two of this article, we will consider the design of a ground support station. Tested circuits and practical examples will be presented to augment the text. We hope that the information in this series will allow the amateur with a limited electronics background to construct his own single channel telemetry system.

Before the requirements of a telemetry system can be determined, one must have an understanding of the communciations process. A model of this process is depicted in Figure 1. Every communications system must have a source--something to be communicated. Usually the information from the source is not suitable for direct transmission and must be encoded into a suitable code to make it compatible with the communications link. This link is made up of the transmission device, the transmission medium, and the receiving device. The decoder, usually performing the inverse function of the encoder, converts the information from the link into information usable to the destination.

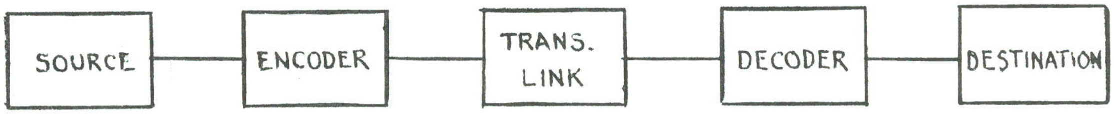


Fig. 1 MODEL OF THE COMMUNICATION PROCESS

In a rocket the source of data can be any one of a number of things: an accelerometer, strain gage, thermistor, pressure transducer, photocell, gyro, etc. Usually transducers produce either a variable voltage or a variable resistance output.

Most transducers in a rocket produce very low frequency outputs, less than ten cycles per second, and such frequencies are not compatible with the transmission link. A number of techniques can be used to make the output transmittable, such as using it to change pulse amplitudes, pulse positions, pulse widths, pulse codes, pulse repetition rates, and frequencies. For the amateur, the simplest system to use in terms of ease of encoding and decoding is that of varying the frequency of a subcarrier oscillator. The Inter-Range Instrumentation Group, responsible for the establishment of telemetry standards in the United States, has designated eighteen telemetry subcarrier channels ranging in frequency from 400 cycles per second to 70 kilocycles per second. The standard frequency deviation with maximum modulating signal is plus or minus 7.5 per cent. The maximum frequency of information that can be transmitted on any subcarrier frequency for good signal to noise ratio is given by Equation 1:

$$\text{B.P.} = \frac{F_oD}{5},$$

where F_o is the subcarrier frequency in cycles per second, D is the deviation percentage (F/F_o), and B.P. is the bandpass of the encoder in cycles per second.

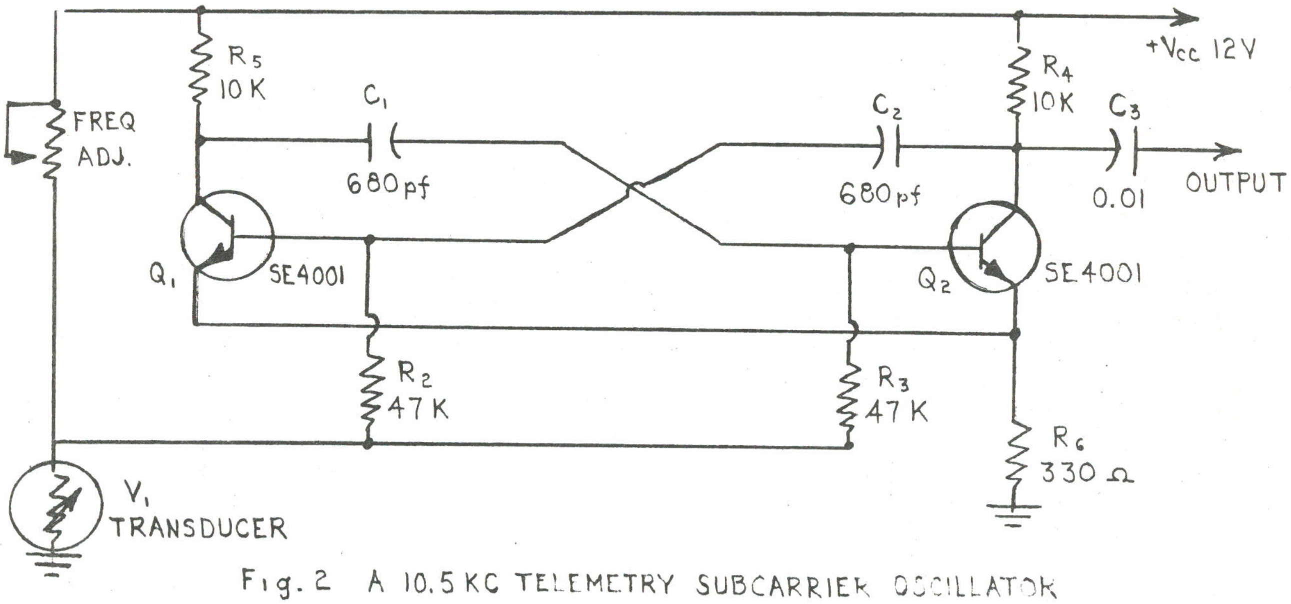


Fig. 2 A 10.5 KC TELEMETRY SUBCARRIER OSCILLATOR

The schematic circuit diagram of a 10.5 kilocycle voltage-controlled oscillator appears in Figure 2. The operating frequency of the oscillator is determined by C_1, C_2, R_1, R_2, and R_3. R_1 is a variable resistor having a value equal to twice the rest resistance of the transducer and is used to adjust the frequency of the oscillator to 10.5 kc. The static resistance of the transducer used with this circuit should not exceed 10 kilohms, or significant loading of the voltage divider R_1-V_1 will result. The maximum information capability of the 10.5 kc subcarrier oscillator is 160 cps. This is equivalent to a resolution of 0.5 G when a 0 to 75 G accelerometer is used as the input source.

Now that the source data has been encoded it is ready for transmission over the radio transmission link. The link consists of an

[redacted]

on board transmitter and antenna system, and a ground antenna and receiver system. Rocket antenna size, receiver availability for a certain frequency, and the Rules and Regulations of the Federal Communications Commission are the three main factors to be considered when choosing a transmission link frequency. The most practical antenna for a small rocket is a simple quarter wavelength brass tube of small diameter passing through the nose cone along the length axis of the vehicle. The length of the antenna ranges from two and one-half feet at 100 megacycles to three inches at 1000 megacycles; the transmitter frequency should be within this range. The equation for length (Equation 2) is:

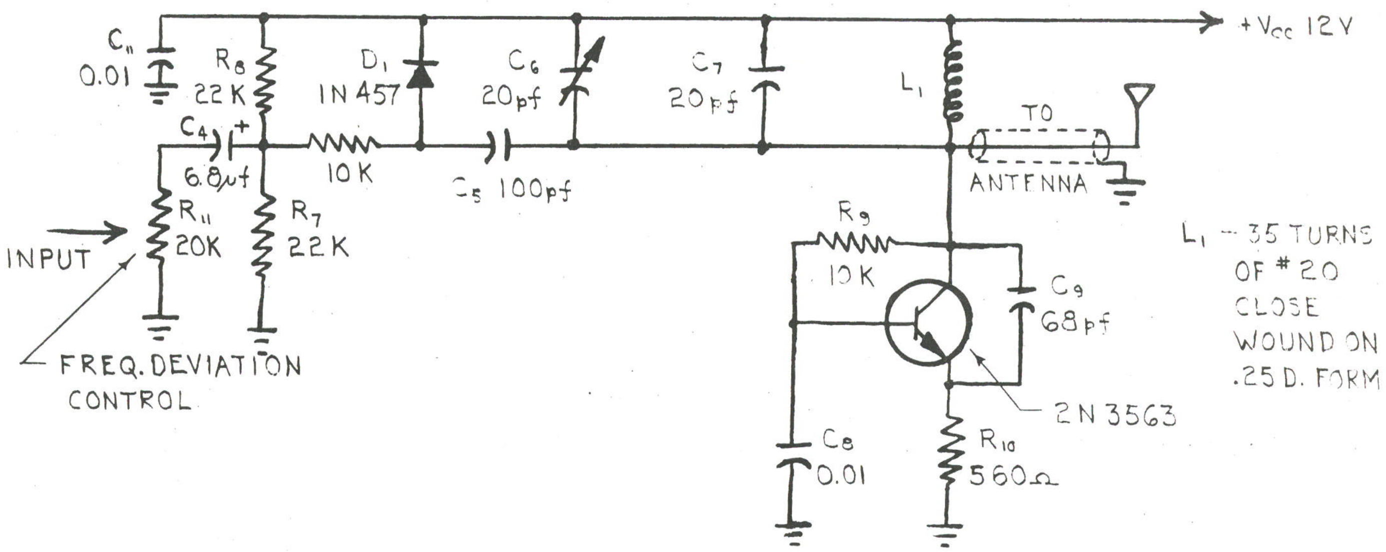
$$\ell = \frac{75}{f_t},$$

where ℓ is the length of a quarter wavelength radiator in feet, and f_t is the transmitter frequency in megacycles.

