A Simple Thrust Measuring Device

FOR SMALL ROCKETS

THIS TYPE DEVICE CAN BE BUILT TO ANY SCALE DESIRED – SPRING SCALES WITH CAPACITIES OF 25 TO 100 POUNDS ARE READILY AVAILABLE – CONSTRUCTION SHOULD BE HEAVY AND RUGGED –

DON'T UNDERESTIMATE POWER OF YOUR ROCKET!

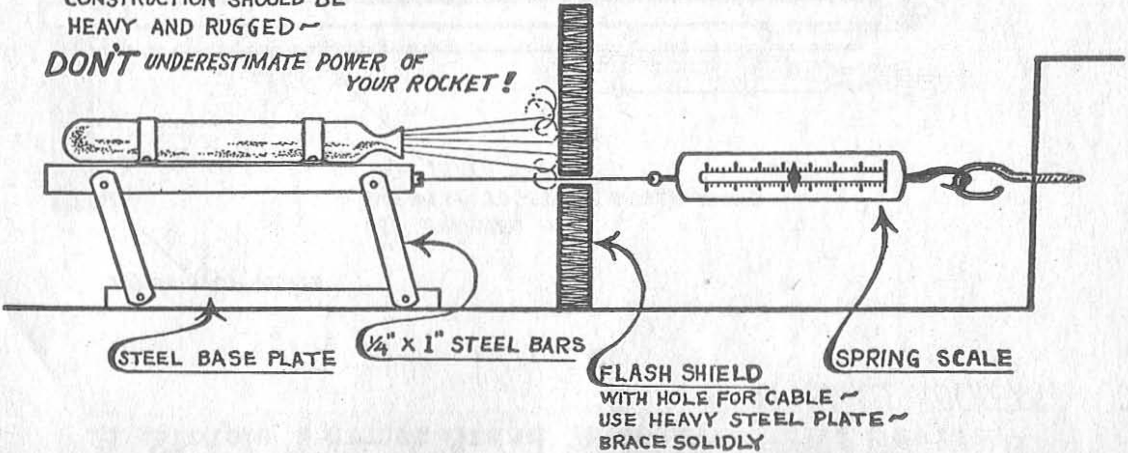


ILLUSTRATION No. 39

A Simple Thrust Stand With Recording Device FOR SMALL ROCKETS

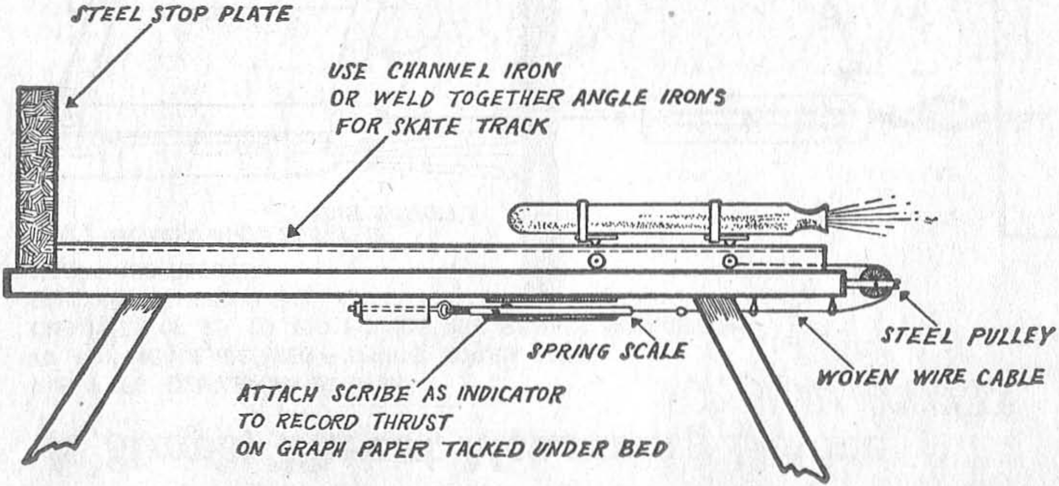


ILLUSTRATION No. 40

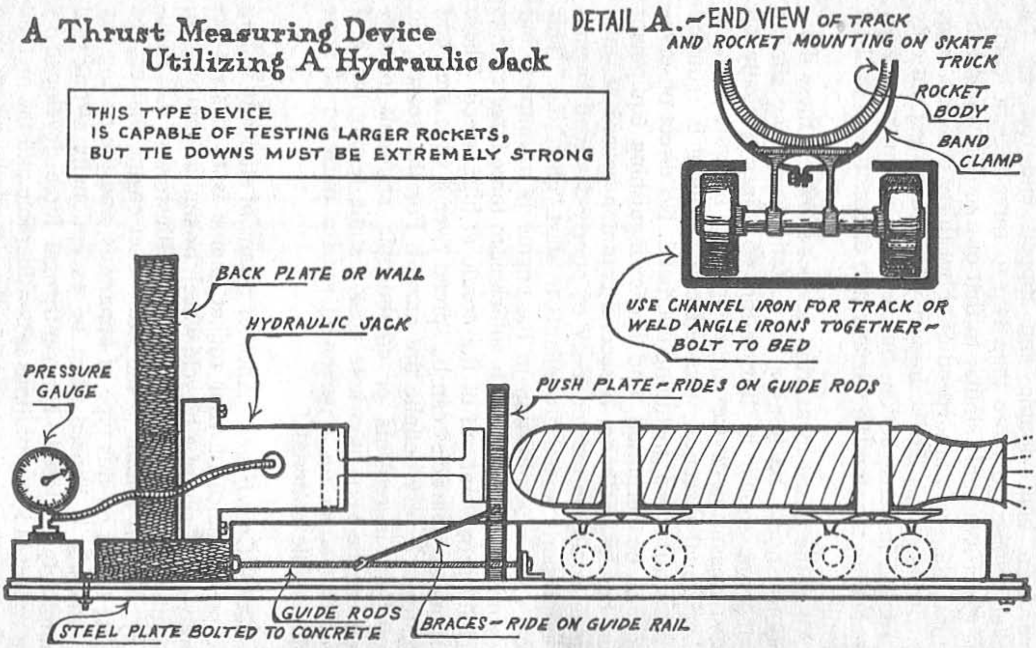


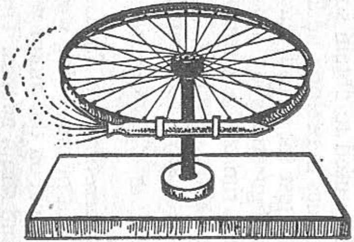
ILLUSTRATION No. 41

even a small rocket is about one hundred times as great as you imagine, if you have never seen one fired. Test stands similar to the one shown in Illustration *40* above have been bent double and flipped end-over-end by rocket engines no more than two to three feet in length. The effect is roughly similar to that of a motorcycle crashing into the stand at a speed of about thirty miles an hour. To withstand this terrific impact your stand must not only be rugged in construction, but securely anchored as well. Embedding the stand in a heavy slab of concrete is the best solution.

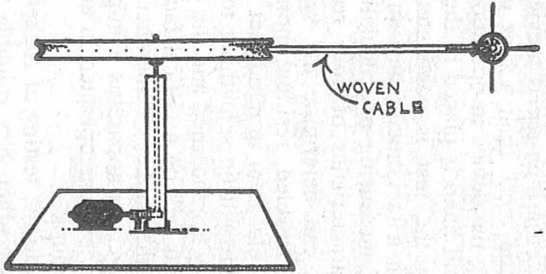
All of the thrust-measuring devices shown in these illustrations should be housed in a static firing bay similar to the one shown in Illustration *46*. Since virtually all thrust-measuring devices are designed to measure thrust in a horizontal direction, protective barricading is required in every direction, including overhead. No direct observation can be permitted, and fire extinguishing equipment must be close at hand. A second common hazard of static engine testing is the tendency of poorly-designed engines or improperly mixed propellants to start "chunking." This occurs when combustion in the engine is incomplete but pressure in the test vessel is sufficient to force large chunks of solid propellant out of the nozzle at high speed. These still-burning particles can be spread over a wide area and constitute a very definite fire hazard. For this reason, no propellant ingredients or combustible materials of any kind can be kept anywhere near a static testing bay and overhead cover on a personnel bunker must be of non-inflammable material.

A Rocket Centrifuge: Another means of statically testing the performance of your rocket engine is to strap it securely to the rim of a bicycle wheel, or similar contrivance, mounted as shown in the sketch in Illustration *42*. Naturally, there is a limit to the size rocket engine that can be safely tested on this type of apparatus, and the testing bay in which it is housed must be exceptionally strong and completely enclosed. The centrifugal force developed by the rocket in its revolutions is considerable and the method of lashing the rocket engine to the rim of the wheel must be strong and secure. The axle on which the wheel rotates should be oversized to withstand the outward pull of the

USING A BICYCLE WHEEL AS A CENTRIFUGE
FOR IMPULSE AND AERODYNAMIC TESTS



SMALL ROCKETS MAY BE LASHED TO RIM OF TIRELESS WHEEL FOR TOTAL IMPULSE, VELOCITY & BURNING TIME TESTS ~ BY CALCULATING ANGULAR MOMENT OF WHEEL YOU CAN DETERMINE IMPULSE ~ USE TACHOMETER AND ODOMETER GEARED TO SHAFT TO GET SPEED AND DISTANCE ~



POWER WITH ELECTRIC MOTOR & HIGH SPEED GEARS ~ OR WITH A SMALL ROCKET ~ TO FLIGHT TEST ROCKET SUSPENDED FROM CABLE ~

CONSTRUCTION OF THIS DEVICE MUST BE HEAVY AND RUGGED ~ OPERATE ONLY IN COMPLETELY ENCLOSED AREA, HEAVILY BARRICADED ~

ILLUSTRATION No. 42

rocket, should have no wobble and be as frictionless as possible.

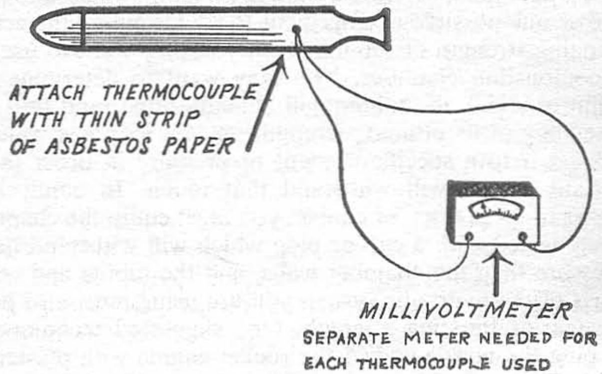
Very little, if anything, can be observed of the character of the exhaust jet with a testing device of this type, and it may not be possible to calculate or record burning time accurately. Even a high-speed movie camera would probably catch little more than a blur of light on its film in photographing the device in operation. But if a clock with a sweep second hand is placed in the field of vision of the camera when the test is conducted, and the device is equipped with a tachometer and an odometer, you have the means of measuring or calculating many of the performance characteristics of your rocket. From the data obtained you can determine the velocity, total impulse, total distance traveled, residual momentum of the rocket after burnout, etc. Bear in mind that the exhaust fume and smoke problem will be something to contend with as far as photography is concerned and the placement of cameras and instruments will be a critical factor as well as proper ventilation of the bunker. Remember, also, that this could be a very dangerous apparatus if improperly used. Such a device should never be operated in any place other than a well-fortified bunker.

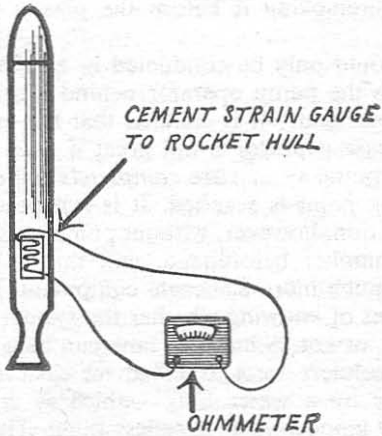
In addition to the testing of rocket engines, this type of device can have other very valuable uses, just as a centrifuge has. Whether powered by a rocket engine or an electric motor the apparatus could be used to obtain some idea of the ability of mechanical devices to perform under acceleration. You can also use it to test the aerodynamic stability of fin designs and hull configurations by attaching your rocket, or scale model, to the rim of the wheel with a short length of cable in order to allow it relatively free flight. This would do as good a job as any wind tunnel you could devise.

Measuring Motor Wall Temperature and Stress: Illustration *43* shows you the method of measuring wall-temperature and stress at various points on the motor wall through the use of thermocouples and strain gauges. The latter can be obtained from any engineering laboratory or supply house. The millivoltmeter and ohmmeter are common items of electrical supply. Wall-temperature changes and the conductivity of the chamber casing can also be meas-

ILLUSTRATION NO. 43

MEASURING CHAMBER WALL TEMPERATURE AND STRESS



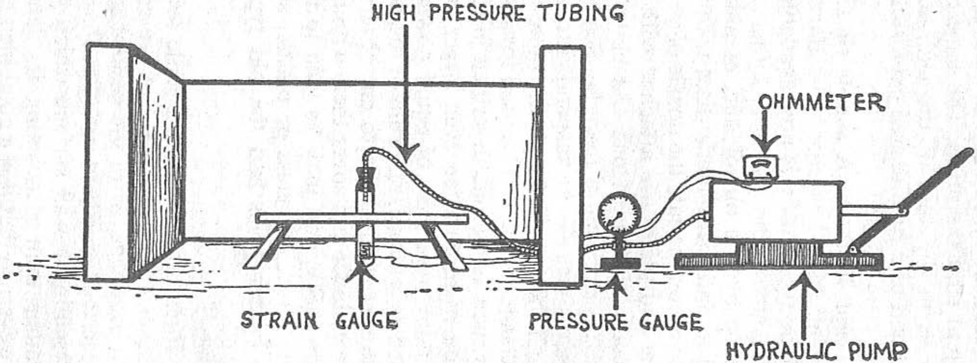


ured to a certain degree through the use of temperature paints. These paints are commercially available and are designed to change color or melt and run at specific temperatures. By establishing a pattern of them along the outer surface of the combustion chamber you can get a pretty good idea of the rapidity with which heat reaches the outer surface and follow the progress of heat transfer as burning progresses longitudinally up the chamber.

