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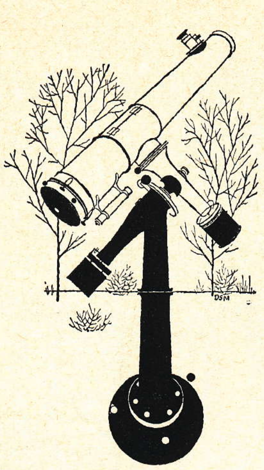


THE AMATEUR SCIENTIST

About the activities and the trials of amateur rocket experimenters

If, during a weekend drive in the country, you should happen to see a thin trail of white smoke shoot 100 feet into the air, you will find an unusual group of scientific amateurs near the bottom of it. They will be equally proficient in handling explosive chemicals, differential equations, machine tools and irate policemen. In short, they are amateur rocket experimenters. Occasionally they dream of setting foot on the moon, and people who live nearby wish they would—or at least that they would move away! Sometimes the roar of their rocket motors can be heard night and day. But if amateur rocket experimenters are short on local popularity, they are long on enthusiasm and persistence. They have been at it for at least 30 years, and have given rise to nearly all the leading professional rocket workers.

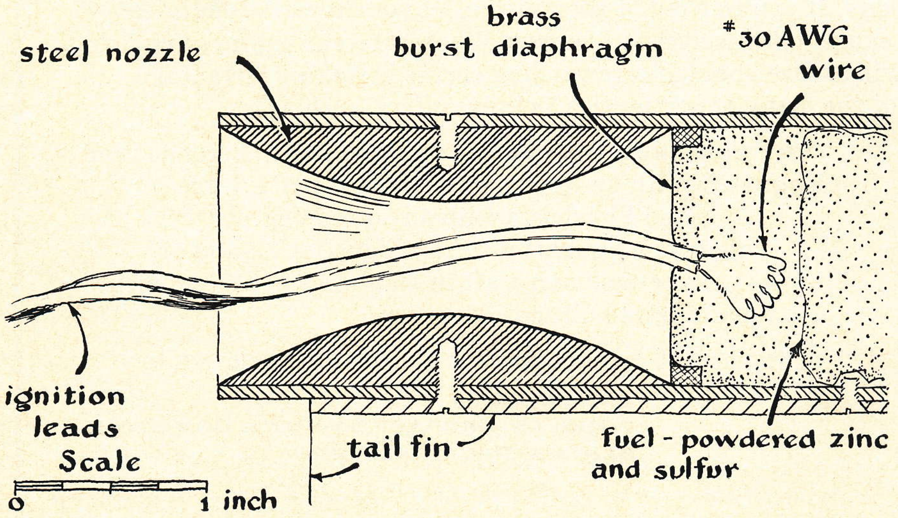
Rocketry is not an avocation for the lone amateur; it requires more in the way of resources than he can usually provide. Rocket experimenters pool their talents and their cash. That they can do so successfully is indicated by the substantial number of amateur rocket groups scattered across the U. S.

Elbert G. Barrett and John H. Granger of the Reaction Missile Research Society, Inc., an amateur group in State College, N.M., write: "Amateur rocket societies give their members an opportunity to participate not only in the theoretical study of rockets and their practical testing, instrumentation, guidance and firing, but also in the many pleasures and satisfactions which come with belonging to a team. The modern hobby was initiated in Germany in 1927, with the formation of a group which included Willy Ley, Max Valier and Johannes Winkler. By 1931 the German amateurs had built a liquid-fuel rocket that could rise to a height of about a mile. Wernher von Braun, Hermann Oberth and many others joined the group; at one time it had nearly 1,000 members. When the Nazis came to power, the society was disbanded and its equipment and experimental results were seized.

"Another pioneer group was the American Interplanetary Society, formed in 1930 by seven men in New York City. The early years of the group were fraught with difficulty, chiefly because of the lack of a permanent proving ground. Upon the completion of a test firing on borrowed (but not always authorized) ground, the group would load its gear into cars and light out for home, often just ahead of the police. But the Society persisted. Finally, through the use of static test stands, as distinguished from flight tests, a rocket engine that performed reliably and consistently was developed by James H. Wyld. He and three other members ultimately succeeded in raising enough money to form what has since become a well-known manufacturing enterprise: Reaction Motors, Inc. Some of their engines have chalked up impressive firsts: they have powered the *Bell X-1*, first plane to pass the sonic barrier, and the Martin Viking rocket, holder of the altitude record for single-stage rockets of 158 miles. In 1933 the American Interplanetary Society changed its name to the American Rocket Society; since 1940 the group has not engaged in experimental work because its members are widely scattered and many of them have become professionals.