Transmitters can be operated legally by the amateur in the 88-108 megacycle standard FM broadcast band, the 144-148 megacycle "ham" band, the 220-225 megacycle "ham" band, the 420-450 megacycle "ham" band, and the 890-942 megacycle Industrial, Scientific and Medical band. Receivers for the amateur bands have very small bandpass capabilities, typically plus or minus three kilocycles maximum, and are unsuitable for all but very low frequency telemetry. The amateur must also have a valid amateur radio operator's license to operate in these bands. Receivers of any type that will cover the 890-942 megacycle range are difficult to find.

This leaves the 88-108 megacycle FM standard broadcast band for which high quality, wide band receivers are readily available. Legal requirements for custom made telemetry transmitters operating in this band are given in Part 79 (formerly Part 15) of the Federal Communications' Rules and Regulations. In short, the Commission requires that the transmitter have a radiated field intensity of less than 50 microvolts per meter at a distance of 50 feet from the transmitter, that the transmitter must not cause harmful interference to a duly licensed, operating FM station, and that the transmitting device be submitted to the Commission for their approval prior to operation. These requirements are not difficult to meet, and an engineering approximation can be submitted to fulfill the first requirement.

The schematic circuit diagram of a 108 megacycle FM transmitter that will meet the requirements of the Commission is shown in Figure 3. The transmitter has an output power of three to five milliwatts when operated on a supply voltage of 12 volts. The center frequency of the oscillator is primarily determined by the self resonant frequency of the tank network consisting of L_1, C_5, C_6, C_7, and the junction capacitance of diode D_1. The oscillator is set to the operating frequency by tuning C_6, until the "carrier" is heard in a receiver tuned to the operating frequency. Modulation is accomplished when the junction capacitance of D_1 is electrically varied by the incoming modulating signal, thereby changing the self-resonant frequency of the LC tank. Modulating frequency response is flat from 5 cycles per second to 500 kilocycles per second and frequency deviation can be made as high as one megacycle by proper adjustment of R_{11}.



L₁ — 35 TURNS OF #20 CLOSE WOUND ON .25 D. FORM

Fig. 3 A 108 MEGACYCLE FREQUENCY MODULATED TRANSMITTER

The maximum deviation that a standard FM broadcast receiver will accept without desensitization is plus or minus 75 kilocycles. Deviation is set to the proper value by connecting the voltage controlled oscillator to the input of the transmitter. A receiver is tuned to the operating frequency of the transmitter; a very high frequency note should be heard at this point. The deviation control, R_{11}, is adjusted to produce the loudest tone with the least amount of distortion.

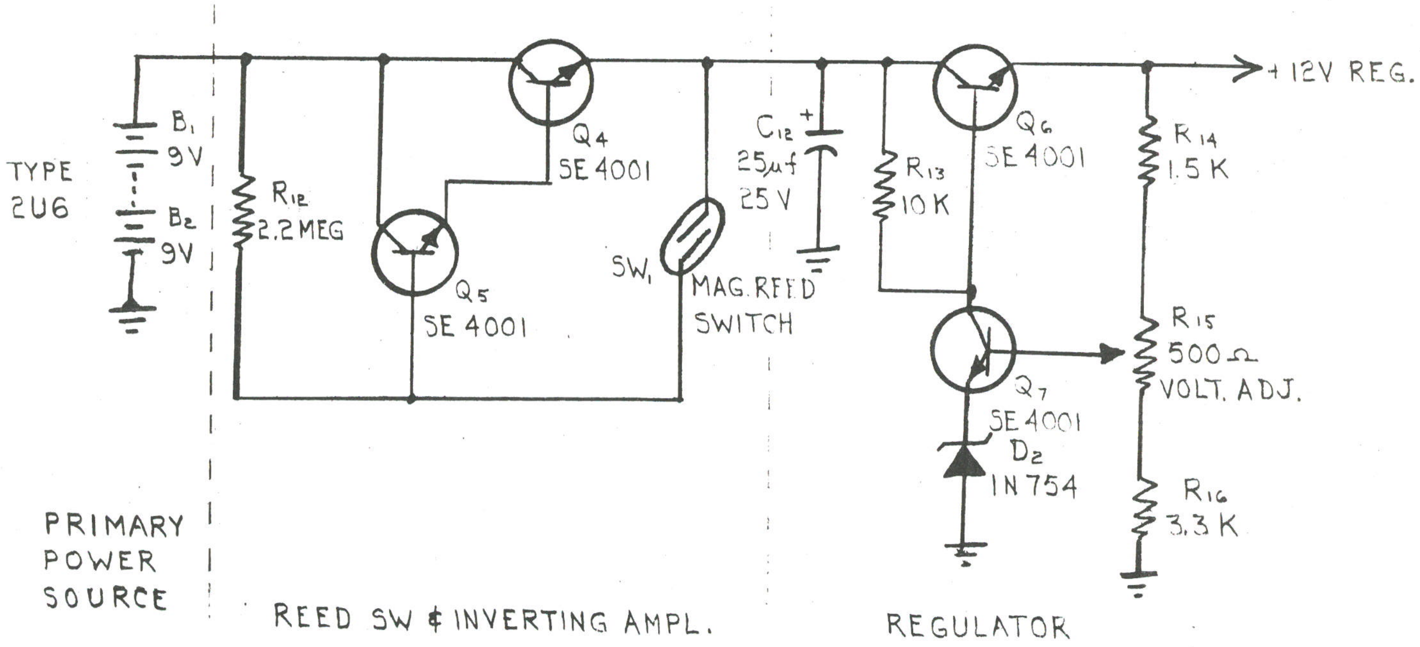


Fig. 4 A 12 V. REGULATED POWER SUPPLY WITH MAGNETIC SWITCH. QUIESCENT CURRENT DRAIN IS 10 MICROAMPERES.

For overall system stability, the telemetry encoder oscillator and transmitter should be operated from a stabilized voltage source. Such a source is shown in Figure 4, with the addition of a magnetic switch to turn the telemetry system on.

The primary battery supply consists of two nine volt transistor radio batteries connected in series. A magnet and reed switch combination is used to turn on the telemetry system. A magnetic reed switch is placed in close proximity to the inside wall of the nonferrous metal cover for the instrumentation section of the rocket. The magnet is mounted outside of the rocket over the reed switch on an external support. The power to the telemetry system is inhibited until takeoff when the rocket pulls away from the magnet.

Then voltage is applied to the regulator which drops the 18 volts from the magnetic switch amplifier to 12.0 volts. Regulation provided by the regulator is better than 0.1 per cent for current drains up to 25 milliamperes. The voltage output can be adjusted over a small range by varying R_{15}. The power supply is more than adequate for the rest of the telemetry system.

Needless to say, the mechanical considerations are just as important as the electrical considerations in rocket instrumentation. All resistors and capacitors used in the system are small enough that inertia effects in unpotted circuits will not be a problem. L_1 in the transmitter should be made very rigid or rocket flight vibration will frequency modulate the transmitter output. If at all possible, printed circuit boards should be used in construction.

All of the electronic components that are used in the system, except possibly the transistors, are available from local electronics distributors or mail order houses. All resistors are ¼ watt, carbon composition units. Capacitors having values below one microfarad are disc ceramic; those having values above one microfarad are electrolytic types.

Thus far some of the aspects of getting information out of a rocket have been covered. Part two of this article will delve into the problems of receiving the signal and accurately decoding it into useful information.

For an overall introduction to radio telemetry, the reader is referred to Marvin Tepper's Fundamentals of Radio Telemetry, published in 1959 by John F. Rider, Inc., of New York. For particular referencing of Mr. Lorenz's article, Reference Data For Engineers (Fourth Edition), published by International Telephone and Telegraph, New York, (p. 964 ff), will be useful.

BURNING RATE BOMB: A Proposal

By Charles Pooley,
Reaction Research Society

Much of the frustration for the amateur rocketeer comes from having to guess certain performance parameters, some of which are rather critical. One of these, for solid propellant rockets, is the linear burning rate of the propellant, or the rate at which the flame advances through the propellant.

In a solid propellant rocket, the pressure in the motor (which should be a known fraction of the bursting pressure of the motor casing) is dictated mainly by the throat area and by the rate of production of gas from the burning propellant. The production rate is the exposed burning surface times the density times the linear burning rate.

Density is normally constant, and easily calculated. The exposed burning area varies with time, and can be somewhat difficult to calculate. (See RRS NEWS 100 for an incremental method of calculation.) But generally, these two factors can be predicted by an amateur. It is to the linear burning rate that we give our attention.