A Device for Testing Bursting Strength: Illustration *44* shows one possible arrangement for determining the actual bursting strength of tubing which you may want to use for a combustion chamber. You may want to determine the point at which the tubing will actually burst, and thus get a reading of its ultimate strength, or you may just want to subject it to a specific amount of pressure in order to be certain that it will withstand that much. In conducting either of these tests, of course, you must equip the chamber being tested with a cap or plug which will withstand more pressure than the chamber walls, and the tubing and other parts of the hydraulic system you are using must also have a superior bursting strength. One suggested technique is to plug the nozzle end of the rocket engine with plaster of paris. This would have to be done by immersing the nozzle end in the wet plaster with the hydraulic tube already inserted, and then removing it before the plaster is completely set.

Such a test should only be conducted in a heavily revetted cubicle with the pump operator behind a thick steel plate or similar barricade. It is claimed that the explosion effect when the case ruptures is not great if both the test chamber and the pump system are *completely* full of liquid when the bursting point is reached. It is not practical to achieve this condition, however, without pumping all of the air out of the chamber beforehand, and this is scarcely feasible without much more elaborate equipment. Besides, you have no means of knowing whether the system is completely free of air, or not. A bursting tank can be a dangerous thing. Two soldiers were killed at an eastern Army post one summer by a water tank—which is ordinarily considered a very innocent and harmless thing. They were filling a truck-mounted tank from a water tower when it suddenly exploded, hurling jagged steel fragments in all

DETERMINING BURSTING STRENGTH OF A CHAMBER



PLACE CHAMBER UPRIGHT IN A RACK ~
(FRAGMENTATION FROM A BURST IS ALWAYS RADIAL IN DIRECTION)
PLUG NOZZLE WITH PLASTER OF PARIS ~
COMPARE PRESSURE READINGS WITH STRAIN GAUGE READINGS ON OHMMETER AS PRESSURE RISES ~

directions. The men had forgotten to remove the bleeder cap which allows air to escape from the tank as water is let in.

If you don't want to put together a piece of apparatus as complex as this, you can still give your rocket engine a pretty good pressure test with an ordinary grease gun of the type used to lubricate machinery. Such a gun will produce pressures up to 10,000 pounds. The same precautions should be taken as in the case of the hydraulic system, though the likelihood of a high degree explosion is less.

A Home-Made Wind Tunnel: A simple rig for creating a low velocity wind tunnel is shown in Illustration *45*. Plastic tubing of the type shown is now available in a considerable range of sizes. The plates at either end of the tunnel can be made by you out of steel or aluminum, or you may be able to find ready-made discs with the proper size receptacles to accommodate the nozzle of your vacuum cleaner hose. The end plates are attached with a bonding cement. The vacuum cleaner at one end blows the air in and the other one sucks it out of the tube. Scale models of rockets and fin assemblies can be suspended from the hook protruding through the top of the plastic tube.

One vacuum cleaner alone can be used for testing liquid vapor generators such as the one described in Chapter 10.

You can, if you wish, build an even larger wind tunnel by using two window type fans of equal power, and any large cylinder such as a barrel, oil drum or discarded water tank. In this case you would have to cut observation slits in the sides of the cylinder and cover them with transparent plastic. If you are lucky, you may be able to find a very large transparent cylinder of glass or plastic, such as are used to enclose barber poles and the old type gasoline pumps.

A Static Testing Bay: A design for a static testing bay is shown in Illustration *46*. A good deal of the construction can be done with sandbags, as in the case of most of the emplacements described in Chapter 8. Sandbags have the advantage of presenting a wall surface which will absorb fragmentation rather than ricocheting it. Sandbags will catch on fire, however; so that it is a good idea to wet them down thoroughly prior to any test firing, or to treat them

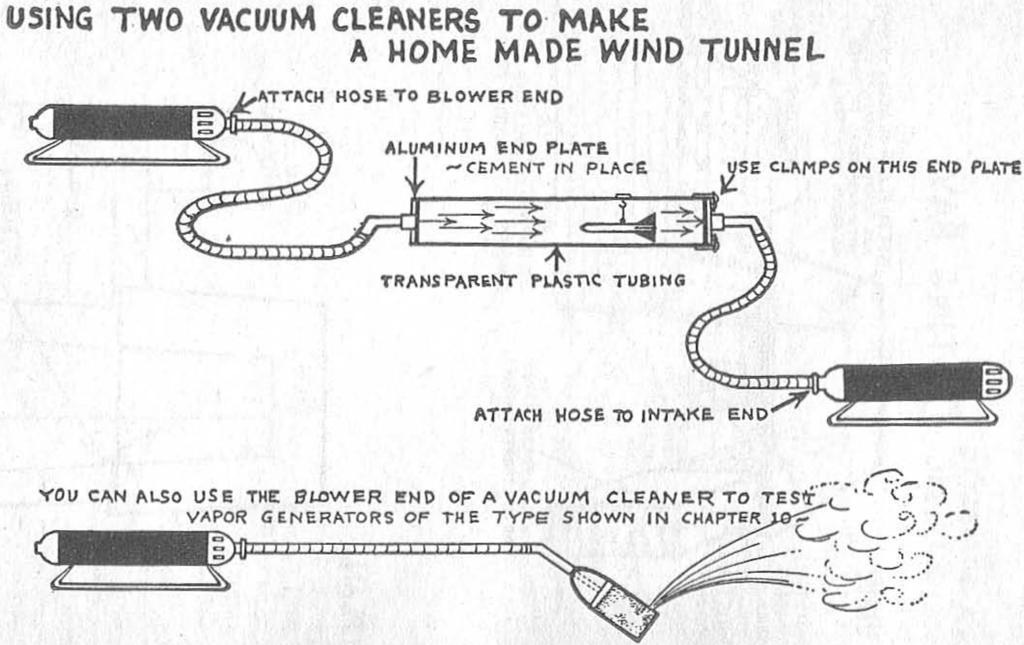
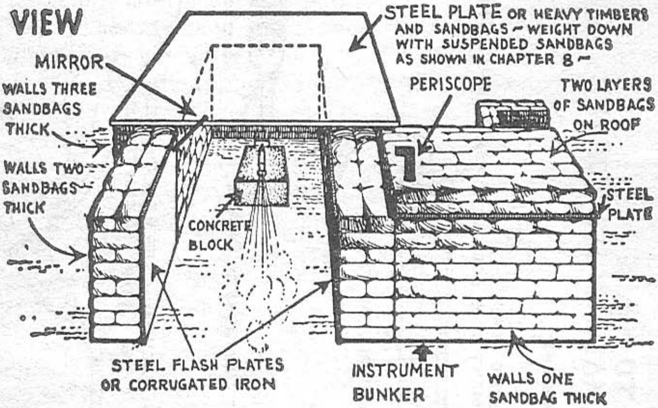


ILLUSTRATION No. 45

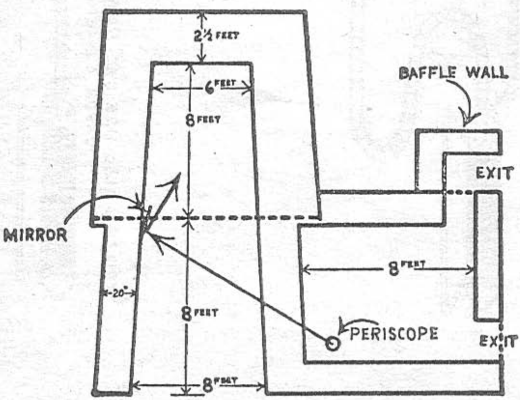
Illustration No. 46

A SUGGESTED
STATIC TESTING BAY

VIEW



PLAN



with some fireproofing compound. A testing bay should be well vented and should always have an open side in the direction that the exhaust gases are propelled. The open side should be on the side of the bay opposite to the prevailing winds so that exhaust fumes are dissipated as rapidly as possible. A baffle wall can be constructed at a reasonable distance from this open side so as to stop any solid object, such as a blown out nozzle, that may fly in that direction.

The rapid dissipation of fumes, smoke and other exhaust products is an important factor in the efficient functioning of any static testing facility. Not only do the fumes obscure observation and make the recording of test data difficult, but they may also be a toxic hazard for personnel exposed to them, and it is even conceivable that a heavy enough concentration of such fumes could result in a secondary explosion of considerable violence. Whenever static firings are in progress it is a good idea to allow a long enough interval between tests to ensure that fumes and tiny dust particles from previous firings are dissipated and have not accumulated in the immediate area of the bay.

Another important feature of a testing bay is a means of rapid exit for any personnel in the observation bunker. In the event of fire, or sudden concentration of noxious fumes, serious injury may be prevented if all persons are able to leave the area immediately. Never construct any kind of a bunker or shelter that has a bottleneck entrance.

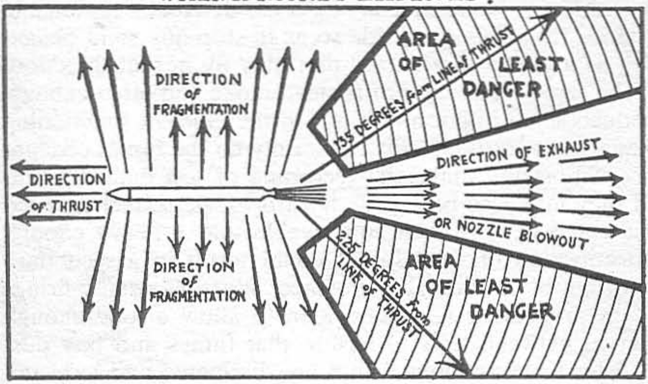
Trajectory Calculations

After you have designed and constructed a rocket, and then subjected it to some of the tests outlined in this chapter in order to get an idea of how well it will perform, you will probably want to be able to predict how high it will go and what sort of a flight pattern it will follow before you take it out to a launching site to flight test it. You will need to know the approximate maximum anticipated performance of the missile, because many of the actions and preparations you initiate at the launching site are predicated on what you expect your rocket to do. To cite an obvious example, you don't even know how large a launching site is needed until you have some idea of what your rocket's ultimate altitude and range might be.

Chapters 8, 9 and 10, which follow, cover the basic

ILLUSTRATION No. 47

WHAT IS THE AREA OF LEAST DANGER WHEN A ROCKET EXPLODES?



requirements for the design of a good launching site and the procedures you should follow in launching your rockets and in tracking and evaluating their performance. Chapter 8 treats very briefly with the question of the maximum *lateral* range of a rocket and presents a very simple formula for calculating it, as a guide in determining the land area required for launching. But for those of you who would like to know a little more about how the complete trajectory of a free flight missile is calculated, a simplified version of the computations involved is presented here. This version was prepared by the Propulsion Research Division of the Mechanical Engineering Department at the Polytechnic Institute of Brooklyn expressly for students of high school age. It eliminates from consideration some of the factors affecting the flight of a free ballistic missile, and it assumes that the angle of flight (in reference to the vertical) remains constant throughout the powered portion of the flight and that this angle is an extension of the angle of the launching rack.

The following symbols are used in the computation:

c	effective exhaust velocity
g	gravitational acceleration at earth's surface (32.2 fps)

H	Height, or altitude (maximum)
h_b	height at burnout
ln	logarithm
M*	$\dfrac{\text{initial weight—burnout weight}}{\text{initial weight}}$
Q	angle of flight at burnout
t	time (in seconds)
t_b	time at burnout, or time of powered flight
v	velocity (fps)
v_b	velocity at burnout
Y	launching angle
cos	cosine
sin	sine
tan	tangent

A Simplified Method for Computing Over-all Flight Performance of Small Missiles

In order to maintain maximum simplicity in the calculation of the missile's trajectory, certain assumptions have been made. First, it has been assumed that the path of the vehicle, up to the instant of burnout, is linear: i.e., this portion of the trajectory may be approximated by a straight line. Secondly, the deviation from the vertical over this path shall not exceed five degrees. Finally, the equations shall not include drag terms.

The entire trajectory assumed for the vehicle is shown by the sketch in Illustration *48*. For the sake of clarity it is broken into three segments, each of which is discussed separately, and then tied together at the end of the discussion.

For the powered portion of flight, if the average deviation from vertical flight is denoted by the angle Y, and if the orientation (flight attitude) of the vehicle at burnout is taken as equal to this angle, then the cutoff, or burnout, velocity at the end of the burning time (t_b) is :

$$v_b = [-c\, ln(1-M^*) - gt_b + v_o] \cos Y$$

where: c is the effective exhaust velocity in fps (See Chapter 4 for calculation of this value)

g is the gravitational acceleration ($32.2 fps^2$)
v_o is the initial velocity (fps)

M^* is the ratio $\frac{\text{init. wt.—burnout wt.}}{\text{initial weight}}$

If the initial velocity (v_o) is zero, as in the case of unboosted firing, this term is dropped and the equation reduces to:

$$v_b = [-c\ ln\,(1-M^*) - gt_b] \cos Y$$

The height (h_b) at the end of burning can be found by the equation:

$$h_b = \left\{ ct_b \left[1 + \frac{1-M^*}{M^*}\ ln\,(1-M^*) \right] - \frac{1}{2} gt_b^2 + v_o t_b + h_o \right\} \cos Y$$

If all elevations are taken with respect to ground level, then h_o is equal to zero, and again letting v_o equal zero, the equation can be re-written as:

$$h_b = \left\{ ct_b \left[1 + \frac{1-M^*}{M^*}\ ln\,(1-M^*) \right] - \frac{1}{2} gt_b^2 \right\} \cos Y$$

The total horizontal distance traveled during the period of powered flight (x_1) is then:

$$x_1 = h_b \div \tan Y$$

Once these values have been determined, a simple trajectory analysis for a regular projectile is applicable.