"A third pioneer group is the British Interplanetary Society. The day when man will achieve space flight has doubtless been substantially retarded because the law in England forbids laymen to experiment with rockets. The British Society's gifted members have, however, continuously published a fine journal devoted to space flight and allied subjects.

"The outbreak of World War II interrupted the work of all rocket societies. Then, in 1943, George James of Glendale, Calif., founded the Southern California Rocket Society, later renamed the Reaction Research Society. At about the same time the Chicago Rocket Society was organized. These turned out to be vigorous groups, and interest in rocketry has been growing ever since. The Reaction Research Society staged a number of successful mail flights by rocket in an effort to emphasize the peaceful use of the art. The lack of adequate space for testing prevented the Chicago



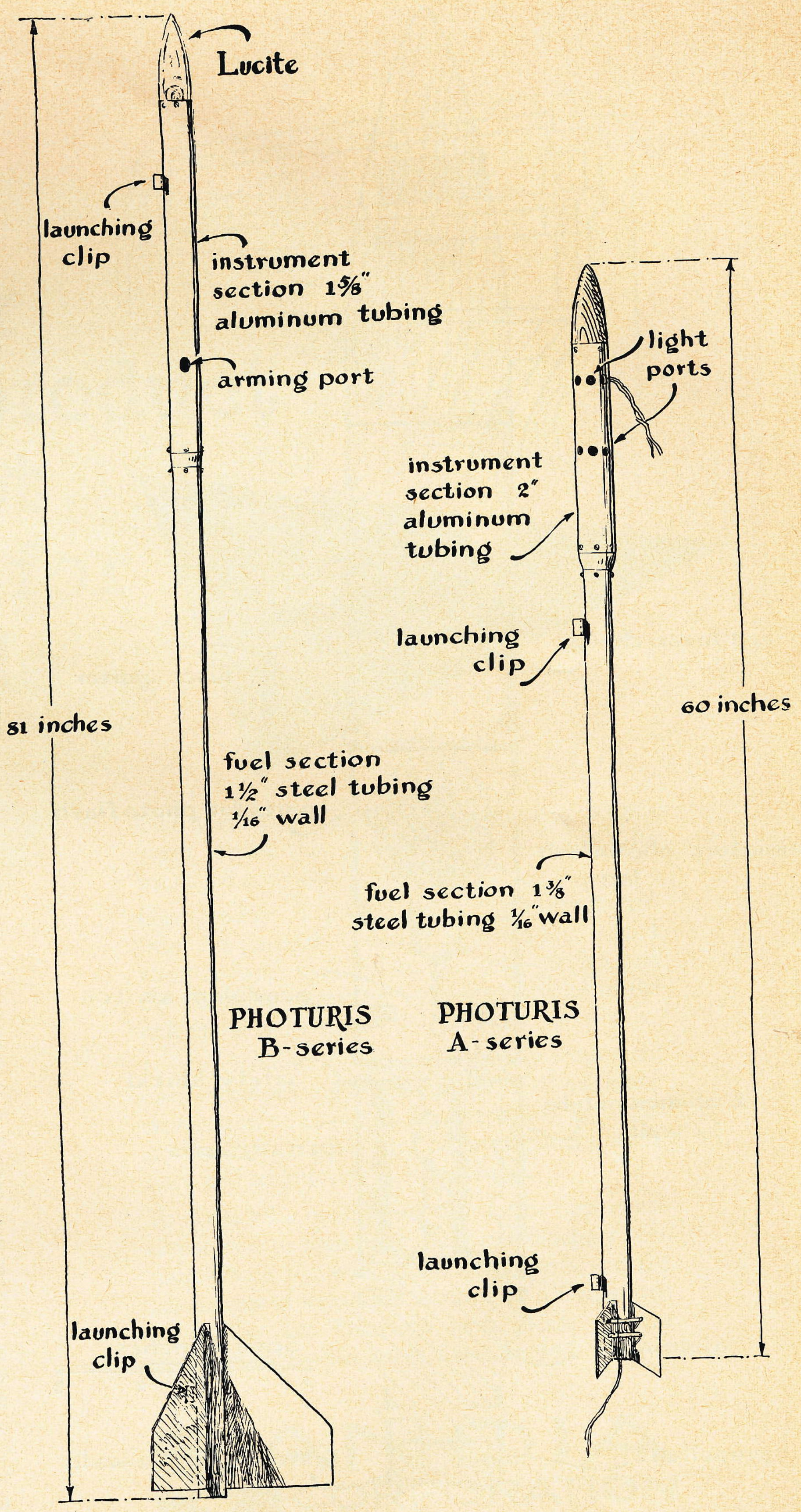
Details of nozzle and ignition system of a rocket built by an amateur group

group from undertaking comparable experiments. Nonetheless an impressive number of ideas and much useful data have come out of its program of theoretical work.