The burning rate is usually given in basic texts as

$$R = a + b \cdot p^n ,$$

where a and b are dependent on the initial temperature of the propellant, and near room temperature have slight effect on R, the burning rate; p is the pressure; and n is a constant, a characteristic of the particular fuel.*

Suppose we ignore a and b, and assume $n = 1$, so that $R = p$, or at least R is proportional to p. And in almost any motor, the pressure is proportional to the gas flow rate because of the nozzle, so that here would be an unstable condition. Any slight rise in pressure would be met with a proportional increase in burning rate, which in turn would increase the pressure until an explosion took place.

On the other hand, if $n = 0$, then R would be constant ($p^0 = 1$). Any small increase in pressure would not be augmented by an increase in burning rate, and the pressure would not build up catastrophically. We would then have a stable situation.

---

*A good derivation of this formula, as well as an explanation of the physical assumptions, is given by Francis Warren in Rocket Propellants published by the Reinhold Corporation, New York, in 1960.

In practice, n is usually between 0 and 1, and although the propellant is in a stable condition, any pressure fluctuations (or, more likely, miscalculations) tend to be aggravated to some unknown degree.

And there lies the problem. To know the burning rate of the propellant at varying pressures so that the rest of the motor can be designed to fly and not disappoint. It is proposed, then, that a device be built which will measure the rate of burning of some propellant sample, while subjecting it to varying pressures.

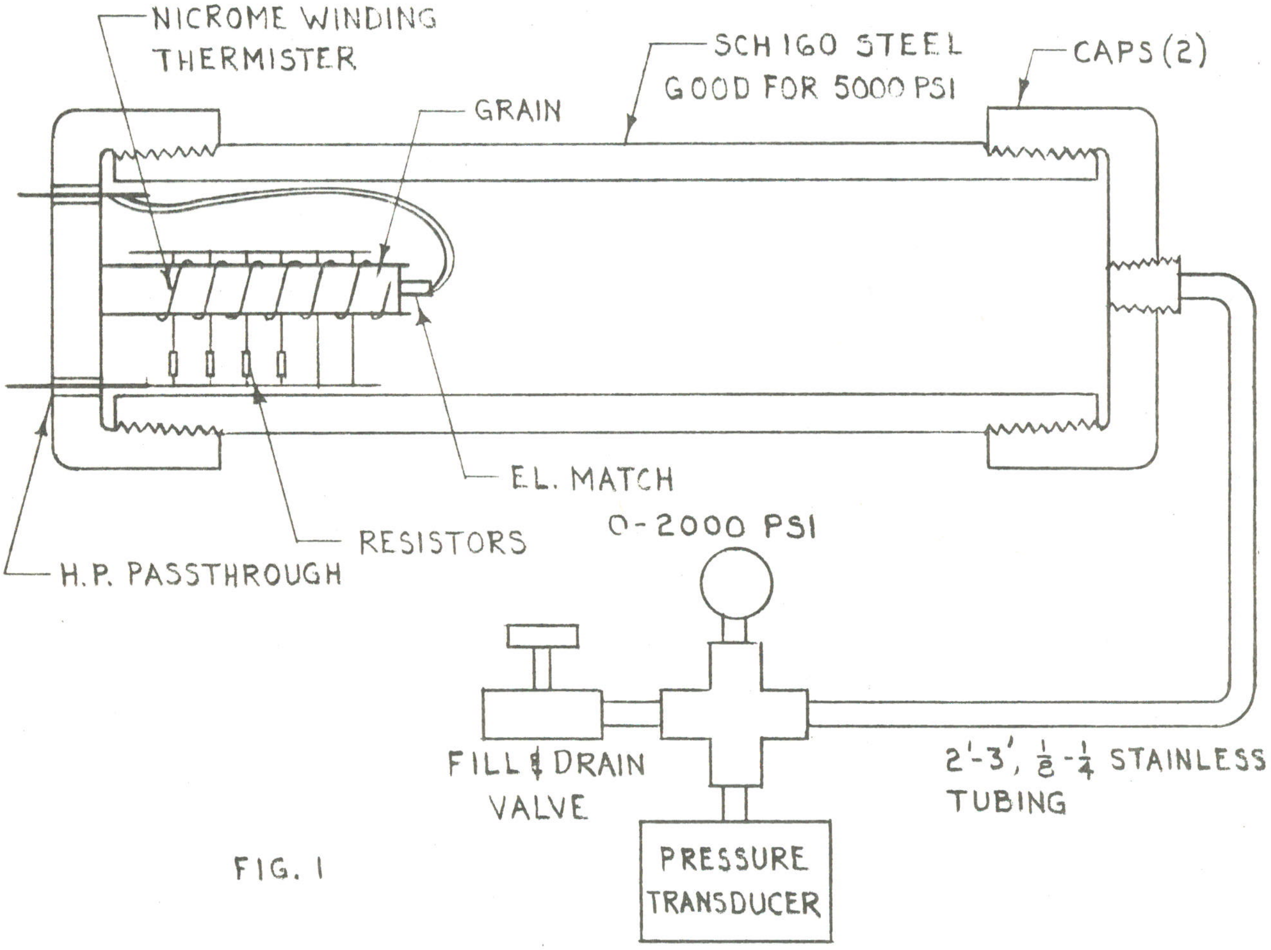


FIG. 1

GAS PRESSURE CONTROL. SUFFICIENT VOLUME SO PRESSURE RISE FROM GRAIN IS LIMITED.

GAS PRESSURE. In the interest of safety and simplicity, constant pressure will be maintained not by a relief valve but by constructing the container of such ample volume that the amount of propellant used could not burst it. It can be shown that a propellant sample will not increase the pressure in an already pressurized container by more than would be caused by pumping in the grain's weight in the kind of gases it produces and heating the resulting gas by the amount of heat produced by the grain. These are both rather easily calculable quantities. Departures in the behavior of a grain under test from such a "perfect grain, such as condensing components and heat loss through the walls of the device, tend to reduce the pressure rise.

Such a pressure vessel is shown in Figure 1: there is a holder for the grain and igniter, electrical passthroughs, a pressure transducer to record the pressure while the grain is burning, a pressure gauge, and a valve for admitting and dumping gas. The vessel could be constructed of high pressure pipe and fittings, and should be hydrostatically tested to several times the highest pressure expected.

The grain temperature could be checked and regulated before ignition by fitting a thermistor and winding of nichrome wire around the grain.*

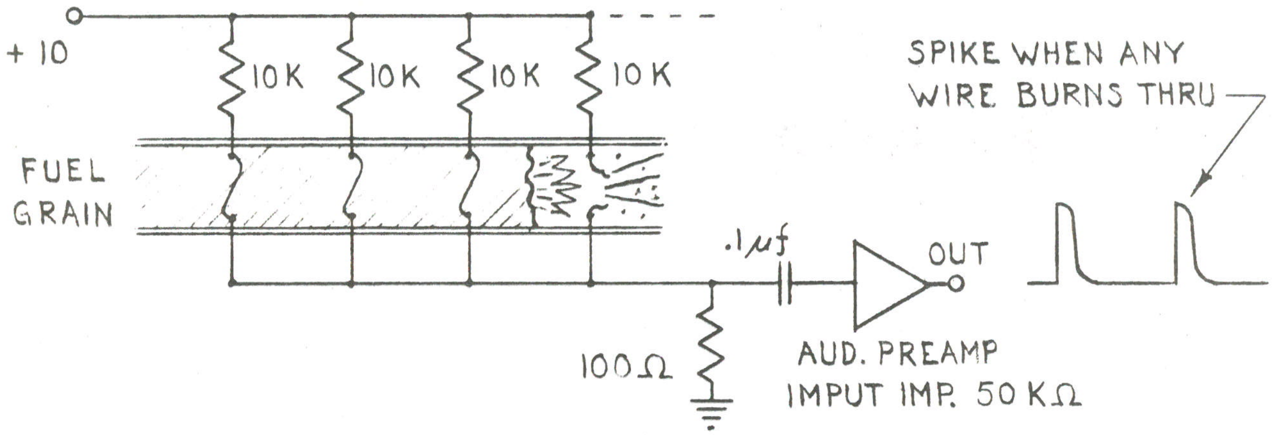


FIG. 2 BURN RATE INDICATION PREAMP IS A SPECIALLY BUILT AMPLIFIER OR SCHMIDT TRIGGER.

RATE MEASUREMENT. It would be difficult to show a continuous rate of burn, and instead a system of showing the instant the flame burns past given points is given in Figure 2. Fine wires are threaded through the grain at regular intervals, and connected as shown. Each time any one of them burns through, a sharp, regular pulse comes from the amplifier.

---

*The June 1961 ARS Journal suggests a more effective system for preheating the propellant strand. By surrounding the strand with a massive heat sink, and then preheating, or cooling, for periods on the order of six hours, the strand can be brought to the desired temperature, and then removed from the oven and transferred to the test bomb with no significant loss in temperature. Tests show that the bomb can hold the test temperature for at least six minutes, and there is little need for more than two or three minutes between transfer and test.