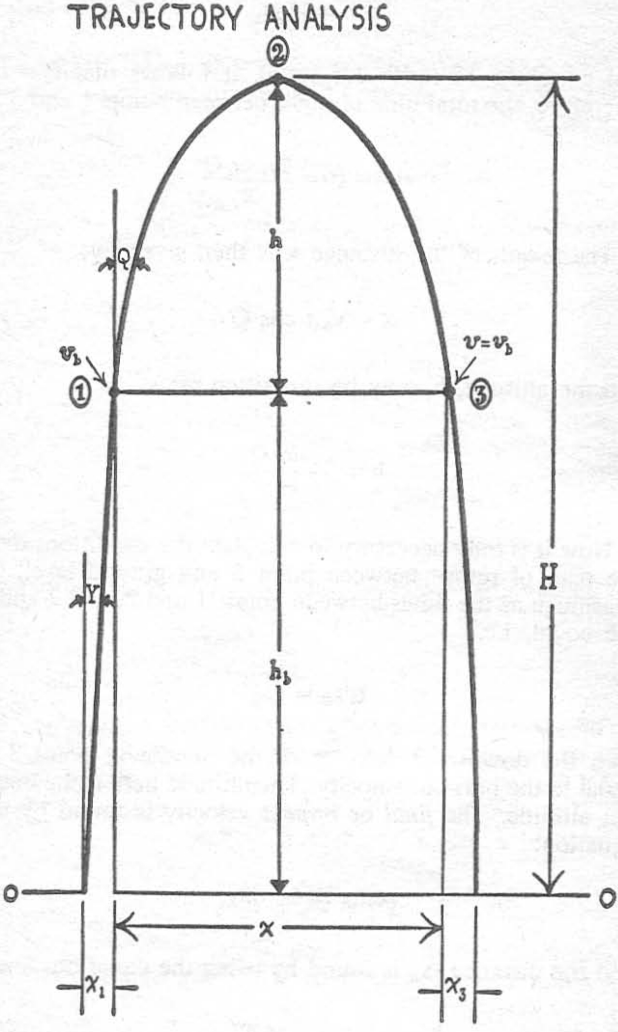
All values are now measured from the instant of burnout. The time (t_2) in which the projectile reaches the apex of its flight is found by the relationship:

$$v_b \sin Q = gt_2$$

During this period the projectile rises to a height *over the altitude at burnout,* represented by h, and given by the relation:

$$h = \frac{1}{2} gt_2^2$$

ILLUSTRATION No. 48



The time required for the projectile to reach point 3 in the diagram is given by:

$$-h = \tfrac{1}{2} g t_3^2$$

and since the altitudes are equal, it follows that $t_2 = t_3$. Therefore, the total time of flight between points 1 and 3 is

$$t = t_{1\text{-}3} = 2t_1 = \frac{2v_b \sin Q}{g}$$

The length of the distance x is then given by:

$$x = v_b\, t \cos Q$$

and the altitude, h, may be re-written as:

$$h = \frac{v_b^2 \sin^2 Q}{2g}$$

Now it is only necessary to calculate the conditions over the path of return between point 3 and ground level, O. Inasmuch as the times between points 1 and 2, and 2 and 3 are equal, i.e.:

$$t_{1\text{-}2} = t_{2\text{-}3}$$

then the downward velocity of the missile at point 3 is equal to the burnout velocity. The altitude here is the burnout altitude. The *final* or *impact* velocity is found by the equation:

$$v^2_f = v^2_b + 2gh_b$$

and the distance x_3 is found by using the equation:

$$x_3 = h_b v_b \sqrt{\frac{2}{gh_b}}$$

The time required to traverse this final segment is:

$$t_f = \frac{v_f - v_b}{g}$$

and the total time of flight, from the time of firing to impact is:

$$T = t_b + t_{1\text{-}3} + t_f \quad \textit{or} \quad T = t_b + \frac{2v_b \sin Q}{g} + \frac{v_f - v_b}{g}$$

The total range, X, is then found by summing the segments x_1, x and x_3. Thus:

$$X = x_1 + x + x_3$$

or

$$X = \frac{h_b}{\tan Y} + v_b\, t_{1\text{-}3} \cos Q + h_b v_b \sqrt{\frac{2}{g h_b}}$$

Chapter 8

LAYOUT AND CONSTRUCTION OF THE LAUNCHING SITE

Launching is the high point in rocket experimentation, the ultimate thrill for the researcher. There is little sense of achievement to be gained from the design, construction and testing of a rocket which ends up as a static display. For this reason safe proving grounds must be provided where well organized and serious research groups can launch rockets that have passed all preliminary tests.

You have been given some pointers in Chapter 1 on how to go about establishing an authorized launching site, how and where to seek sponsorship and the importance of co-ordination with the proper authorities. Do not neglect these things. Do not attempt to launch your rockets without adequate facilities, sufficient preparation, proper supervision and official permission.

This chapter and the one which follows are written for those who have met these requirements. They present the best available information on launching techniques and safety precautions for student researchers. Read the chapters carefully, study the drawings closely and follow the instructions given. Reread them frequently to make certain you have missed no important point. Prepare a checklist to make sure you have overlooked no essentials in building your launching site and in the procedures you establish for firing operations.

Remember also that while the launching may be the thrilling climax of your work, it is not the ultimate goal. It is only the final step in reaching that goal, which is to study the behavior of the rocket in flight, to record and analyze the information provided by the instruments you have built into it and then to evaluate what you have learned from the rocket. Take this final step carefully and with deliberate seriousness or it may prove to be your last.

PRIMARY SAFETY CONSIDERATIONS

Before you begin to build a launching site you must think seriously about the dangers involved for yourself and the public, and about how to avoid or minimize them. There are some basic elements which promote safety and reduce the likelihood of accidents. You will find them wherever dangerous conditions require the continuous observance of safety practices—rifle ranges, blasting areas, chemical plants, etc. Learn these safety elements by heart. Get in the habit of thinking in terms of them and of constantly asking yourself whether you are observing them in every phase of your operations. They are:

Remoteness: Be as far from the point of danger as you reasonably can while still controlling the operation.

Cover: This is the military term for any object or condition which provides physical protection for the man exposed to danger. Trees, rocks, gullies, foxholes, bunkers, trenches and sandbags are forms of cover. So is the ability to "hit the ground" automatically when an explosion occurs.

Provide plenty of cover for your group and use it.

Limited Observation: No one should be permitted to watch a dangerous operation whose presence is not essential to its success. Those who *must* watch should do so only from behind protective barricades.

When viewing the launching, cover bunker slits with shatterproof glass or use periscopes.

Assignment of Tasks: Probably nothing is more conducive to safety than orderly procedure. Confusion is the helpmate of disaster.

Make certain that everyone in your group knows his job and knows which jobs are the responsibility of others. Don't permit arguments about assignments. Assign one man to each job and hold him responsible for it. Be sure every job is covered.

One-man Control: It may not be democratic, but it is efficient. On a ship, in an airplane, in almost any military operation, and at professional rocket launchings, one man is boss. His word is law.

Your group must decide who is to be boss at your launching site. Nothing should be done until he gives the order for it. His decisions must be obeyed.

"Scouts Out" Security: Safety for the public demands extra precautions. You must consider the hazard your operations present to other persons.

Put guards at strategic points of observation to warn away passersby and to alert your control center to the presence of aircraft and other possible hazards.

Fire Fighting and First Aid: You must have fire fighting equipment on hand and be capable of fighting fire wherever it may occur. You must have first aid supplies and people who are trained to use them.

Routine: There must be routine in everything you do at a launching site or any other place where there are hazards. Routine means habit. Psychologists know that in emergencies people react according to habit. If your routine is good, your members' habits will be good and accidents can be minimized.

Layout of a Launching Site: Illustration No. *49* shows the recommended layout of a safe launching site which the average rocket group can build and maintain. More elaborate layouts using the same principles can be designed by advanced groups which have the resources.

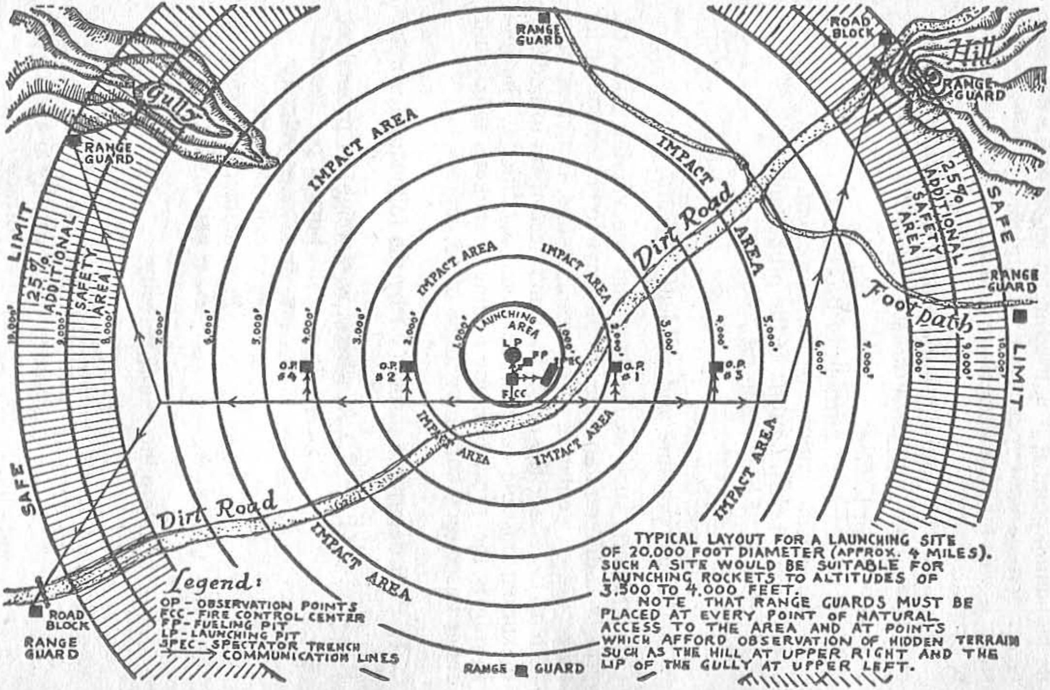
How big a launching area will you need? Its size will, in most cases, be determined by two factors: the size and range of rockets to be launched from it, and the amount of land you can get permission to use.

Very large areas of uninhabited land are found only in the West and Southwest. For rocket groups in other parts of the country it is generally more sensible to ask the question the other way around: what size rocket can you launch safely in the land you have available to you?

Many groups will find that the answer to this question is —none! In this case it is wiser to plan your group's program of activities with major emphasis on design, research and static testing. Then, when your members have enough money saved to travel to a distant launching area, the rockets you have developed will be more likely to perform as expected and you will not have to ask yourselves, "Was this trip really necessary?"

To find out what size rocket you can launch within the land area you have permission to use, you need to know

ILLUSTRATION No. 49



not how *high* your rocket will go when launched vertically, but how *far* it will go if launched at an angle of 45 degrees. A rocket, or any projectile, will travel farthest away from its launching point if it is fired at an angle of 45 degrees. Never assume your rocket will go straight up. Always assume it will take off erratically and travel the full length of its potential trajectory.

To calculate the potential trajectory, or maximum range, you need to know the following things about your rocket:

a. its weight loaded.
b. its weight after burnout of propellant.
c. the specific impulse of the propellant.
d. the total burning time of the propellant.
e. the rate of burning in lbs./second.
f. the exhaust velocity.
g. the nozzle exit area.
h. the exit pressure and ambient pressure.

Other factors, such as air drag and the varying effect of gravity at different altitudes would have to be considered in an accurate calculation of maximum range. But since they all tend to reduce the range we don't need them to find the maximum possible range under ideal conditions. The following is the procedure for finding a rocket's maximum range based on a launching angle of 45 degrees.

1. First determine thrust (F) by the following formula.

$$F = \frac{\dot{w}}{g} v_e + (P_e - P_o) A_e$$

where:
$\dot{w}$ = weight of propellant burned per second
v_e = exhaust velocity
P_e = exit pressure
P_o = ambient pressure
A_e = exit area

2. Next, determine cutoff velocity:

$$v_c = g_e I_{sp} \left(l_n\, n - \frac{n-1}{\psi} \right)$$

where:
g_e = gravity at earth surface
$n = \dfrac{\text{loaded weight}}{\text{cutoff weight}}$

ψ = initial thrust-weight ratio $\left(\text{or } \frac{F}{w_i}\right)$

l_n = logarithm

3. Then determine range (X)

$$X = \frac{v_c^2}{g} \operatorname{Sin} 2\phi$$

where: X = range

ϕ = launching angle (in this case 45°)

Illustration No. *49* shows the area needed to launch rockets which are capable of reaching altitudes of 3500 to 4000 feet. Note that the area is circular. Since we do not know in what direction the rocket will fly if it takes off erratically, we must provide a "safe area" in ali directions. Always launch your rockets from the center of your launching site, never from the perimeter or anywhere else in the area.

The shaded area in the sketch indicates an additional safety margin provided by extending the radius of the circle 2000 feet beyond the calculated maximum *range* of the rocket. This second perimeter should be the outside safety limit of your launching site. The location of this perimeter is largely a matter of judgment and can be varied according to the type of terrain you are in, observation conditions, and whether the surrounding area is populated or heavily traveled. In no case should you establish the radius of the outside perimeter at less than 125% of the calculated maximum range. Its purpose is to provide an extra margin of safety to allow for minor miscalculations, variations in fuels, strong tail winds, etc.