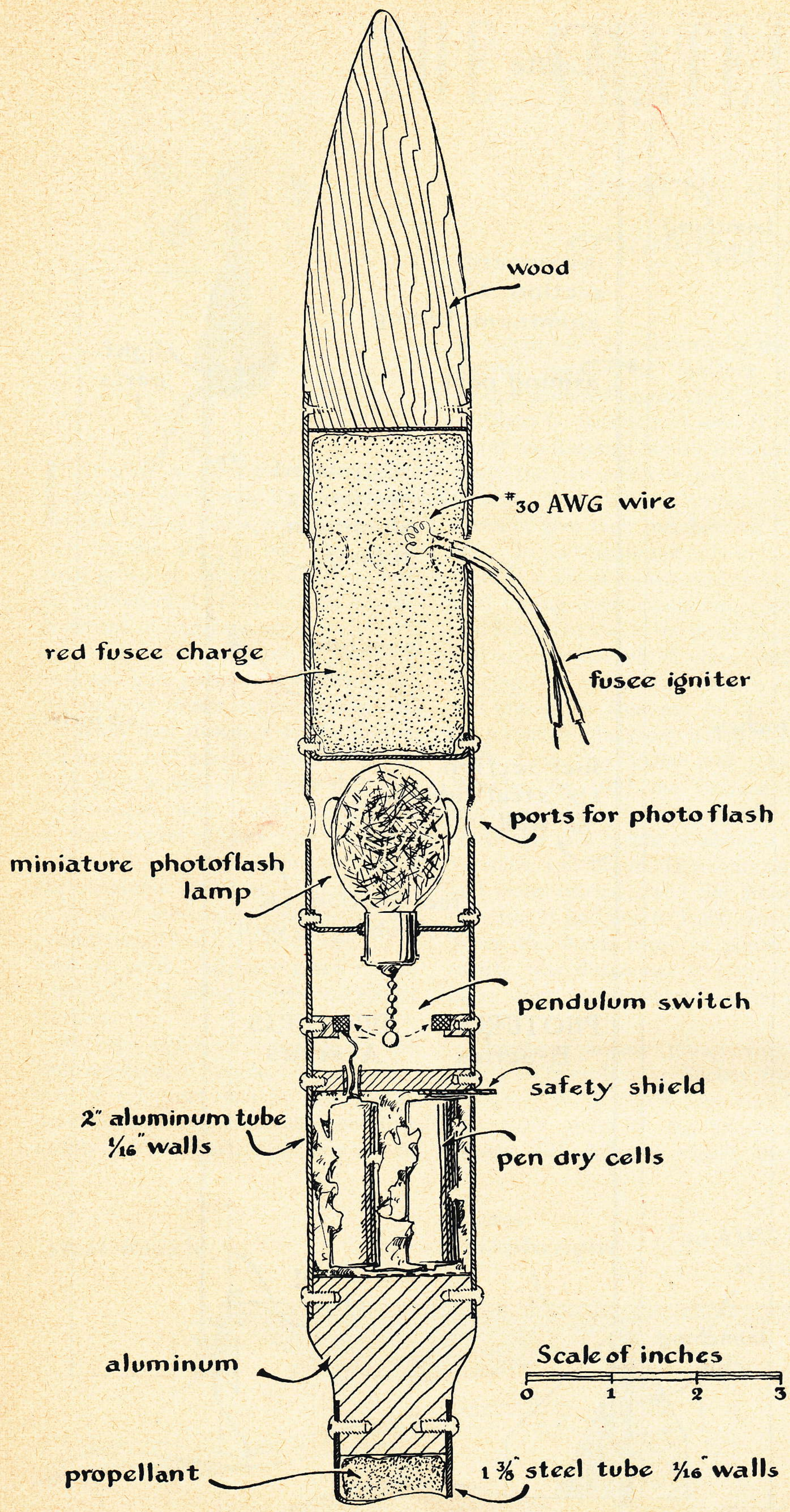
"Representative groups formed since 1943 include the Pacific Rocket Society, the Philadelphia Astronautical Society, the M.I.T. Rocket Research Society, the Intermountain Rocket Society, the Boise Rocket Research Society, the Society for the Advancement of Space Travel and our Reaction Missile Research Society, Inc. All are affiliated with the American Astronautical Federation, formed as a national organization to collect and distribute information and to promote space flight. Numerous other groups are now in existence; it is hoped that a complete roster of rocket societies can soon be compiled." (Any recently formed group may forward its address to this department for listing.)