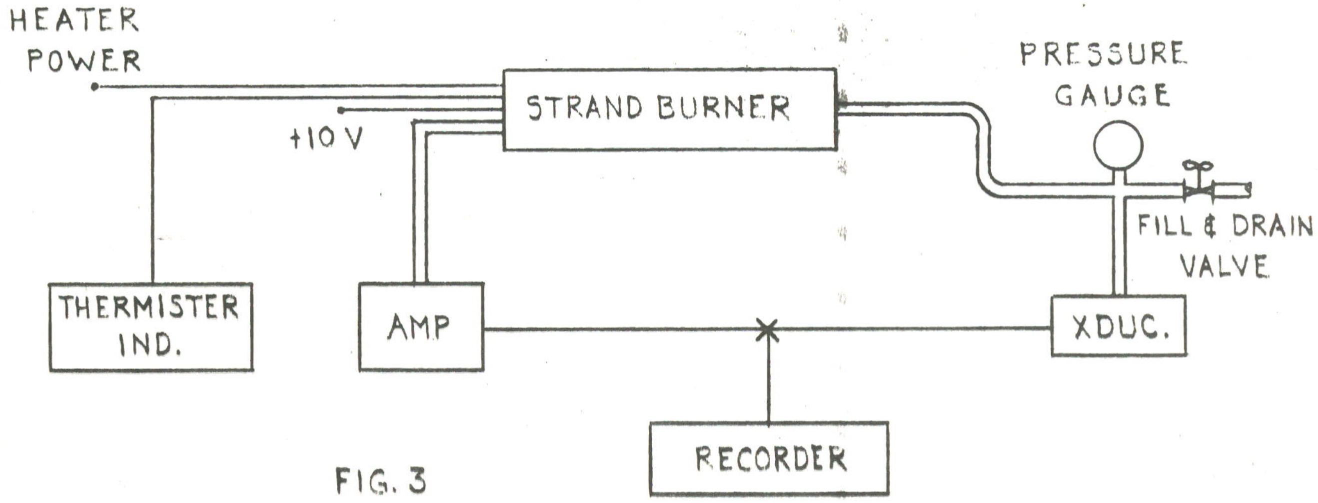


FIG. 3

SYSTEM. Shown in Figure 3 is how this would be set up. The pressure transducer (any of several fast-acting units available) gives some electrical signal proportional to pressure. The recorder is a single- or two-channel pen recorder, having a fairly rapid paper advance. Figure 4 shows what a record might look like. The sharp spikes of the pressure trace will indicate the burning rate.

The operation of the device would be as follows. (1) Install fuel sample. (2) Pressurize with nitrogen or air to starting pressure--a little below the pressure range to be investigated. (3) Heat or cool to room temperature the grain. (4) Fire, with recorder on. (5) Valve off gas when cool.

With the information gained, a propellant can be used with the parameters now predictable, important in "optimizing" a small solid propellant rocket. The wall casing may be chosen without fear of it blowing out or of being too heavy. One would now have a "scientifically designed" rocket.

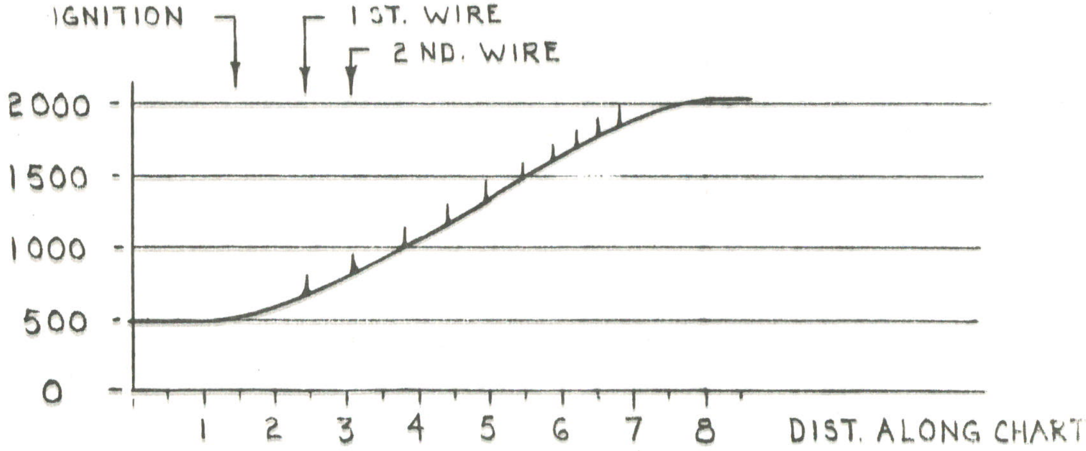


FIG. 4

POSSIBLY WHAT RECORD MIGHT LOOK LIKE, LEFT, BURNING RATE TAKEN AS AVERAGE BETWEEN 2 SPIKES, PRESSURE AS MEAN BETWEEN SPIKES.

PEAK SENSING
EXPERIMENTS

By Don Girard,
Reaction Research Society

The Society, in recent years, has had relatively little success in deploying parachutes from a rocket in flight. The most significant experiments along this line were conducted by Dennis Shusterman in 1964 using photo-sensitive devices, but Mr. Shusterman met with mechanical limitations. It was generally felt by the Society that the theory was good, and that a step-by-step program of study would yield a reliable system. This article reports the first results.

Rocket vehicles are expendable, not through desire, but by nature. Most motors may be fired once, and soft recovery serves little purpose. It is not so with the package, for both life and father's camera are priceless.

In large vehicles, parachute deployment may be triggered by barometric sensors, ground information (telemetry), gyroscopes, or airstream indicators. In small vehicles, from one to six inches in diameter, for local altitudes, say ten miles, more compact units are needed.

Simple inertia switches will not work for missiles essentially ballistic, as the weight or trigger element must move forward relative to the motion of the rocket. This implies the rocket accelerates at a slower rate than the trigger, which is the situation from burnout to impact. Gravity accelerates both at equal rates, but drag forces consistently impede the motion of the rocket from the time of burnout, or at the duration of powered flight. The trigger will be in a forward position, or closed, for flight up and flight down, perhaps great for observation, but useless for parachute deployment.

Timer devices are at best chancy, for there is a presumed foreknowledge of the performance of the rocket: it will reach such and such an altitude requiring so much time. Calculations of this time are complicated by experimental knowledge that time up is not equal to time down, but rather is of the order of one to one and a quarter.

Mechanical accelerometers are possible solutions, since when the drag force decreases to some small value, this change is acceleration may be sensed within the rocket. Drag force is proportional to the square of the velocity, and there is always present at least a small horizontal drag force, implying a need for experimental verification of accelerometer calibrations.

Gyroscopes are excellent attitude references, or peak sensors, but are quite expensive.

What is left? What hope is there for solution? We turn in desparation, nay, in enlightened confidence to the mystery of electronics. Our search is not without effort. Theory abounds, but application is scarce.

To quote from Mr. Shusterman's article of NEWS 99:

> **"A simple attitude sensor is one which uses the sun's light as a reference. When the sun is above the rocket as it travels upward (assuming a stable flight), the observed light intensity is more or less constant. At peak altitude when the rocket turns downward, the light intensity is greatly reduced.**
>
> "A design approach would place a photosensitive device pointing upward in the nosecone of the rocket, responding to light intensity changes by variations in resistance or voltage output. This change will actuate a circuit, which in turn fires a separation or parachute ejection charge."

A history of one success in eight attempts, using a back-facing photocell, and a silicon controlled rectifier as a latching relay, prompted Bob Schreiner and the author to undertake a series of tests on a modified design.