When you have all the necessary permissions and clearances discussed in Chapter 1, you are ready to determine what you need at your launching site. Before we consider that, however, it is necessary to define a few terms we will be using throughout the rest of this chapter so that you will be certain to understand exactly what is being said, and particularly to avoid confusion as to the ground area being referred to.

Launching Site: The entire area of the launching facility, including the outside safety perimeter. The term "range" may be used interchangeably with the term "launching site" to indicate the same thing.

Launching Area: The immediate working area in the center of the launching site. It includes the launching pit, firing bunker, fueling pit, observation bunkers, etc.

Launching Pit: The actual pit or barricade from which the rocket is launched. It contains the launching rack or platform.

Impact Area: Any area where a rocket lands, or is expected to land. To be realistic you must consider your entire launching site as potential impact area.

Impact Point: The spot at which a specific rocket actually lands.

Impact Zone: The predicted area of impact of a specific rocket or series of rockets launched at the same angle. The size and distance from the launching pit of an impact zone will vary with the type of rocket and the angle of launching. Impact zones will generally be oval in shape with the long axis pointing toward the launching pit. The length of the long axis will vary according to altitude reached and launching angles, with the axis generally growing shorter as the launching angle approaches the vertical.

Road Block: Any barricade, rope, chain, sign or manned post established at a point on a road or path beyond which persons or vehicles are not permitted to pass.

Road Guard: A person assigned to man a road block.

Range Guard: A person assigned to stand at a point or patrol an area on the perimeter of a range for the purpose of preventing access to it.

Countdown: The final safety and operational readiness check prior to launching. It should be highly systematized and proceed on a rigid time schedule, with the final 15 seconds being counted out orally.

Fueling Pit: The pit or barricade within which rockets are fueled. This is not, and should never be, the place where fuel is stored.

"By the Numbers": A method of doing things step-by-step, with each step numbered in sequence to ensure that none is omitted. The numbers are called out as each step is performed. The system also permits everyone within hearing to know what is going on. The countdown is a method of firing missiles by the numbers. In the armed forces every important or hazardous operation is done this way.

Protective Pits and Barricades: A safe launching site is not just an open area out in the country. As Illustration No. *49* shows, it requires intelligent planning, some material and a great deal of pick and shovel work. The more pick and shovel work you do, the safer you will be. The illustrations which follow show you how to construct a variety of emplacements that are needed at a well-equipped launching site. They are not the most elaborate that can be built, nor are they the simplest. They are designed so that they can be built by the average rocket group with easily obtained materials.

For the launching site shown in Illustration No. *49* you need:

a launching pit	(Illustration *53*)
a firing bunker	(Illustration *55*)

The firing bunker should also be the control center. A separate control center may be established but this increases communications problems and the chances of premature firing.

fueling pit	(Illustration *56*)
observation bunkers	(Illustration *58*)
range guard shelters	(Illustration *60*)
spectator shelters	(Illustration *61*)

The most important emplacement is the launching pit. Even if you have nothing else on your site, a properly built launching pit can give a great deal of protection to those participating in the launching.

It is most important that the launching rack be emplaced in a pit or surrounded by a barricade, the top of which is approximately one foot higher than the nose of the rocket as it rests on the rack in launching position. The purpose of this barricade is to absorb fragments which would fly laterally, and somewhat upward, in the event of an explosion. The pit should be at least four feet deep. If your launching site is located in rocky soil you can combine a two-foot deep pit with a partial barricade high enough to extend above the nose of the rocket. You may also use a four- to six-foot barricade built at ground level.

How you build your barricades and emplacements will depend on what materials are available to you. Reinforced concrete would give the greatest protection, but it is unlikely that many groups can afford this type of construction. In any case, it is not necessary, considering the size and power of rockets you will be testing and launching. Plain concrete, bricks, cinder blocks, railroad ties and heavy timbers are excellent. If you are willing to do the shovel work, however, you can do a satisfactory job and provide maximum protection against fragments that fly laterally with nothing more than dirt or sand.

Less than thirty inches of sand will stop a .30 caliber bullet fired from a Garand M1 rifle at a range of 100 yards. The M1 has a muzzle velocity of about 2900 feet per second. It is not likely that fragments from an exploding rocket will develop velocities anywhere near this figure and dirt will give you all the protection you need from them. With dirt as your basic construction material you can build all of the protective emplacements shown in the illustrations. Besides costing nothing, dirt has the advantage of absorbing fragments on impact instead of ricocheting them off as stone or concrete would do.

The material thickness tables in the Appendix show you the types and thicknesses of materials which the U. S. Army has found will stop projectiles and bomb fragments of varying sizes at varying distances. You will note, for instance, that 40 inches of sand or earth in sandbags will protect you from the fragmentation of a 500-lb. bomb which explodes only 50 feet away from you.

With dirt, your basic building block is the sandbag. Shovel the dirt into burlap bags or 100-pound flour sacks. Don't fill the bags too full. Tie the mouth of each securely, leaving enough space at the top so that the bag will lie flat when placed in position. This helps to prevent gaps in a sandbag wall, makes a stronger wall, and keeps the bags from splitting. If you can cover your walls with tarpaulins or any water-resistant covering you will find that they withstand the ravages of weather much better and last longer.

Lay the sandbags so that the long axis is at right angles to the long axis of the wall you are building. This gives you a thicker wall and lets you build to a greater height without danger of the wall collapsing. The rows of sandbags should be laid so that each bag is centered over the crack between the two bags beneath it, the same way a brick wall is built. After a little tamping and with time for the bags to settle, you will have a pretty solid wall. This type of construction is shown in Illustration No. *50*.

An alternative method is also shown, in which the bags are laid crosswise in the first row, lengthwise in the second row, crosswise in the third row and so on. Assuming the bags are roughly twice as long as they are wide, this method usually results in a more stable and better aligned wall, and it is recommended.

Illustration No. *50* also shows another type of dirt construction you can use if you can't get sandbags, but can get timbers or logs. This is called crib construction and consists simply of erecting a framework, or crib, to give basic shape and rigidity to your wall. You fill the interior of the crib with rocks and dirt, the more dirt the better. Walls built this way should be 24 to 30 inches thick and should be buttressed at intervals with diagonal supports if your timbers are not heavy enough to withstand the weight of the dirt and rocks by themselves. Thin branches, matting, wire mesh, chicken wire or canvas placed along the interior of the crib walls will hold the dirt in place. The tops of the walls should be covered to prevent rain from washing the dirt away.

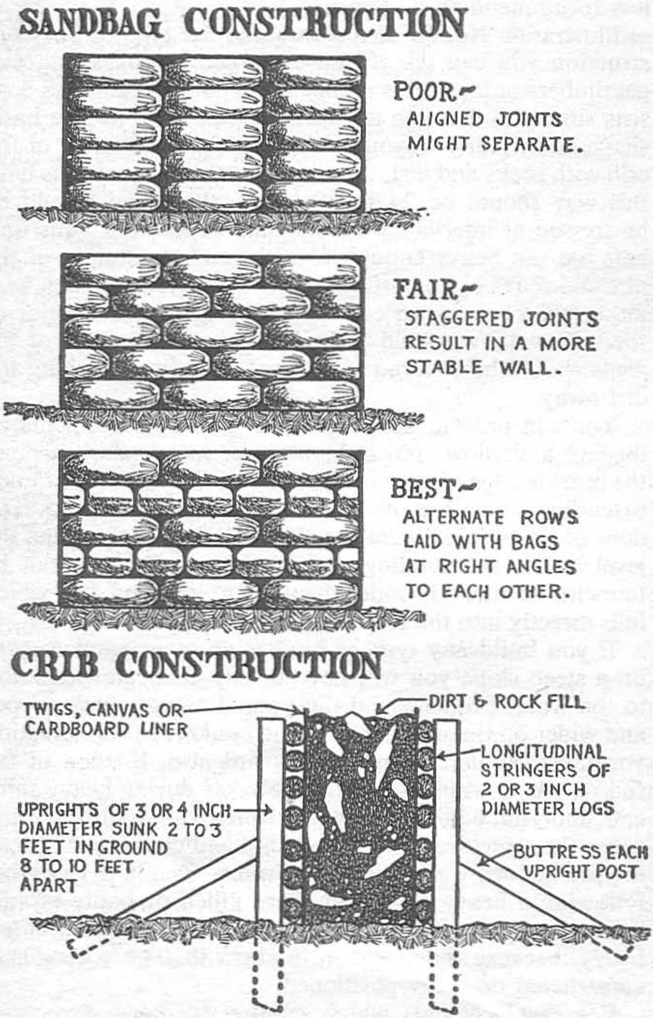
You can prevent flooding inside your emplacements by digging a shallow trench four to six inches deep around the outside edge of each emplacement with a lead-off trench extending a few feet in the direction of low ground. The floor of the emplacement should be slightly higher than the level of the surrounding ground and small holes can be tunneled at intervals under the walls to drain off rain which falls directly into the emplacement.

If you build any type of bunker or other emplacement on a steep slope you will have to pay particular attention to the water problem and dig your drainage ditch deeper and wider on the uphill side of the bunker. In this situation you must be alert to another hazard also. Erosion of the soil on the downhill side of the bunker during heavy rains can undermine the ground on which the walls rest and cause the structure to slide downhill and collapse. This can happen suddenly and without warning, even in dry weather following a heavy rain. Men were killed or badly injured in Korea, where the hills are steep and the rains extremely heavy, because they slept in bunkers that were carelessly constructed or badly positioned.

For emplacements which require overhead cover you must keep a few things in mind:

a. Make certain the walls of the bunker are strong

ILLUSTRATION NO. 50



enough and thick enough to support the load of the roof.

b. Be sure the timbers you use for roof beams are heavy enough.

c. Do not try to span too great a distance with a roof consisting of sandbags and timbers. Eight feet is the maximum, five or six feet is preferable. Use posts or sandbag partitions to reduce the length of the span wherever possible.

Roofs can be built simply by laying a framework of timbers across the open area between the walls as shown in Illustration No. *51*. The timbers should be as uniform in girth and length as possible and fairly smooth. The main support beam should be six or eight inches thick and the crossbeams which are laid across the main beams should be three or four inches thick if you plan to put three layers of sandbags on top. Three layers of sandbags on a roof measuring six by eight feet will weigh about 4000 pounds.

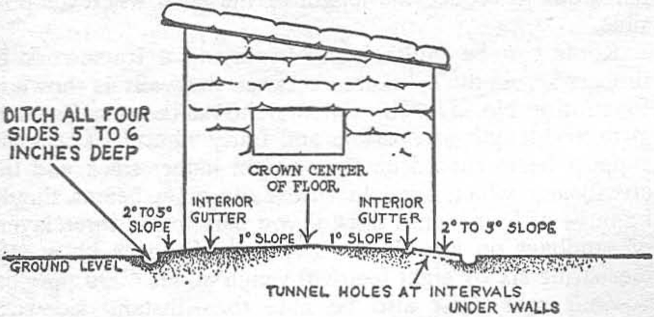
Your roof must also be able to withstand sideways stresses and for this reason the beams should be joined in some manner at the points where they intersect. There are several methods of doing this. If someone in your group is handy with an ax you can notch the beams at all points of intersection so that they nest together evenly. The beam ends which rest on the walls should also be notched so that they present a flat surface to the top of the wall. If notching sounds like too much work the beams can be bound together with baling wire or old electrical cord. Surplus sales stores usually have Army "commo wire" (communications wire) available which is excellent for this purpose. It is a light, tough, pliable wire with a glossy black rubber coating. It is used primarily for stringing field telephone lines, but the American soldier uses it for everything from shoelaces to hanging out wash.

Extra stability can be given to your roof by allowing the beam ends to project beyond the sandbag wall a foot or so (as shown in Illustration *51*) and suspending a loaded sandbag from the butt end of each. This helps to settle the beams in place, prevents side-slippage, and acts as a counterweight to the downward thrust of the roof load in the center.

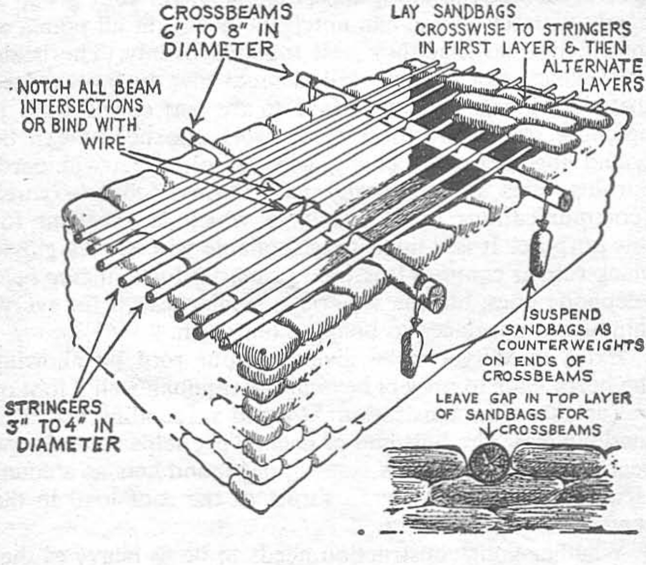
Whether your construction needs to be as heavy as that shown in the illustration is a matter of judgment. The illustrations show the heavy type of construction to emphasize

ILLUSTRATION No. 51

DITCHING & DRAINAGE



ROOF CONSTRUCTION



the need for safety. You may be able to use lighter construction with complete safety—one or two layers of sandbags on the roof instead of three. You can determine your needs with a little calculation and perhaps a few tests. The primary considerations are the weights of the rockets you intend to launch and the altitudes you expect them to reach.