"Amateur rocketry has a variety of attractions beyond the spectacular but short-lived flight of the rocket. The design and construction of the missile, its launching apparatus and instrumentation pose many intriguing problems. The rocket must be aerodynamically stable both before and after burnout; this problem of stability can be attacked in many ways and invites endless designs and tests. The design of small motors and special propellants can challenge a sophisticated knowledge of mathematics, physics and chemistry. Because of space limitations the instrumentation of small rockets calls for great ingenuity; it should appeal to radio amateurs, particularly those interested in miniaturization. Similarly, amateur photographers always find a ready-made welcome in rocket societies because pictures are needed of take-offs, flight paths, instrumentation records and the apparatus before and after firing. Being a member of a team that coordinates so many fields of interest in carrying a program through to the climax of firing a rocket with instrumentation gives one a feeling of pride in accomplishment with few parallels.

"Members of amateur rocket societies have no illusions that true space flight will be achieved through their efforts. They have neither the funds nor access to the necessary materials. But they can acquire first-hand information concerning the nature of the problems now awaiting solution. By exchanging information and undertaking certain types of experiments beginners can learn the basic facts of rocket flight. Finally, rocket enthusiasts can help enlist public



Rockets with optical and electronic instrumentation built by the group



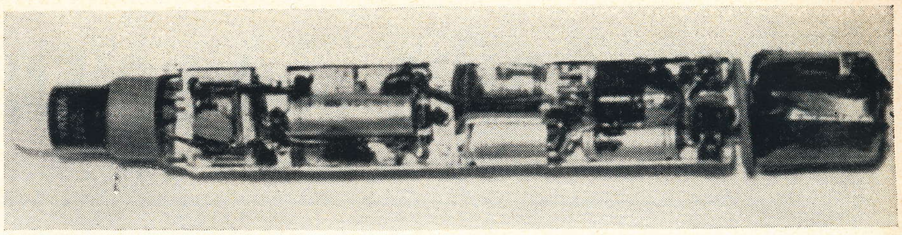
Instrument section of a "Photuris A" rocket

support for such national efforts as the project to launch artificial satellites of the earth.

"A relatively elementary project undertaken recently by the Reaction Missile Research Society illustrates the sort of experimental work appropriate for beginners and points up some of the tribulations which the amateur rocketeer learns to take in stride and enjoy. The project was conceived by Walter La Fleur, who was then doing graduate work in mathematics at the New Mexico College of Agriculture and Mechanical Arts. The purpose of the project was to record information on the trajectory of a rocket by means of a light source carried in the missile. Incidentally, amateurs enjoy naming their rockets. La Fleur's was to carry a flashing light, so the idea of calling it *Firefly* was proposed. It turned out that another group had used the same name, so we dubbed ours *Photuris,* a classical word for firefly. Our 'A' series was a low-cost program, each missile setting us back about $9. Series 'B' involved electronic instrumentation and each rocket cost $50. In order to record the flight information under the best photographic conditions, all firings were made on moonless nights.

"The *Photuris A* basically consisted of a thin-walled steel tube of 1 1/4 inches inside diameter to which a 2-inch aluminum tube was attached by means of a reduction fitting. The steel section carried the fuel and was fitted with a convergent-divergent nozzle and fins, as shown in Roger Hayward's drawing on page 174. The aluminum tube housed the rocket's instruments and was closed at the top by a wooden nose-cone. A compartment at the top of the instrument section was charged with fusee powder, which burns with a brilliant red light. The powder was ignited electrically by passing a heavy current through a fine Nichrome wire buried in it. The lower compartment of the instrument section was fitted with a miniature photoflash lamp, a pendulum switch and a battery supply. The principle of the switch was being tested as a possible means of releasing a parachute in future missiles. The switch was designed to close when the missile turned over at the top of its trajectory. A record made by the photoflash bulb would prove or disprove the merit of the idea.