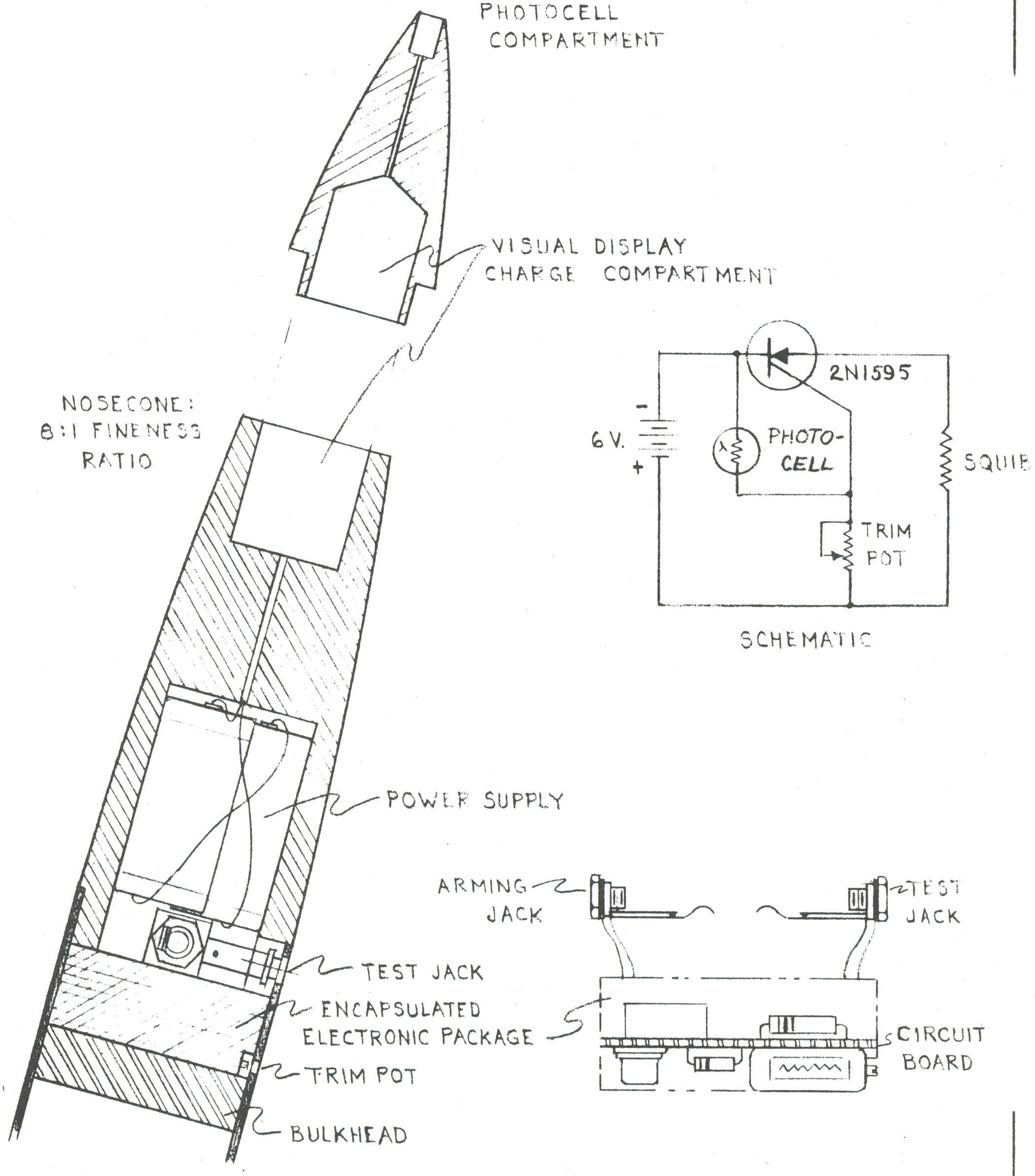
Five identical motors were built, a foot and a half long and two inches in diameter. It was expected the rocket would reach about 1200 feet altitude, enough to subject it to flight strain, but not so far that it would be lost from visual tracking. The propellant was zinc dust and sulfur.

The circuit operates in the following manner. The photocell resistance is at a maximum when there is complete darkness. It is a photoconductive device. The photocell and trim pot serve as a voltage divider across the battery. When a large voltage appears across the photocell (when light intensity decreases), this same voltage drop (neglecting leakage current) appears across the cathode to gate of the silicon controlled rectifier, and implies a heavy gate current. The gate is then opened, and current flows cathode to anode through the load, and the squib is fired.

Without the shunt resistor (photocell), the trim pot is adjusted to just draw cathode to gate current necessary to open the SCR. Then this value is halved (approximately), the shunt replaced, and at some maximum value of shunt, the current through the SCR is about twice that to open the gate, and the load fires.

Field conditions demand both a safety jack, and a test jack; the safety to prevent premature firing, and the test to adjust the circuit to desert light.

The trim pot and SCR were encapsulated in mil spec epoxy, to dampen transmitted vibration, and to act as a heat sink from the motor combustion.


PHOTOCELL COMPARTMENT
VISUAL DISPLAY CHARGE COMPARTMENT
NOSECONE: 8:1 FINENESS RATIO
2N1595
6 V.
-
+
PHOTO-CELL
SQUIB
TRIM POT
SCHEMATIC
POWER SUPPLY
ARMING JACK
TEST JACK
TEST JACK
ENCAPSULATED ELECTRONIC PACKAGE
CIRCUIT BOARD
TRIM POT
BULKHEAD

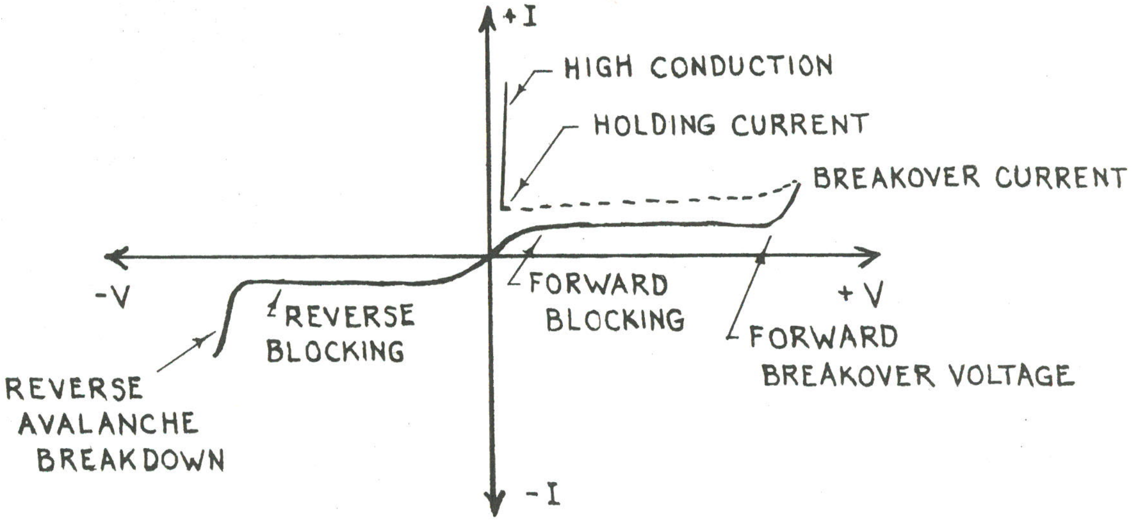
G.D.

The squib for the experiment would fire a display charge at turnover, rather than separate a parachute compartment.

And it came time for the first testing. The rocket went up, the rocket went down, it landed, the squib fired, some words were spoken, some modifications made.

For the second, and subsequent experiments, it was felt an ultraviolet filter, together with a larger battery supply, would allow a successful firing. At this time we don't know. The cloud cover that kept us company the entire weekend would not permit a proper distinction between light up and light down.

Hindsight (though we're not sure we've come forward enough to call it that) forces us to consider several factors before considering the experiment complete. A spectrograph analysis of our firing area must be taken, in winter and in summer. The circuit temperature must be monitored during firing. Battery supply size must be standardized, or squib current draw reduced.



A typical voltage-current curve for an SCR is given here, together with an explanation of the various regions of operation. In the forward blocking region, increasing forward voltage does not significantly increase current until the point of avalanche multiplication. Past this point, the current increases rapidly until the sum of the carrier junction currents is greater than one. At this point the SCR goes into high conduction, provided that the current through the device remains greater than a minimum value called the holding level.

In the reverse direction, the SCR exhibits characteristics very similar to ordinary back-biased silicon rectifiers. For increasing gate currents, the region between breakover current and holding current is narrowed, and the forward breakover voltage is reduced.