The altitude is the most important factor because it determines the velocity at which your rocket will hit the ground. Velocity determines depth of penetration, with due allowance for the weight of the object. Did you ever stop to think that the only thing lethal about a bullet is the speed with which it travels? A lead slug tossed across a room at you would do no more than sting you. But when it comes at you at a speed close to 2000 miles an hour it is an entirely different matter. All that has been added to the slug is velocity. But velocity turns it into a killer. The same thing is true of your rocket. If it falls from a great enough altitude it can kill. A rocket which reaches a height of 1000 feet will hit the ground at approximately 175 miles an hour. This is not very fast. It is only a little faster than Pancho Gonzales hits a tennis ball, and twice the speed of one of Herb Score's fast balls. But if you have ever seen a batter "beaned" by a fast pitch you will know that you don't want to be in the way of a rocket falling from 1000 feet. Gauge your construction accordingly.

If your group intends to test rockets capable of reaching 10,000 feet you had better figure on good, heavy overhead protection. From an altitude of 5,000 feet a rocket body will reach a speed of 386 miles per hour by the time it hits the ground: from 10,000 feet, 545 miles per hour. From 20,000 feet your rocket would be hitting the ground at supersonic speed (775 MPH).

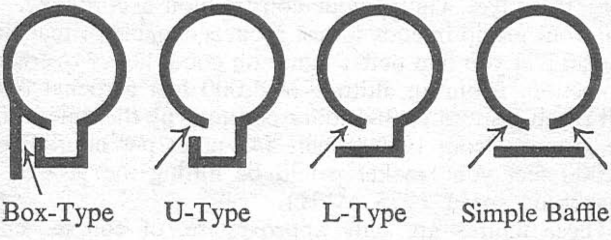
These figures are only approximate, of course, since they do not allow for aerodynamic drag (which would vary for every size and shape of rocket) nor for the fact that the pull of gravity (and consequently the rate of acceleration) varies with altitudes. They are good enough, however, for the purpose at hand. You will find a discussion of how to calculate the velocity of a free-falling body in Chapter 10, and the table of velocities in the Appendix shows the calculations for various altitudes as a ready reference for tracking purposes.

The designs shown for the various types of emplacements in Illustrations *53* through *62* are self-explanatory and there is no need to discuss the construction of each in detail. There are certain important features of each, however, which must be stressed, and some explanation must be given of the purpose of each emplacement, the part it plays in the operation of the launching site, and the equipment needed in it, if any. Let us take them up in the order they have been listed.

The Launching Pit: We have already discussed certain features of the launching pit. You will note that the illustration shows access doors for convenience in entering the pit. It also provides access for wire leads to the launching rack and for the pull wire which is used in the procedure for handling a misfire described in Chapter 9. Details of the launching rack and the platform on which it rests are shown in Illustration *63* which will be discussed later.

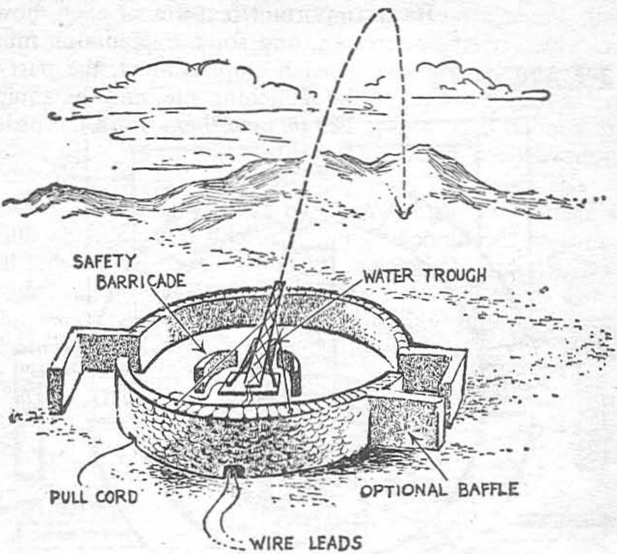
The access door is nothing but a rectangular opening in the wall protected by a baffle. Baffles should be used to close off access doors to all emplacements. They are of four general types:

ILLUSTRATION NO. 52



Note that the baffle should extend far enough beyond the opening so that it is impossible to see into the emplacement from any direction, as shown by the line-of-sight arrows. The baffle, also, must be of the same height as the emplacement wall and of the same thickness. The U-shaped baffle gives the best all-around protection, but it is complicated to build and is not really necessary. It is used by the Army in combat areas where it is desirable to prevent light from showing through a doorway at night.

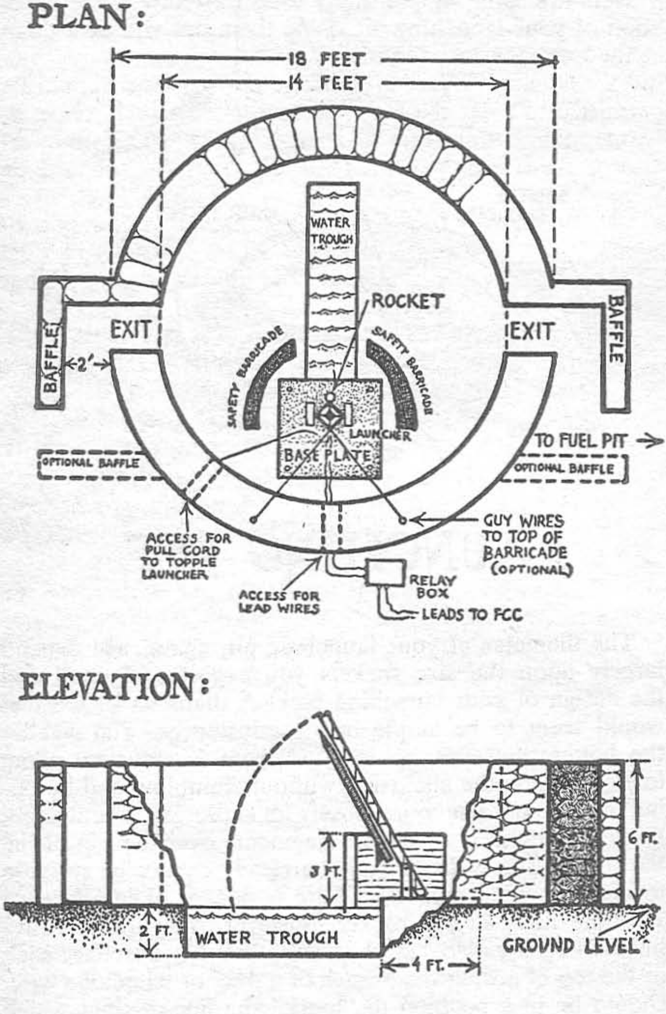
ILLUSTRATION NO. 53



LAUNCHING PIT

The diameter of your launching pit, again, will depend largely upon the size rockets you expect to launch and the design of your launching rack. A diameter of ten feet would seem to be ample in most instances. The smaller the better, however, as long as there is sufficient room to work inside the enclosure without stumbling and bumping into things. The more closely an explosion is contained, the less likely it is to scatter fragments over the top of the barricade. The walls of your barricade cannot be so close to the launching rack that there is danger of interference with the flight of the rocket, however. You must always have what is called "mask clearance." No obstacle, such as the top of a wall, the branch of a tree, or telephone wire, should be in a position to "mask" the line-of-sight which your rocket will follow in flight. You'd be surprised how frequently this important rule is overlooked. The launching

ILLUSTRATION NO. 54



pit shown in Illustrations *53* and *54* has an inside diameter of 14 feet. This is ample for launching rockets up to 8 feet in length, and includes a water trough 8 feet long and 2 feet in width.

Here are some simple safety rules to follow in the operation of your launching pit. Type them out and post them at the entrance to your pit.

1. *Nobody whose presence is not essential* should be permitted to enter the launching pit when a rocket is in it. If one man can perform all the necessary setting up operations, then *only one man and a supervisor* should be allowed inside.

2. *Never stay in the pit* longer than is absolutely necessary to set up and perform the necessary safety checks. (This does not mean that you should hurry your work, but get out as soon as possible.)

3. *Never have more than one rocket* in the pit.

4. *If a rocket starts to burn,* or a fuse sputters, *get out*. Throw yourself flat on the ground *outside* the barricade and as close to the wall as possible. Bury your face in the dirt. *Never* attempt to stop the burning, or touch or move the rocket in any way.

5. *Always wear protective* clothing, including helmet, face shield and gloves in the pit. *Do not attempt* to work with the gloves on if it is awkward.

6. *Always sight* along the launching rack to make certain nothing will interfere with the flight of the rocket, *before* you place the rocket on the rack. (Mask clearance) Shout, "Clear!", so that your supervisor will know you have done it.

7. *Always* have a bucket or trough of water in the pit, and a first-aid man on call.

8. *Never* allow fuel to be stored in the launching pit.

9. *Fly a red flag* from the barricade whenever a live rocket is in the pit.

10. *Fly a yellow flag* from the barricade whenever personnel are in the pit.

In regard to safety rule number 4, you might consider providing two access doors to your launching pit in order to provide better means of escape in an emergency. This is not essential, but if you don't mind the extra work it is probably advisable.

The Firing Bunker—Control Center: The firing bunker is the next most important emplacement at your launching site. It should also be your fire control center and the control center for the entire operation of the range. Some groups may prefer to have a firing bunker that is separate from the control center and in which only the firing operation takes place. To do this, however, makes it necessary to have good telephone, or visual signal communication with the control center. Remember that every time you introduce a need for more communications you provide another opportunity for something to go wrong. For this reason it is advisable that the firing bunker and the control center be one and the same place. If the topography of your launching site is such that you cannot get good observation of the entire range from the point at which it is most convenient to locate your firing bunker, then you may be justified in establishing a separate location for the control center. Otherwise keep them together. From this point on we will assume that they are co-located.

The primary functions of the fire control center are to:

a. Maintain visual or wire communications with all parts of the range.

b. Give all procedural directions and orders.

c. Execute all safety checks, or order them executed.

d. Determine that every station on the range is in readiness.

e. Determine when an emergency exists and make all decisions in an emergency.

f. Keep all stations on the range informed of the status of operations at each critical point.

g. Give the order to take cover.

h. Give the order to fuel the rocket.

i. Give the order to fire the rocket.

j. Fire the rocket.

k. Give the "all clear" signal.

l. Take reports and record the data for each flight.

m. Announce the results of each firing.

n. Declare rest periods, or "breaks," when all range operations cease.

REMEMBER THIS:

1. Nobody on a firing range, or launching site, moves from one place to another or takes any action without a specific order from the control center.

2. It is the duty of every person on a range to report any unusual occurrence to the control center immediately, and also to make routine reports upon the completion of assigned tasks.

The emplacement which you build for your fire control center (Illustration *55*) should be designed so as to give adequate protection, but at the same time it should afford reasonably good observation of the entire launching *area* and to certain other designated points within the launching site. Consequently the placement of windows and observation slits in the walls of the bunker will be determined by the topography of your particular launching area and the locations of observer bunkers, etc. The arrangement shown in the illustration is not intended to be followed precisely.

Your fire control center will also be the heart of whatever communications system you establish for your range. It must have communication with the launching pit, the fueling pit, observer bunkers and range guards. The section on communications which follows will give you ideas on installing and operating a satisfactory communications system.

There is another important point to remember about your control center. The purpose of control is to eliminate confusion and ensure safe, orderly procedure. If you have confusion in your control center you will have it elsewhere on your range. Keep people out of your control bunker who don't have any business being in there. People naturally like to be at the center of operations. It makes them feel important. But you cannot afford to humor people when you are dealing with danger. Make it an ironclad rule in your group that no one is allowed in the control bunker who does not have a specific job to do. There is a separate shelter provided for spectators.

One final consideration in the construction and location of your control and firing bunker is its distance from the launching pit. There are several factors to be considered in determining this distance (*see* Quantity-Distance Tables in Appendix). But when all these factors have been evaluated, and proper considerations of *safety* and *control* taken into account, it seems most reasonable to establish a distance of 50 yards to 100 yards between launching pit and control bunker. The distance of 100 yards is preferable, of course, for maximum safety; but at this distance you may have difficulty in getting your electrical firing system to operate. If you are firing small rockets (1 foot to 3 feet in length) a distance of 50 yards is adequate providing you have a soundly constructed firing bunker and good range discipline. Generally speaking, the explosive effect of rockets has been over-emphasized; mainly because people who have been injured by them have been foolish enough to be standing right next to them. For purposes of comparison, the Army's 4.2-inch (105MM) high explosive mortar shell (which weighs approximately 25 pounds, is nearly 2 ft. long, and 4.2 inches in diameter) has an *effective* burst radius of only 45 yards, laterally. This projectile was *designed* to kill. It is the product of generations of development work by ordnance experts. It is packed with TNT and has a shell casing designed for maximum fragmentation effect.* It is not likely that amateurs using inferior materials, slower burning fuels and with no ordnance experience, could accidentally produce a more lethal effect. When one considers, in addition, that the launching rack is surrounded by a barricade, and a protective bunker houses the firing personnel, it is obvious that a distance of 50 yards is sufficient.

It never does any harm, however, to provide yourself with an extra margin of safety wherever possible. Therefore, if you are planning to launch rockets larger than three feet in length, and if the topography of your site will permit it, a distance of 100 yards between launching pit and control bunker is recommended. Bear in mind that increased cable length in your electrical system will probably require stepped up voltage, if the system is to be effective.