"Both the 'A' and 'B' rockets employed zinc dust mixed with powdered sulfur as a propellant. First we thoroughly stirred a mixture of 85 per cent zinc to 15 per cent sulfur. Then we used one of two methods of loading the propellant. In the first method we poured the pow-



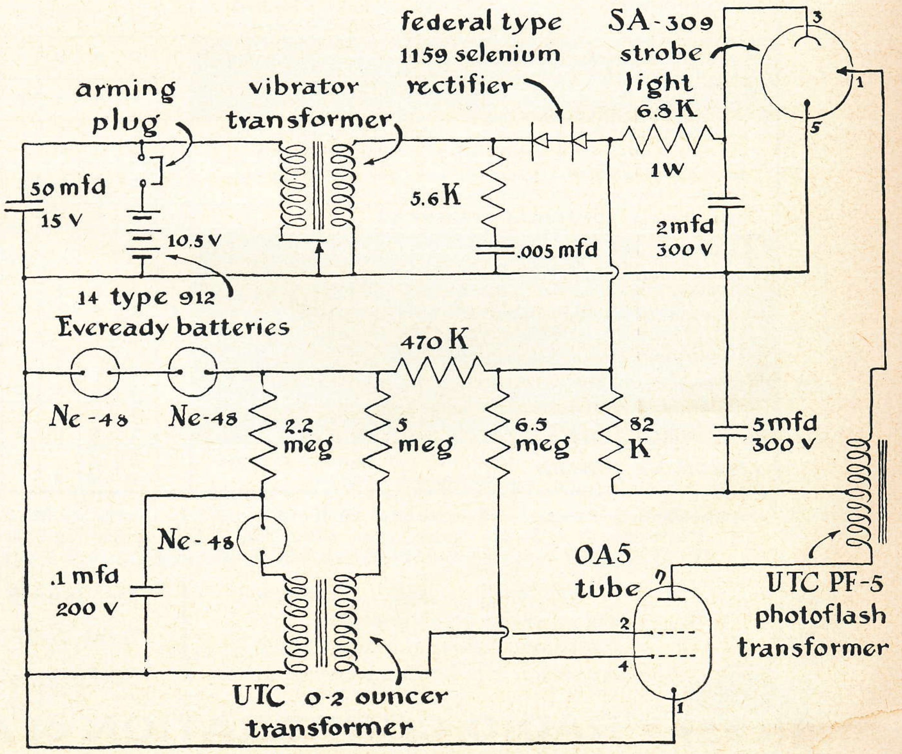
Strobe-light assembly of the "Photuris B"

been strong enough. The burst diaphragm temporarily closes the combustion chamber so that pressure can build up within it. The diaphragm thus establishes the rate at which the propellant burns. If the diaphragm bursts too soon, the burning rate will be low at the outset and the rocket will not rise from the launcher promptly. Because the tail fins of the rocket will not stabilize it effectively at low speed, the rocket will thus be aerodynamically unstable during the early part of its flight. The next morning we ran two static tests which proved that the burst diaphragm had in fact been at fault. A thin diaphragm employed in the first static test resulted in a performance identical with that of the previous night: slow burning and a remainder of unburned fuel. A heavier diaphragm used in the second static test resulted in perfect burning.

"*Photuris 1-A* not only had motor trouble; its instrumentation section also behaved badly. The signal flare did not ignite properly, the lower end of the wooden nose-cone burned away (although supposedly protected by a layer of asbestos insulation) and the ports provided for flare exhaust appeared to be too small. The pendulum switch apparently worked. Two observers reported seeing a flash as the missile turned over at the top of its trajectory.

"Following our tests *Photuris 2-A* was fitted with a stronger burst diaphragm. A low-current relay system was installed to improve the ignition of the signal flare. The flare section was provided with larger exhaust ports, and both the top and bottom of the flare compartment were fireproofed with a thick layer of plaster of Paris.