SECTION 8

A SURVEY OF STATIC FACILITIES

By Don Girard,
Reaction Research Society

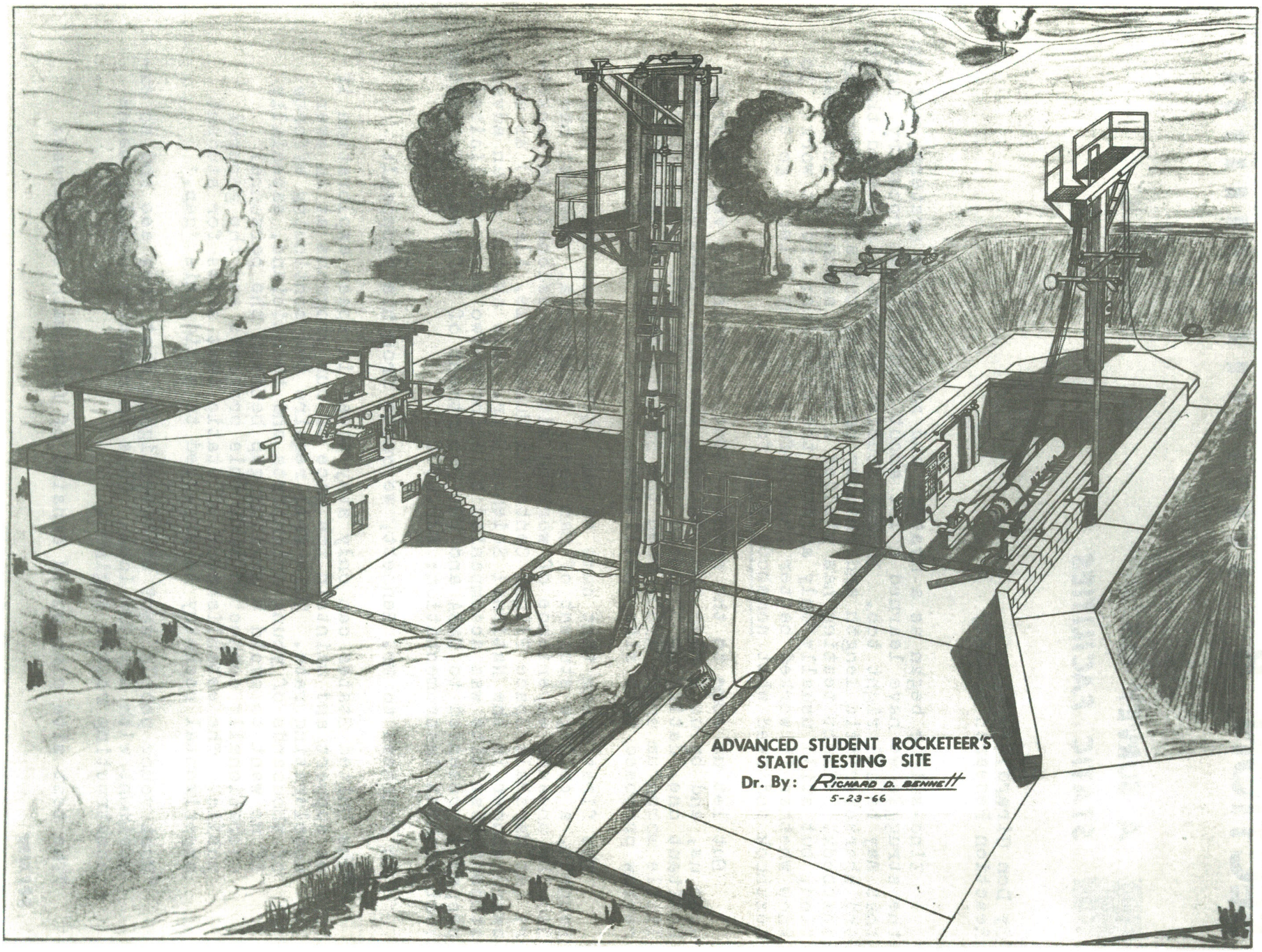
Zinc-sulfur began as a mystery and may end as a mystery, but in the struggle we have learned a lot about professional rocketry, and that may be all right too. In our studies we have discovered thrust and characteristic length and chamber pressure, but always from the textbook. Flight testing has yielded a certain amount of information, but still usually only answers the question: did it work? To know whether it worked better than before, ah, my friend, go to the textbook and read what somebody else found out.

But let us come to the point. Static testing is very nearly upon us, and by us I mean the Society, the RRS. That process was a hesitant one, dating to proposed structures in 1960 and gaining little momentum until 1966, when the Society began in earnest to review proposed test site facilities.

The first dream that came to our attention was that of Rick Bennett, a college student of San Jose, California. Bennett had had the unusual experience of working with professionals in rocketry (at Marshall Space Flight Center in Huntsville, Alabama) as an award winner in the National Science Fair. His sketch of an advanced student test site was accompanied by a forty-two page unsolicited proposal presented to NASA and the Department of Defense. Estimated cost without instrumentation: $20,000.

In fairness to Mr. Bennett, we quote from his proposal:

> "The United States can only stay ahead in space exploration if we support and maintain the pace of our programs at an ever accelerating rate. This will require the continuing efforts of thousands of young scientists and technicians, especially if we want to avoid a serious gap between the personnel operationally connected with this progress and the general public. The establishment of static test sites for student experimental rocketry is proposed to avoid this 'gap.'
>
> "Most young people want to investigate what they see and to experiment with any new idea. This in rocketry usually means constructing rocket engines.
>
> "The test site plan would consist of four main test areas:



ADVANCED STUDENT ROCKETEER'S
STATIC TESTING SITE
Dr. By: Richard D. Bennett
5-23-66

(1) a low thrust area designed for close observation of small propulsion systems both liquid and solid, for rockets up to 500 pounds in thrust; the low thrust area should be capable of handling wind tunnel and blow-down equipment; (2) a medium thrust area, designed for vertical testing of complex low to medium thrust rockets, both liquid and solid, for rockets up to 3,000 pounds thrust; (3) a high thrust area for horizontal and vertical testing of high thrust solid rockets; and (4) a blockhouse-workshop."

Despite a cover letter by Konrad Dannenburg of the Marshall Space Flight Center, Bennett's proposed has received little enthusiasm and some criticism from NASA administrators. NASA's traditional response to student rocketry has been the look but don't touch approach. Information is given with some freedom, but NASA will not sponsor actual experimentation. (The Department of Defense does test amateur rockets under special circumstances.)

A government-sponsored test facility expressly for amateurs of any design is extremely unlikely, according to one source at the NASA Western Operations Office. However, according to that same authority, there is some movement underfoot to sponsor such a facility through industry, much as automobile experiments are sponsored. But no such facility exists now, and the RRS is forced to consider Bennett's proposal in the light of individual financing and initiative.

The question is, of course, one of day to day use. Exceptional rockets have been, and continue to be tested with the co-operation of the armed forces. Normal experiments require normal equipment: three test bays are extravagant, elevator platforms luxurious, blow-down equipment absurd. Expedience guides us here, and suggests that far too many hours are to be spent on structures, and too few on instrumentation.

A less fanciful test cell is suggested by Lt. Col. Charles M. Parkin, Jr.*, but research has yielded little legitimate information as to vehicle strappings and instrumentation.

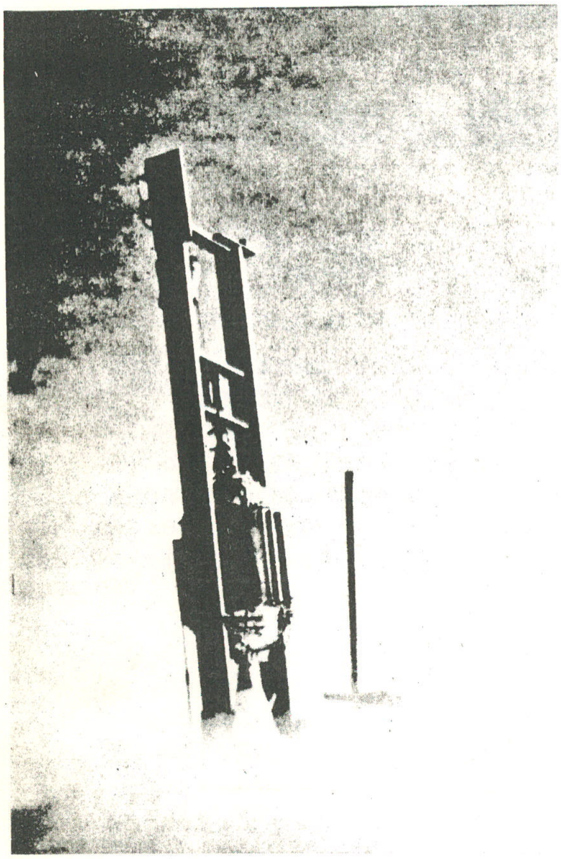
The Society did find significant information from two static sites that have been constructed and are in current use for student experiments. The first we would report on is the Perkins Rocket Safety Test Center in Sacramento, California, supervised by the Rocket Research Institute.

That test complex has two blockhouse control buildings commanding the test activity from opposite sides. Two stands are used, one an I-beam with a concrete bay at its base, the other an elaborate twin I-beam structure that pivots from the horizontal to the vertical. The second stand was built to test hot water rockets for Truax Engineering, and is available for use to student rocketeers. (See photograph.)

---

*Author of <u>Rocket Handbook For Amateurs</u>, published by the John Day Company, New York.

This second stand, while professionally engineered, is however a special purpose structure, and is not immediately adaptable to the Society liquid rocket needs. Two ideas were garnered: allow the thrusting to occur between the strength-carrying elements; and counterbalance the stand for smooth pivoting.



The first stand, the one normally used, brought these observations: the thrust cell fixture must be integral with the stand, and not a tag-on; there must be a secondary platform for work above eight feet; communications must be direct from the stand to the controls station (electronic if need be); and the positioning guides for the rocket should be strong enough to take considerable lateral forces.

The bipropellant liquid test cell at the Massachusetts Institute of Technology, the second complex we would report on, gave the Society an experienced report as to the controls necessary for liquid work. The MIT engineers detailed the regulation of compressed air, high and low pressure nitrogen, high pressure oxygen, fuel, and coolant during low-thrust rocket operations.