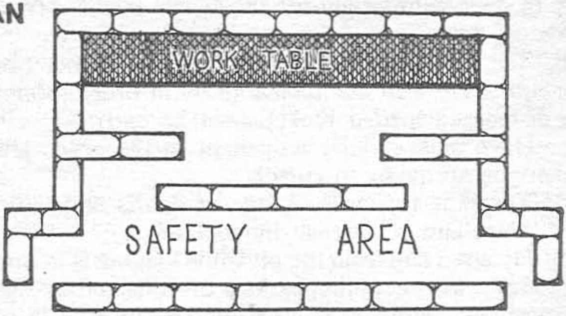
The Fueling Pit: The purpose of a fueling pit is, of course, to minimize any accident which might occur during the loading process. It is designed to afford maximum possible protection for those doing the fueling, and also to contain any explosion to prevent injury to other persons in the area. The design shown in Illustration *56* is not too difficult

*Army ordnance experts have calculated that a flying fragment must produce a minimum of 58 foot pounds of energy to have a casualty effect. This means that a one ounce fragment would have to travel at a velocity of 246 FPS (166 MPH) to injure severely. You can use your knowledge of basic physics to calculate the possible casualty effect of one of your rockets if it exploded.

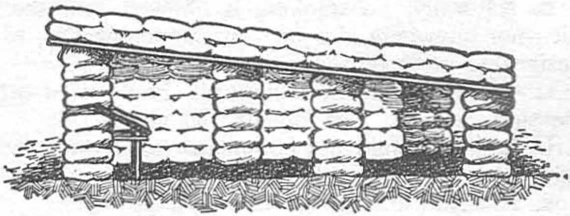
Illustration No. 55

FIRE CONTROL CENTER
OR CONTROL BUNKER

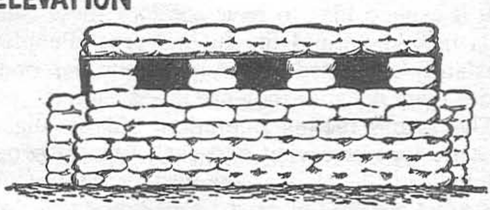
PLAN



SIDE ELEVATION CUTAWAY VIEW



FRONT ELEVATION



to build and will prove convenient to work in. *It is not the place where fuel or oxidizers should be stored,* for obvious reasons.

Here are some points to keep in mind in regard to the location and operation of a fueling pit.

a. Nobody should be allowed in or near the fueling pit during loading operations, except the fueling supervisor and the persons designated to do the loading (normally two).

b. The fueling pit should be remote from other emplacements, *but close to the launching pit* in order to minimize the distance a loaded rocket must be carried.

c. Have only enough propellant in the pit to load the rocket you are going to launch.

d. Keep the fueling area free of debris and return unused propellant to storage immediately.

e. Fly a red flag from the pit while loading is in progress.

f. Have wire communication, or some other signaling arrangement, with the control bunker and notify control when loading is completed.

g. Only the control center should give the order to move the rocket into the launching pit.

h. Naturally, no smoking is allowed near the fueling pit—nor anywhere else on your launching site, except in designated areas during announced breaks.

i. All persons in the fueling pit should wear protective clothing, helmets, face shields and gloves.

j. Fueling should not commence until the order is received from the control center.

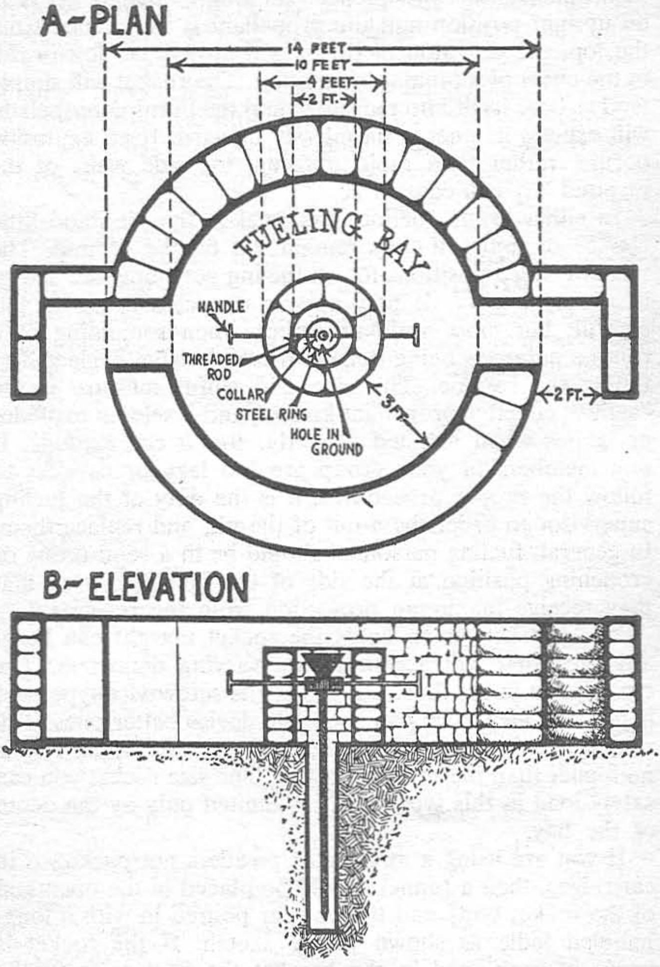
k. Always use a funnel with loose powders.

It is a good idea to have some of these rules posted on signs in and around the fueling area. People need to be constantly reminded of safety regulations or they tend to ignore them because they are inconvenient.

The actual fueling operation will be slightly different for each type of rocket and each type of propellant. You will have to develop a standard procedure of your own. The most commonly used propellant (and apparently the safest one that will give any appreciable amount of thrust) is the combination of zinc dust and sulfur. As indicated in the chapter on propellants it is most widely used in loose powder form and is either poured directly into the rocket

ILLUSTRATION NO. 56

FUELING PIT



chamber and tamped down, or is prepackaged in tubular cartridges. Whichever method is used, the rocket should be placed in an upright position in the revetted fueling bay (Illustration *56*) in the center of the fueling pit, and the powder fed in from the top. Whether your rocket is designed to be loaded from the nozzle end, or the nose, is of no particular consequence. As long as the rocket is in an upright position and the propellant is introduced from the top, the direction of thrust will always be downward, in the event of a premature ignition. The rocket will simply tend to bore itself into the earth, and the burning propellant will expend its energy harmlessly upward. If an explosion occurs, rather than rapid burning, the side walls of the revetted bay will contain it.

In either event, fueling personnel in the pit stand little chance of injury if they remain flat on the ground. The recommended positions for all fueling personnel are shown in Illustration *57*. It may appear unnecessary to be this careful; but most accidents occur when something of a routine nature is being done and people have neglected to follow the routine. The zinc and sulfur mixture is the "safest" effective propellant known, and it seldom explodes or ignites when handled properly. *But it can explode.* If any members of your group are too lazy or careless to follow the proper procedures, it is the duty of the fueling supervisor to order them out of the pit, and replace them. In general, fueling personnel should be in a semi-prone or crouching position at the side of the fueling bay so that they receive maximum protection from the revetment.

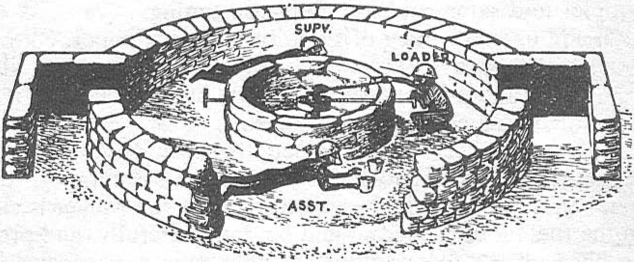
The bracket which holds the rocket upright can be of any type that will accommodate varying diameters. The type shown in the illustration is of the screw-vise-type, and is just one idea. You can probably devise better ones. The rocket should always be inserted so that its upper end is no higher than the revetment wall. The size rocket you can safely load in this type of bay is limited only by the depth of the bay.

If you are using a mixture of powders not packaged in cartridges, then a funnel should be placed in the open end of the rocket body and the powder poured in with a long-handled ladle as shown in the sketch. If the rocket is properly positioned in the bracket the person doing the loading will be able to see the edge of the funnel. In

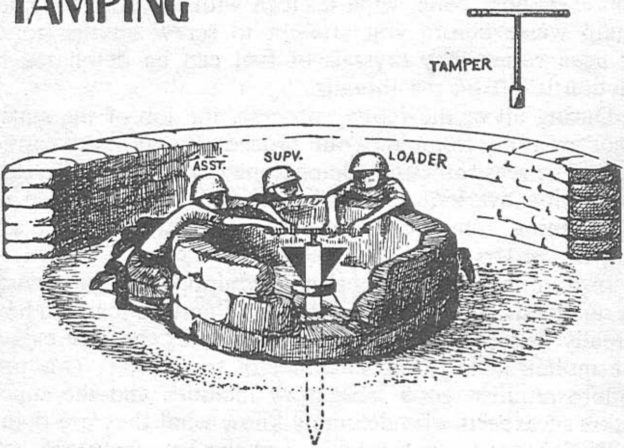
Illustration No. 57

FUELING PROCESS

LOADING



TAMPING



loose-powder loading, the assistant loader is probably best employed in filling the ladle for the loader; or he may do the tamping from the opposite side of the bay. The powder should be tamped down lightly but firmly with a right-angled tamper, similar to the one shown in the sketch, after each ladleful, and settled by vibration.

If your propellant is prepackaged in cartridges, each cartridge should be dropped into the rocket tube by the loader with a pair of long-handled tongs (ordinary fireplace tongs will do) or similar device; and the tamper should simply press each cartridge firmly into place, being careful not to rupture the cartridges. Cartridge loading is generally simpler and safer, and less time-consuming.

Wadding or packing of some type (tissue paper, cotton, wool waste, or even soft wax) may then be inserted with the tongs and pressed down firmly by the tamper, if a burst diaphragm is not being used.

If your rocket is so designed that you have removed either the nozzle or nose cone in order to accomplish the loading, it should now be replaced while the rocket is still in the fueling bay. This should be done carefully, and preferably with the tongs until final tightening is necessary. If your rocket has a threaded section for attachment of the nozzle or nose cone, wipe it clean with a piece of slightly damp waste before you attempt to screw on the nozzle or nose cone. Tiny crystals of fuel can be detonated by friction if left on the threads.

During all of the fueling process, the job of the supervisor is simply to monitor the procedure and make corrections if he sees something being done improperly or a safety precaution overlooked. He should also be responsible for maintaining communication with the control center and relaying orders.

If your group is well enough equipped and supervised by qualified chemists and engineers, it may be that you have already begun to use propellant mixtures that are cast in the molten state in the chamber of the rocket. This procedure requires good laboratory facilities and the supervision of experts who definitely know what they are doing. If the laboratory is not located at the launching site, and it is unlikely that it will be, you then have the nasty problem of transporting loaded rockets over public highways. Bear in mind that you must have a permit to do this and that extreme caution must be exercised in the interests of the public safety. It is a good idea to enlist the aid of some trucking concern or industrial firm that has had experience in the transportation of explosives. Considering all of the things that can go wrong, or cause variations, both in the mixing process and in the behavior of a rocket using a cast charge, it is not recommended for any but extremely advanced groups.

Once the rocket is loaded and ready to be taken to the launching rack the control center must be notified. Do not remove the rocket from the fueling bay until the order to do so has been received from the control center. Remove all excess propellant from the fueling pit and notify control that this has been done. When you do remove the rocket from the bracket, do so very carefully. Do not jar or shake it. Take it immediately to the launching rack and place it in position.

If, for any reason, the rocket should start to burn or sputter on the way to the launching rack, do one of the following (whichever is quickest and most convenient):

a. Immerse it in a trough of water.
b. Throw it back in the fueling bay.
c. Throw it back in the launching pit.
d. Thrust it, nose down, into soft sand.

Whichever you do, throw yourself flat on the ground behind the nearest barricade and keep your head down until the rocket has spent itself. If you have some type of prearranged alarm signal, give the signal so that others may take cover. Do not expose yourself unnecessarily to do so, however.

Observer Bunkers: Usually two observer bunkers are needed at the approximate locations shown in Illustration *49*. These are the points from which sightings of the rocket in flight are made and which have the basic responsibility for tracking. Each should be manned by two men. If desired, two two-man teams can be stationed at each bunker in order to provide comparative information on sightings. If your group is large enough you may want to build additional observer bunkers at other strategic points on the range. They can be useful for two reasons:

a. They can provide alternate data as a check on the accuracy and reliability of data obtained from the two primary observation points.

b. They provide an opportunity to train additional observer teams.

The protective shelters for observers do not have to be as elaborately constructed nor as rugged as the emplacements so far discussed, because they are relatively remote from the launching pit. Since no blast or fragmentation from an explosion could reach this far, there is no real need for lateral protection. An overhead cover is advisable however. The arrangement shown in Illustration *58* should be adequate. The sandbag wall in front of the shelter is intended not so much for protection, but as a convenient resting place for instruments, charts, and sighters' elbows when observing through binoculars.

Since the details of observers' operations are covered very thoroughly in Chapter 10, we will not discuss them here, except to indicate how the observer teams tie in with the operation of the range as a whole. To begin with, it is desirable that there be direct communication with the control center, either by field telephone or visual signal. This is necessary first of all in order to alert the observer teams to the precise time of launching. Secondly, good communications considerably speeds up the reporting and evaluation of observer data. It is virtually essential that the observer teams be able to hear the pre-firing countdown, as they must have their instruments trained on the launching rack and the predicted flight path of the rocket in a state of instant readiness.