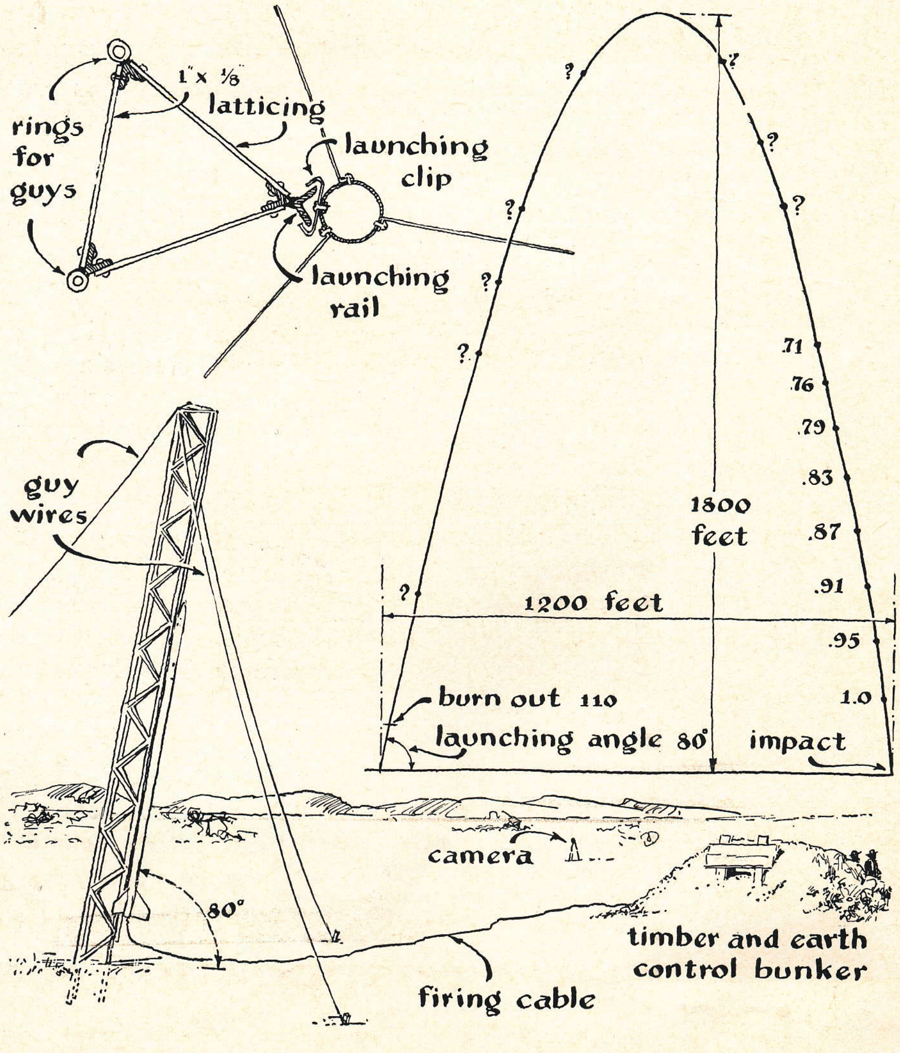
"The time required for these changes, other activities of the Society and unfavorable weather delayed the next test for about two months. Finally the big night came and we threw the switch. The motor refused to fire. Investigation revealed that the propellant in contact with the ignition filament had fused into hard pellets. The combustion chamber



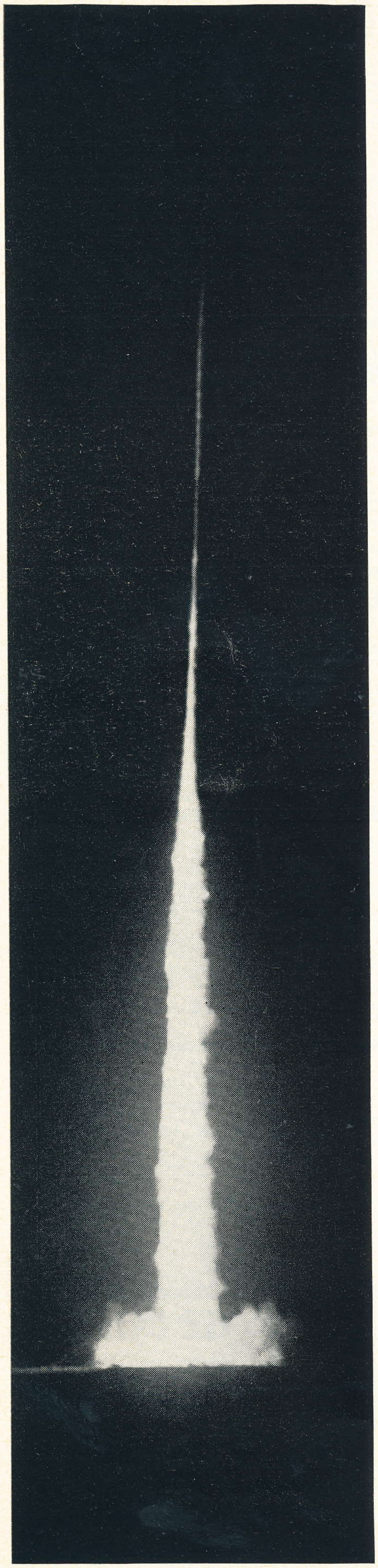
Wiring diagram of the strobe-light assembly der into the nozzle of the steel tube in small amounts, lightly tamping each added amount by jouncing the rocket. In the second method, which is more effective but less convenient, the powder is packaged in small cardboard cylinders, the ends of which are closed with tissue paper. These cartridges, each of which contains the same weight of powder, are loaded into the combustion chamber end to end. The second method has the advantage that every rocket loaded in this way has nearly the same thrust. It has the disadvantage that the nozzle must be removed during loading. In both methods of loading the powder is set off by an electrical ignition unit embedded in the last batch of powder to be added.