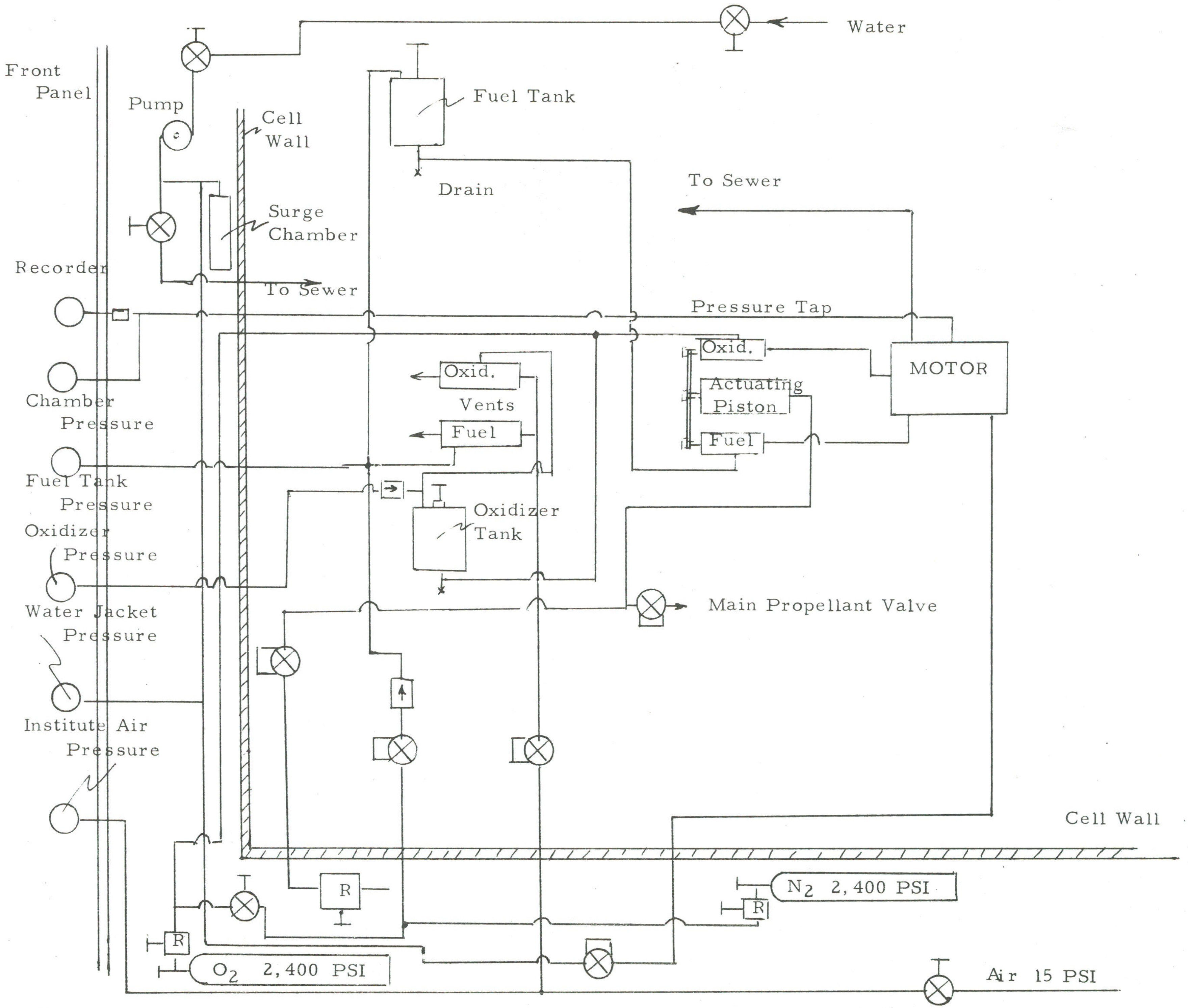
Oxygen and nitrogen are supplied from standard cylinders, compressed air (15 psi) is supplied by the Institute, and the water coolant comes directly from the main. The oxygen and nitrogen can be regulated for various pressures.

Electrically operated valves are used for opening the main nitrogen valve, the coolant valve, and the main propellant valve. The propellant vent valves are operated pneumatically, as is a chamber pressure sensing switch (designed to insure a minimum 100 psi chamber pressure before the test begins).

A schematic of the various vents and valving is presented on the following page. The motor thrusts against a cantilevered steel support.

The MIT experience allowed us to judge with some assurance on the controls necessary for work with the hydrogen peroxide and methyl alcohol rocket (NEWS #100) and to report with favor on the proposal of Leroy J. Krzycki incorporated into the book reviews of this issue.

We end our report here, as the major influences on the Society's


Water
Front Panel
Pump
Fuel Tank
Cell Wall
Drain
To Sewer
Surge Chamber
Recorder
To Sewer
Pressure Tap
Oxid.
MOTOR
Oxid.
Vents
Fuel
Actuating Piston
Fuel
Chamber Pressure
Fuel Tank Pressure
Oxidizer Tank
Oxidizer Pressure
Main Propellant Valve
Water Jacket Pressure
Institute Air Pressure
Cell Wall
R
N_2 2,400 PSI
R
R
O_2 2,400 PSI
Air 15 PSI

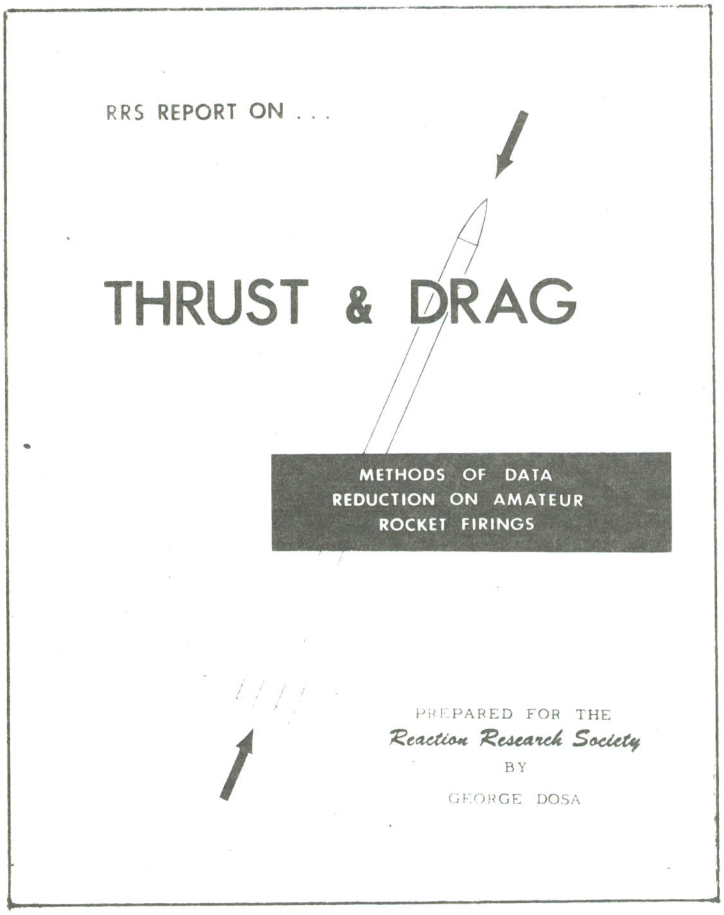
BOOK REVIEWS

Krzycki, Leroy J. How to Design, Build and Test Small Liquid-Fuel Rocket Engines. China Lake, California: Rocketlab

This booklet of about 60 pages is well written and obviously from actual experience. The material is well presented in a logical series of design steps followed by a typical example for design and fabrication, in a most straightforward manner. The book carries through to installing and testing of the system, and follows up with a good bibliography and list of suppliers.

The author has chosen to limit himself to gaseous oxygen for his oxidizer and to the testing of the system only. He has chosen not to go into the areas of performance such as thrust, pressure, and temperature except to mention it casually.

A few of the author's comments detract from the text, such as ". . . amateurs should not consider building uncooled rocket engines," ". . . water is the only coolant recommended," and ". . . advanced metals and fabrication techniques are far outside the reach of the serious amateur builder." Aside from these things, this book is recommended to the serious amateur builder and the author is to be commended for his excellent presentation.



RRS REPORT ON . . .

THRUST & DRAG

METHODS OF DATA
REDUCTION ON AMATEUR
ROCKET FIRINGS

PREPARED FOR THE
Reaction Research Society
BY
GEORGE DOSA

Written expressly for the amateur rocketeer, Thrust and Drag takes data obtained from properly planned movie film and arrives at values for thrust, coefficient of drag, and specific impulse by a series of algebraic calculations.

The text is carefully written, and well illustrated, with graphical results given when possible.

This fifty page report sells for two dollars. The manuscript has been reproduced by the photo offset process, and is attractively bound.