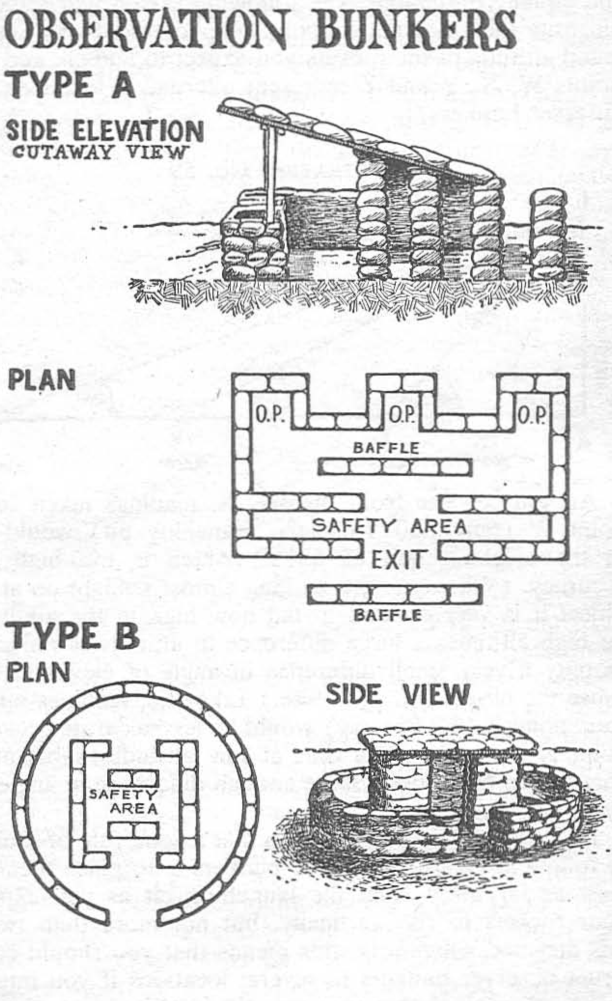
The distance of observer bunkers from the launching pit is determinable by two principal factors, the second of which is the more important:

a. The topography of the particular launching site (i.e., whether line-of-sight observation can be maintained between the observer bunker and the launcher).

b. The anticipated altitude of the rockets you intend to launch.

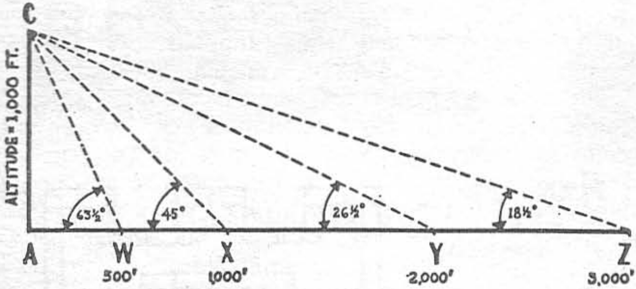
The latter factor is most important because of the fact that visual sightings are only approximate, at the best, and the angle of elevation to be read by the observer should be in a range which will be conducive to the most accurate reading possible. If the angle is too small (20° or less) or too large (80° to 90°) the margin of error is likely to be

ILLUSTRATION No. 58



greater. Generally speaking, if observer bunkers are too close to the launching pit the angles of elevation to be read by observers will be extremely high (close to 90°) and consequently less reliable. If the observers are too far away, the angles to be read will be correspondingly small and equally unreliable. The following sketch will serve to illustrate this principle for you. (AC represents the anticipated altitude of the rockets you expect to launch, and the points W, X, Y and Z represent alternative locations for observer bunkers):

ILLUSTRATION No. 59



As you can see from the sketch, readings taken from point W (only 500′ from the launching pit) would be in the neighborhood of 63½°, which is too high for accuracy. (When you are looking almost straight up at an object it is very difficult to tell how high in the air it is. At high altitudes a large difference in altitude is reflected as only a very small difference in angle of elevation because the observer is too close.) Likewise, readings taken from point Z (3000′ away) would be less accurate because point Z is so far away that at low altitudes substantial changes do not cause a large enough difference in angle of elevation readings.

It can be seen from the sketch that a good rule-of-thumb to follow in locating observer bunkers is to place them at least as far away from the launching pit as you expect your rockets to rise vertically, but not more than twice this distance. Obviously, this means that you should construct observer bunkers in several locations if you intend to launch rockets that vary greatly in altitude capability. Simply bear in mind that elevation readings in the neighborhood of 25° to 45° will probably give the greatest accuracy, and locate your observer teams accordingly.

Range Guard Shelters: The construction of range guard shelters, as shown in Illustration *60,* is relatively simple. Such shelters may not even be necessary for range guards located a considerable distance from the launching area. The only important requirement is to provide some type of overhead cover in the event a stray rocket lands near the perimeter of your launching site. If you consider this highly unlikely at your particular site you may want to dispense with range guard shelters altogether. There is no particular objection to this, except that a shelter makes the range guard feel important and he may appreciate it in the event a sudden thunderstorm delays launching operations.

The range guard, of course, must be provided with some type of telephone or visual communication with the control center so that he can give clearances for firing to commence, or stop the launching operations if he discovers someone has wandered into his area. The range officer must complete a check with each of them before starting any of the countdown procedure. Since the job can be boring, and the man acting as range guard is likely to feel left out of the proceedings, the assignment should be rotated frequently among members of the group.

The number of range guards that you need, and the locations at which they should be stationed, are matters that can be determined only by careful analysis of the topography of your particular site and the means of access to it. The arrangement shown in Illustration *49* is only a hypothetical one, of course. Specifically, you must make certain that all "natural avenues of approach," to use a military term, are covered. This means a man must be stationed on, or be in a position to observe, every road, pathway or trail leading into the site. In addition you should provide for the following:

a. Point-to-point visual contact between range guards across unguarded sections of the perimeter.

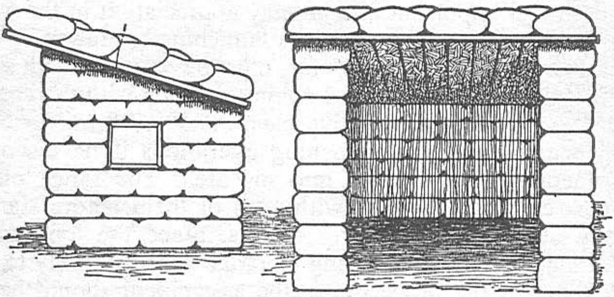
b. Aircraft spotters on prominent terrain features (or up in trees) which afford a commanding view of large land areas surrounding your site.

c. Range guards at intermediate points between the launching pit and the perimeter, for the purpose of relaying

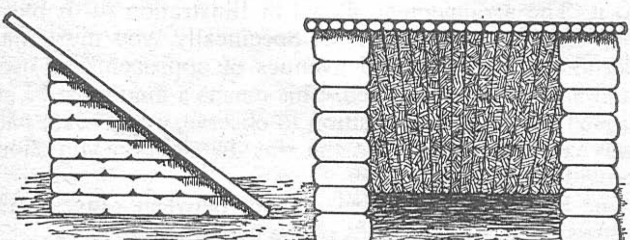
ILLUSTRATION No. 60

RANGE GUARD SHELTERS

TYPE A



TYPE B



signals if you lack telephone communication.

Spectator Shelters: If you are going to allow spectators at your launchings you must provide shelter for them. They should not be allowed in the control center. The type of emplacement shown in Illustration *61* is adequate and should accommodate twenty persons comfortably. A distance of 100 yards to 200 yards from the launching pit is recommended, as spectators will want to be close enough to observe the actual blast off. The bunker should be located close enough to the control center to enable all spectators to hear the countdown and all warning orders issued by control.

Latrines and General Field Sanitation: Since well-organized groups will be using a launching site for extended periods of time some thought must be given to what the Army calls field sanitation. You must provide toilet facilities, water, and rubbish disposal at your site. Two types of latrines are shown in Illustration *62*. The slit-trench type need be dug to a depth of only one or two feet. Regular latrines should be dug to a depth of five or six feet. Both types should have dirt shoveled into them daily and be sprinkled with powdered lime periodically. When half-filled up, they should be covered over completely, marked with a sign, and a new location chosen.

Water is best supplied in the field by a Lister bag. These are generally available at surplus supply stores, as are the five-gallon "jerry cans" usually used by the Army to transport water. A rubbish pit or "sanitary fill" should be dug to take care of all refuse which cannot be burned. Each time refuse is thrown into a pit it should be covered with a layer of dirt and sprinkled with lime.

You can get a good manual on field sanitation which will show you how to live in the field and "keep a good house" by writing to the Superintendent of Documents, Government Printing Office, Washington 25, D. C. Ask for the Army field manual on Field Sanitation.

Communications: Communications in a broad sense is simply a system for "keeping in touch," so that information, orders and reports can be relayed from one person to another. All persons involved in an operation, such as

Illustration No. 61

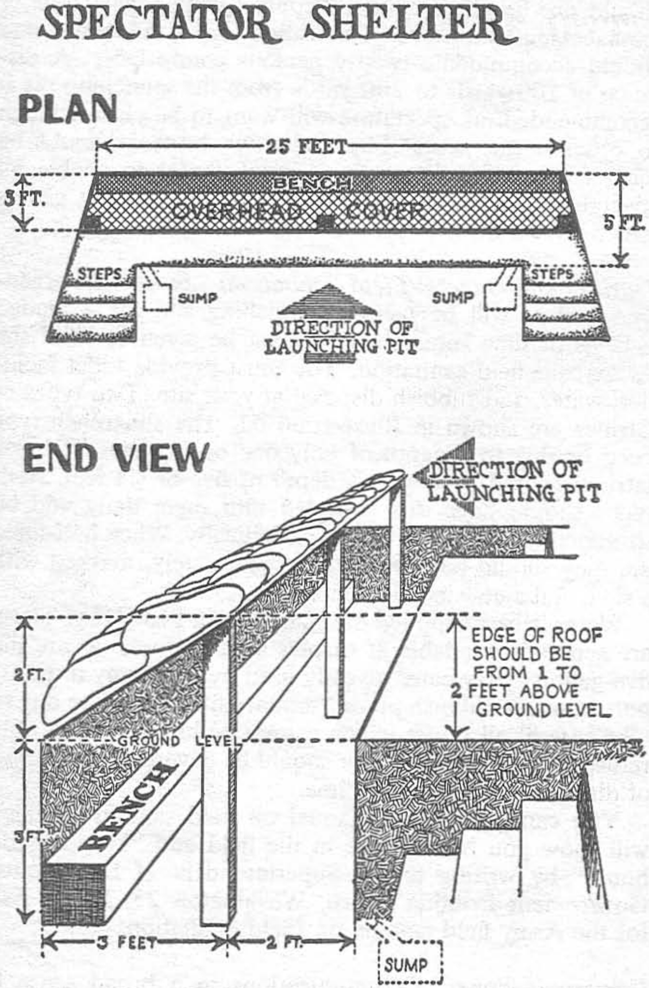
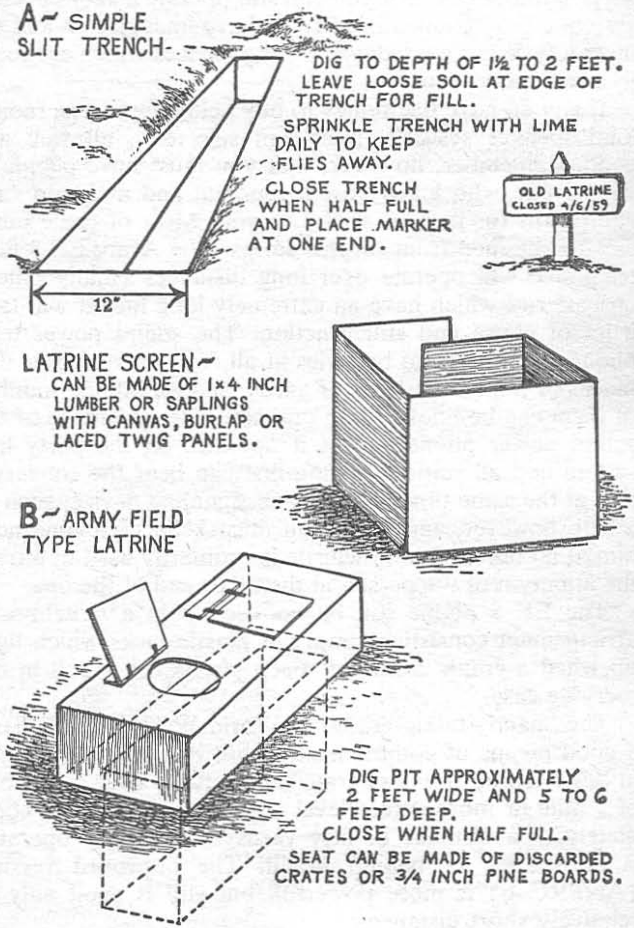


ILLUSTRATION NO. 62

TWO TYPES of FIELD LATRINE



rocket launching, must know at all times what is going on. Otherwise confusion results, time is lost and costly mistakes can be made. The word "communications" in this era of advanced technology is likely to suggest to the mind elaborate networks of wire, telephone, radios and various electronic gadgets. All of this is impressive, but it is not necessary. Without any of it you can still operate a very effective system of communications if you have imagination and the ingenuity to use everyday signaling devices which are readily available to you.

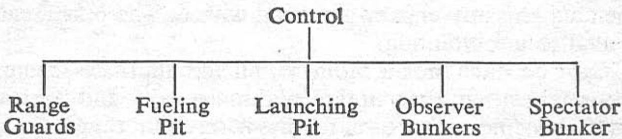
If you do have the money to buy field telephones, radios, loud speaker systems, inter-com sets, etc., all well and good. Remember, however, that you must have people in your group who know how to operate and maintain such equipment for it to be useful to you. Most of these items can be obtained from surplus stores. The Army EE 8 field telephone will operate over long distances (many miles) on batteries which have an extremely long life. It will take a lot of abuse and still function. The sound power telephone which uses no batteries at all, will operate over distances of many hundreds of yards, and an infinite number of them can be hooked into one net. One advantage of the sound power phone is that it operates on the party line system and all stations on the line can hear the conversation at the same time. There is no signaling device, such as a bell, however, and each man must keep his phone near him at all times. A loud whistle is ordinarily used to attract the attention of the person at the other end of the line.