"Both 'A' and 'B' rockets were launched from a tower made of angle sections and strap iron. Clips attached near the top and bottom of the missile ride on a launching rail welded to a corner of the tower. The rockets were fired by remote control from an observation bunker located 50 yards from the tower. The bunker was constructed of heavy timbers and covered by several feet of earth; observation slits were cut in the wall facing the tower. All firings were conducted in a rural mountain area. None of the missiles functioned perfectly in every respect; some were downright failures. This is the usual situation in amateur rocketry.

"In the case of *Photuris 1-A* the motor did not function properly. At 'fire' the fuel ignited and burned for about 10 seconds. The rocket left the launcher slowly, climbed about 30 feet, nosed over and struck the ground with the motor still burning. Subsequent inspection disclosed that two hot spots had developed in the combustion chamber, and that about a pound of propellant had failed to burn. Reasons advanced for the malfunctioning included the suggestions that (1) the fuel had not been packed properly, (2) that during transportation to the test area the propellant had moved away from the walls of the chamber, causing erratic burning, (3) that the constituents of the propellant had not been mixed in proper proportion and (4) that the burst diaphragm had not



Launching tower and trajectory of the "Photuris B" rocket



Take-off of "Photuris B"

was emptied, repacked and fitted with a new ignition element. At the second firing the burst diaphragm ruptured and released a short tongue of flame. The missile did not move from the launcher. Suddenly the wall of the combustion chamber near the exhaust nozzle became red hot and the red area moved slowly toward the nose of the rocket. Subsequent chemical analysis of residue within the combustion chamber disclosed an excess of zinc in the propellant. We changed the fuel mixture to 75 per cent zinc and 25 per cent sulfur.

"*Photuris 3-A* was fired successfully one week later. The instrumentation was the same as that in previous tests. We did not, however, attain our objectives. The flare went out during acceleration, doubtless because its powder had not been properly mixed. The flash bulb failed to operate when the rocket turned over; a subsequent check showed that its supposedly 'new' batteries were dead. As a final contribution to our dismay the rocket shed its fins after three quarters of a second at an altitude of about 75 feet! The total burning time was about one second. The main body of the missile landed 300 feet short and north of the predicted impact area a quarter of a mile away. The divergent section of the exhaust nozzle was badly eroded.

"Despite these failures the group felt it had acquired enough experience with zinc-sulfur propellant to risk the construction of a larger missile with more elaborate instrumentation. Accordingly we began to work on the first of the *Photuris B* missiles. The propulsion section was made of steel tubing 1/16 inch thick, 57 inches long, and with an inside diameter of 1 3/8 inches. It was equipped with three parallelogram-shaped fins with a 60-degree angle of sweepback. The rocket weighed 8.75 pounds empty and 15.4 pounds fueled, a mass ratio (empty weight to fueled weight) of 1:1.8. The fuel mixture was 75 per cent zinc dust and 25 per cent sulfur. The exhaust nozzle was a 30 degree convergent-divergent double cone of steel.

"The instrumentation consisted of a high-brilliancy xenon strobe lamp, a power supply and an associated electronic timing-circuit designed to trigger the lamp at a rate of five flashes per second. Photographs of the flashes, which were bright enough to record on film from a distance of three quarters of a mile, were meant to chart not only the flight path but also to enable us to compute the missile's velocity, its total flight time, its acceleration at any point on its trajectory and so on.

"Providing a direct-current source of 300 volts and .008 amperes for the lamp in the small space available turned out to be a major headache. Because batteries of the desired voltage and current rating were not available, we decided to use flashlight batteries and step up their voltage by a vibrator power-supply of the type used in automobile radios. A series of tests were first run to ascertain if the flashlight batteries could deliver enough power to drive the lamp and associated circuitry for the estimated flight time. A large number of three-minute, high-current tests were run on four brands of flashlight batteries available in local stores. We learned in these tests that although the small batteries used in pen-sized flashlights have about a 20th the volume of the largest flashlight batteries (size D), they deliver half as much energy. Another interesting fact came out of the tests: Inferior cells always show a characteristic drop in voltage during the first 10 seconds following the application of a heavy load. As a result we set up a standard testing procedure which required that all cells to be used in the missile deliver voltage within prescribed limits during a 10-second test interval. As finally assembled, the battery consisted of 14 size-912 cells wired in series parallel. It delivered 10.5 volts and occupied 1 3/4 vertical inches of the instrument section.