Published by the Reaction Research Society, Inc. Copyright 1966

Taylor, Denis. Introduction to Radar and Radar Techniques. New York: Philosophical Library, Inc., 1966

Basically a historical book, Radar and Radar Techniques also gives some simple technical aspects of the radar system. However, its main subject is the history of radar since its inception in WW II. The research alone here was superb, and many interesting aspects, from detecting the launch points of V-2's to finding the location of a quasar are presented.

The text is well written, and presents an interesting and highly readable story; however, for anyone who wishes technical detail, a textbook might be of greater value.

Jennison, Roger C. Introduction to Radio Astronomy. New York: Philosophical Library, Inc., 1966

Far too much popular reading material has been printed on radio astronomy. Here, in a clear-cut text, is an easy introduction to the theoretical aspects of the subject.

The book was written as an attempt to bridge the gap between the popular literature and the highly detailed textbooks, and it succeeds admirably. The mathematics that is introduced is clear, relatively simple, and a concise verbal summary is given after the treatment.

For the interested amateur, looking perhaps for an introduction to the subject, this is the book.

THE LOCAL SCENE

Excerpts from the minutes of the RRS meetings:

Bill Claybaugh, Bob Schreiner, and Don Girard presented a half-hour program to Canoga Park Optimists, requesting financial backing for the NEWS. . . . The work party of May 28-30 established a mile and a quarter of down-range road, and buried one-half mile of communications cable. . . . Decision made not to buy a milling machine, offered at $300, because of a lack of funds. . . .

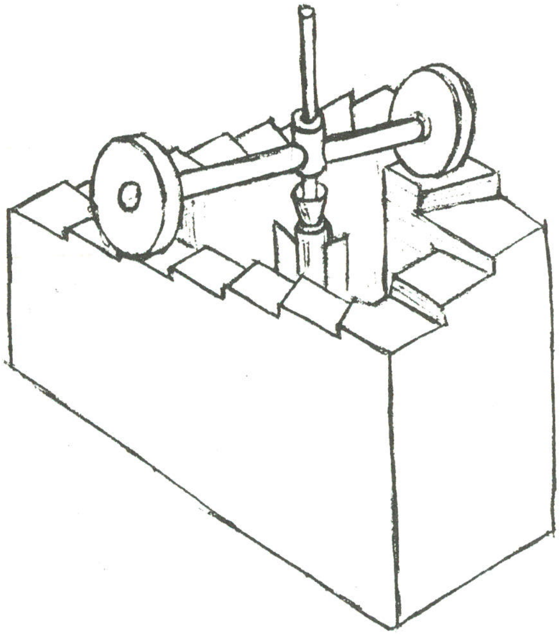
Rick Bennett presented his plan for an advanced amateur test site that includes three test structures. . . . Rick Bennett reported from Marshall Space Flight Center that NASA is offering serious consideration to the proposed amateur test site installations. George James of RRI has asked the Society for criticisms and suggestions of the current proposal. . . .

Two swap meets netted $150 for the Society. . . . George Dosa announced the release of full RRS Beta drawings. . . . First edition of the RRS Technical Notes, a one page brief, dealt with fixall nozzle construction. . . .

Construction of the sorely-needed new blockhouse has begun, due in large part to the generosity of Mr. Lyle Kellogg, of California Precision Concrete Block, in donating block and cement for the project. The solid concrete re-inforced structure is twice the size of the previous blockhouse, and provides better viewing opportunities.

And as a special note, the RRS NEWS 101 achieved a unique position among RRS publications. It paid for itself.

From the desk of Emerson Foxtail, author of the Y-4 standard experimental rocket. . . .



FUEL COMPACTING CELL
DOWN HILL ALL THE WAY...

THE REACTION RESEARCH SOCIETY

announces its JOURNAL of AMATEUR & EXPERIMENTAL ROCKETRY

May we present THE REACTION RESEARCH NEWS, a journal of amateur rocketry published in Los Angeles and distributed internationally.

The Reaction Research Society is one of the oldest rocket societies in the U.S., and is in joint possession of the largest amateur testing area in America. The Society serves to promote experimental rocketry, and at the same time provide educational opportunities in rocket design for the student.

One facet of our work is the publication of THE RRS NEWS, a news magazine of about forty pages that attempts to describe the rocket activities of the Southern Californian area, to present articles of value in amateur work, and to report accurately developments in state and national legislation, the progress of other societies, and matters of public interest.

If you would find the content of this magazine of value, and wish to receive the NEWS regularly, we would be most pleased to enter a subscription in your name, at the following rate:

RRS NEWS, one year subscription, four issues . . . . . . Two dollars.

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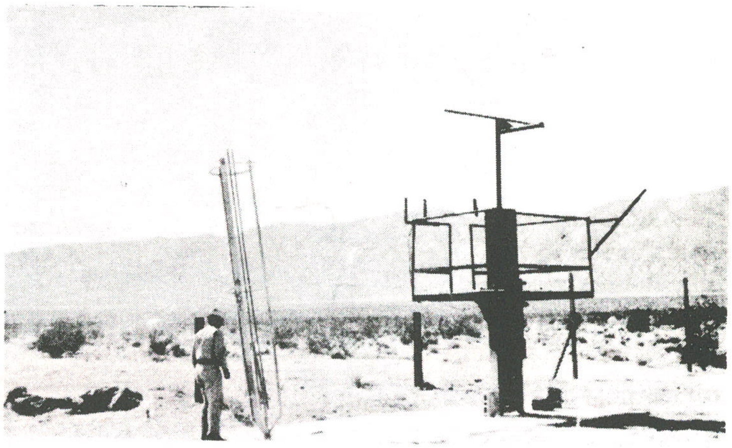

Static test structure at the Society's desert launch area.

RRS NEWS

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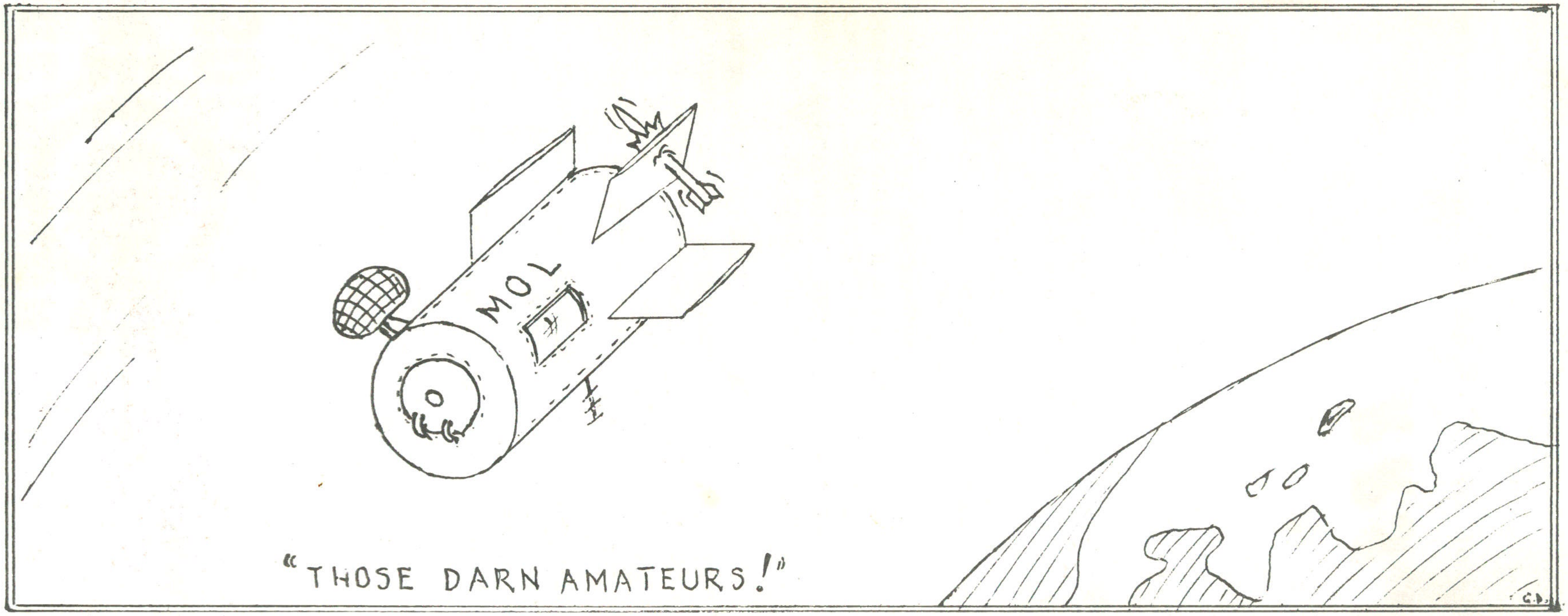
Street Address ______________________________

City ____________________ State ____________ Zip Code ________



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