"The timing circuit consisted of a 2.2-megohm resistor through which a .1-microfarad capacitor was alternately charged by the power supply and discharged by an NE 48 gas-diode tube. Because the supply voltage tended to vary beyond tolerable limits, a voltage-regulating circuit was added. This consisted of two NE 48 gas diodes in series with a 470,000-ohm resistor [*see circuit diagram on page 180*]. The timing circuit worked well and continued to function even when the voltage dropped below the value at which the strobe lamp would fire.

"The problem of triggering the strobe lamp was initially difficult but was finally solved by the use of a trigger tube of the OA type which actuated a photoflash trigger transformer. The trigger tube was in turn triggered by the timing circuit through a transformer of the microphone-to-grid type.

"A hollowed block of clear plastic was cast and machined to size to serve both as the nose-cone of the missile and the housing of the strobe lamp, an arrangement which afforded an unobstructed view of the lamp. The circuit components were mounted in a cylindrical chassis which fit snugly inside the nose-cone.

"The circuit was switched on by inserting a small short-circuiting plug into a port in the instrument section. This connected the plus side of the battery to the body of the missile (which acted as a common ground return for the various circuit components). Bench tests of the circuit proved that the lamp would operate reliably for three minutes.

"The gadget behaved normally—that is, it refused to work when installed in the missile. The difficulty stemmed from the vibrator assembly in the power-supply unit. The reeds of the vibrator were mounted on the side of the transformer, which was attached to the body of the missile. Stresses set up when the transformer was screwed into place disturbed the contact adjustment and function of the reeds. It was apparently necessary to readjust the contacts following the assembly of the missile. Because this problem had not been foreseen, the design of the missile had made no provision for access to the reeds. To correct this shortcoming would have meant rebuilding the rocket, so we decided to settle for an approximate adjustment and proceed with the firing.

"The rocket was launched at the same angle as that of the *Photuris A* series: 88 degrees with respect to the horizontal. The missile reached an altitude of 1,800 feet and landed squarely at the predicted point of impact 1,200 feet away. The motor functioned perfectly [*see photograph on page 182*].

"The trajectory was photographed from a distance of about a third of a mile by a special camera placed at right angles to the flight path. Because the missile passed out of the camera's field, we lost the top part of the trajectory. The missing section of the trajectory was extrapolated from the section that had been photographed, and is shown in the illustration on page 178.

"The strobe lamp did not operate during the first part of the flight, doubtless because of the effects of acceleration on the vibrator assembly, but worked well during the last part. The photograph did not come up to expectations; images of the flashes on the plate, although quite definite once located, were tiny and hard to find.

"The instrument section was destroyed so completely on impact that not a single component could be salvaged. Thus the group decided, for reasons of economy, to delay additional firings pending the development of an adequate parachute system. In the meantime the idea has been advanced of installing a continuous light source in the missile and providing timing by means of a rotary shutter in front of the camera.

"More advanced projects currently under way include the development of a nozzleless, finless missile of high mass ratio, a device to measure range by short-wave radio and a data-recording system. The mass ratios of conventional rockets rarely exceed three to one. The projected missile will have a mass ratio of nine to one. A small cone at the tail of the rocket will replace the conventional fins. Results of wind-tunnel tests on pilot models indicate that a cone should provide better stability than fins.

"A number of rocket societies are investigating both solid and liquid propellants. Our group, however, prefers to concentrate on instrumentation. Liquid fuels are challenging and have spectacular performance, but they are costly. Some of them, like hydrogen peroxide and fuming nitric acid, can get out of hand. Amateurs without experience in rocketry will find excitement enough in the zinc-sulfur mix to outlast their first year in the hobby. In contrast with black gunpowder and other solid propellants, the zinc-sulfur fuel can be used with relative safety even in large rockets. Its burning rate is high—on the order of five linear feet per second regardless of tube diameter. Its density is also high, yet danger from explosive pressures is low. Our society purchases Zinc Dust, Technical Grade, from the American Smelting and Refining Company, P. O. Box 487, Sand Springs, Okla. We do not specify grain size. The current price is $18.25 per 100 pounds. Prices quoted by chemical supply houses usually run somewhat higher, doubtless because of refining costs and certified purity. Flowers-of-sulfur is inexpensive and available locally in most communities from hardware stores and dealers in farm and garden supplies.

"Should you feel the urge to take up rocketry as a hobby, you will be well advised either to join with others in your community who are similarly inclined, or become a member of an established group. Few individuals have the time and skills required for the design and construction of a successful, well-instrumented rocket, and none can be in enough places at once to fire and adequately observe the performance of one. Even if he could, he would be cheating himself of the rich satisfactions which come only through participation in a group project."

A list of rocket societies can be obtained by forwarding a stamped, self-addressed envelope to this department.

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JUNE,