The EE 8 phone can be hooked up in a switchboard arrangement consisting simply of plastic jacks which light up when a crank is turned. Each phone has a bell in the carrying case.

The "handy-talkie" radio of World War II (SCR–6) is a good means of communication but it has its limitations in hilly terrain. It will operate satisfactorily over a distance of a mile or more across level ground, and then fail completely at a distance of fifty yards because one operator is in a ditch or behind a hill. The improved version (ANPRC–6) is more powerful, but still is good only at relatively short distances.

The "walkie-talkies" which are carried on the back are effective at ranges up to several miles. They, too, have their difficulties in hilly country, however. The World War II version is called the SCR–300. The improved model (ANPRC–12) is lighter and more compact and generally more powerful.

Whatever the system of communication you are able to set up on your range, you should design it to include all of the following in the "communications net."



All of these stations must be able to communicate with control, and vice-versa. It is not necessary that any of the stations be able to communicate with each other, however, and it is probably preferable that they do not. You will have better control and discipline if the control center is the one source of information for everyone, and the sole authority for orders.

There are two other important things you should keep in mind about your communications net:

a. Keep it as simple as possible:
   The more gadgets you have, the more frequently it will break down.
b. You must always have an alternate means of communication with every station.

The second of these two rules is the more important. It is a basic rule in all military operations, but unfortunately is a difficult one to enforce. People are prone to rely on the wonderful gadgets of modern technology to the point that they are lost and helpless when those gadgets break down and refuse to function properly. When you are conducting an operation which demands close timing and coordination you cannot afford to put yourself at the mercy of mechanical gadgets. You must have a reliable alternate means of getting messages to people.

An Ethiopian lieutenant in Korea once amazed a group of American officers with a demonstration of perfect control over his platoon in a difficult tactical problem. He used none of the ordinary means of communication. None of his squad leaders carried radios. But each squad leader always had a man in visual contact with the lieutenant to relay hand signals. When any man's attention wandered the lieutenant had an infallible alternate means of communication available to him. He would pull a pebble from his cartridge belt, and at ranges of twenty to thirty yards he could hit any man on the head with it. The pebble never failed to get attention.

Just consider, for a moment, all the alternate means of communication that are available to you and you will probably find many uses for them on your range. Just as the cave man, the Indian and the Roman did, you can send messages to people over considerable distances without the use of telephones and radios. Anything that can be heard, seen or felt is a means of communication. Here are some obvious ones:

Bells	Reflecting mirrors
Sirens	Colored flares
Megaphones	Smoke flares
Drums	Flashlights
Gongs	Flags
Whistles	Hand signals
Horns	Runners

You can use many of these means of communication to notify range guards and observers of the exact status of operations at the launching pit as long as you have had the foresight to establish a prearranged set of signals. Range guards can also use devices such as colored flares to notify the control center that it is unsafe to fire.

Illustration *49*, which shows the basic layout of a launching site, also shows a suggested communications setup. There should be a red flag flying at the control center at all times that firing is in progress. This should be replaced by a green or yellow flag when firing is not in progress. Red flags should fly at all entrances to the launching site during the entire time the range is in use. If there is a prominent piece of ground on your site which can be seen from all directions, you can fly one flag from it and dispense with all others.

The Launching Rack: The most important single piece of equipment on your launching site is, of course, the launching rack. Most groups develop racks of their own design after a little experience, and it is obvious that no single design can be considered ideal for all types and sizes of rockets. You will have to adapt the ideas shown in Illustrations *63* and *64* to suit your own particular requirements. The important things to consider in the design and construction of a launching rack are:

a. That it is long enough to give initial stability to the rocket.

b. That it is rigid and firmly anchored.

c. That it can be elevated and depressed to vary the launching angle.

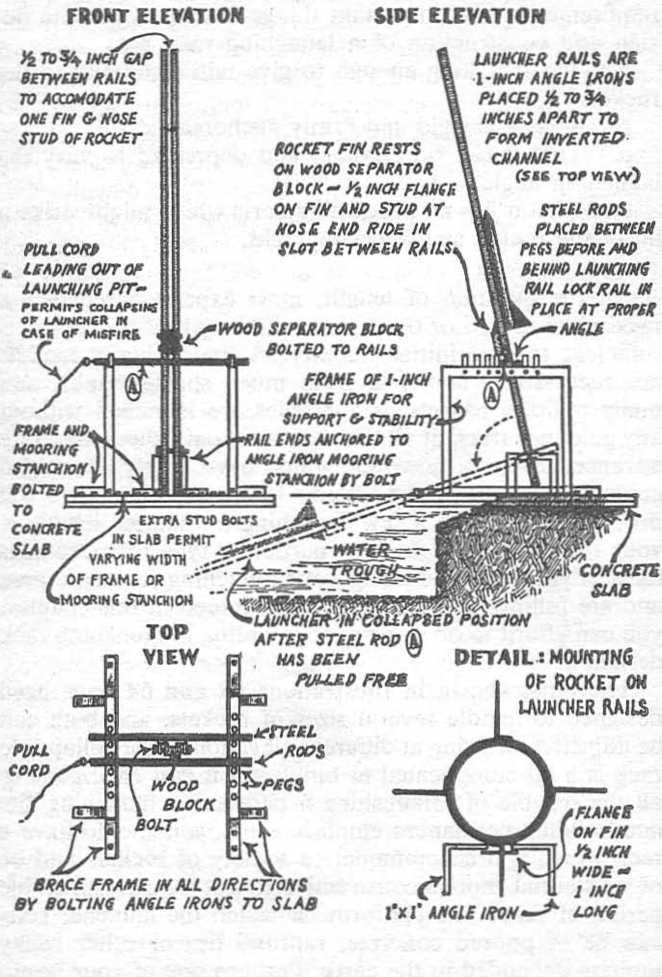
d. That it has no protruding parts which might strike a fin of the rocket and affect its flight.

On the question of length, most experts agree that a rack which is two or three times the length of the rocket is sufficient to give initial stability. Actually, many rockets are successfully launched from much shorter racks, and many military rockets and missiles are launched without any guidance track at all. For the most part, these are more advanced rockets, however, which have highly developed guidance and stabilizing systems built into them. You will probably find, after a few launchings, what the length of your rack should be for any particular type of rocket. As long as you are conducting your launching in a safe area and are following the precautions outlined in this chapter, you can afford to do some experimenting in launching rack design.

The types shown in Illustrations *63* and *64* have been designed to handle several sizes of rockets, and both can be adjusted for firing at different elevations. The collapsible rack is a bit complicated to build, but if you have gone to all the trouble of establishing a permanent launching site and building permanent emplacements, you should have a rack which will accommodate a variety of rockets and be of substantial enough construction to last for a considerable period of time. The platform on which the launcher rests can be of poured concrete, railroad ties or other heavy timbers imbedded in the earth. Perhaps one of your group has a father who is a contractor, or you may be able to get

ILLUSTRATION No. 63

Rocket Launcher... ADJUSTABLE AND COLLAPSIBLE ... FOR ANY SIZE ROCKET



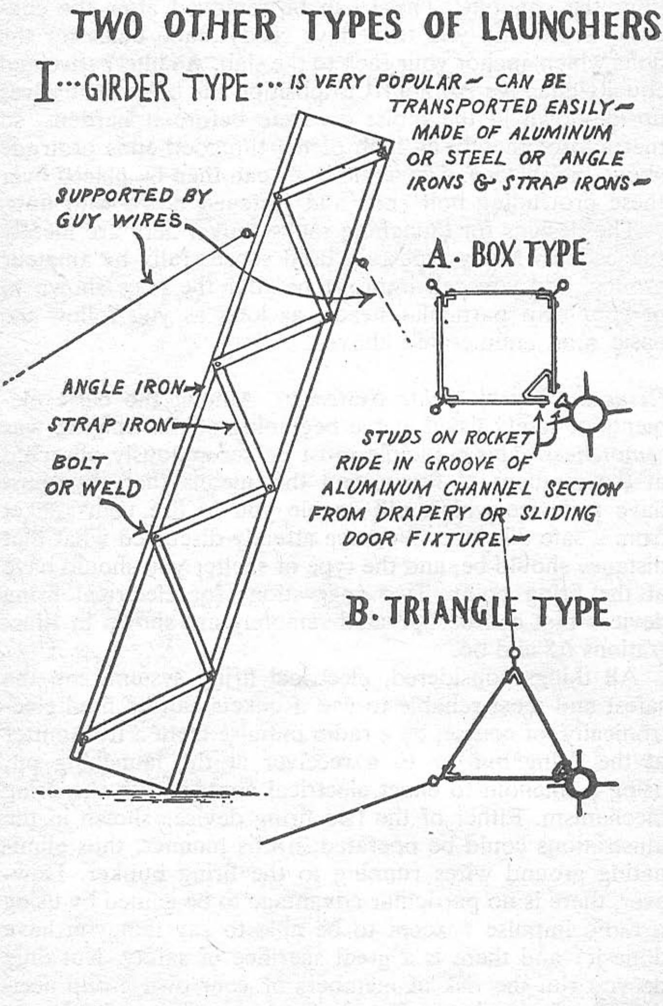
a local contractor to pour this slab for you as a contribution to your project and tap the holes for attaching the angle irons to the concrete. If you pour the slab yourself you can lay pieces of strap-iron in the pit first which have threaded holes tapped in them, the size of the bolts you intend to use. Place wooden pegs upright in these holes when you pour the concrete. These can be removed after the concrete is set, and you then have ready-made holes for the bolts which anchor your rack to the slab. An alternative and equally effective method is to position the bolts themselves upside-down in the moist concrete before it hardens, so that approximately an inch of the threaded ends protrude above the surface. The angle irons can then be placed over these protruding bolt ends and fastened down with nuts.

The designs for launching racks shown here are merely suggestions. Many types are used successfully by amateur groups, and you can improve or alter the ones shown to fit your own particular needs, as long as you follow the basic rules enumerated above.

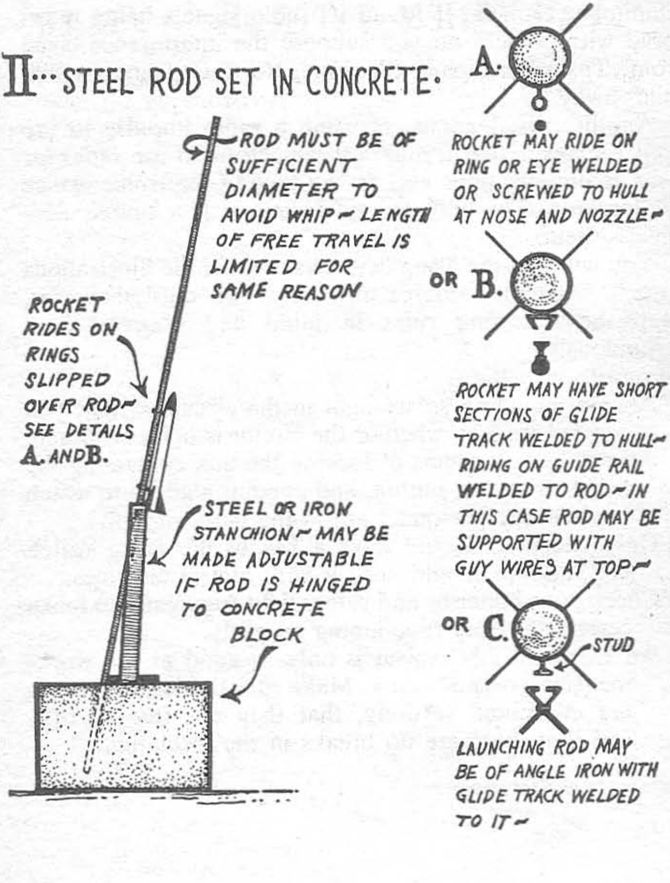
Remote Control Firing Systems: Among the basic elements of safety listed at the beginning of this chapter was *remoteness*. This principle must be scrupulously observed at the moment of firing, and this means that you must have a device which will enable you to fire your rocket from a safe distance. We have already discussed what that distance should be, and the type of shelter you should have at the firing point. Two suggestions for electrical firing devices that can be operated remotely are shown in Illustrations *65* and *66*.

All things considered, electrical firing systems are the safest and most reliable to use. Rockets can be fired electronically, of course, by a radio impulse from a transmitter at the firing bunker to a receiver at the launching pit, using a solenoid to effect electrical contact with the firing mechanism. Either of the two firing devices shown in the illustrations could be operated in this manner, thus eliminating ground wires running to the firing bunker. However, there is no particular advantage to be gained by using a radio impulse (except to be able to say that you have done it) and there is a great sacrifice of safety. Not only do you run the risk of members of your own group accidentally firing the rocket, but you never know when a

ILLUSTRATION NO. 64



II… STEEL ROD SET IN CONCRETE·



taxicab or police radio, or a ham operator, may start transmitting on the frequency you have selected for your own signals. (*See* Chapter 6)

This may seem hard to believe, but it is cited on good authority: when the Navy first started firing high-altitude Aerobee rockets for the IGY program at Fort Churchill in Manitoba, Canada, it found its radio signals being interfered with. Where do you suppose the interference came from? Taxicab radios in Charlotte, North Carolina—1,800 miles away.

Another disadvantage in using a radio impulse to fire your rockets is that it makes it dangerous to use radio for your communications net, or any type of electronic device for tracking. The best and safest means is a simple electrical system.

You will find the firing devices shown in the illustrations easy to assemble, reliable and safe. You must, however, keep the following rules in mind and observe them scrupulously:

Always include a safety light in the circuit so that you can tell visually whether the circuit is open or closed.

Always have a means of locking the box containing the firing switch, or button, and appoint a guard to watch it when any personnel are in the launching pit.

Only one man should have a key to the firing switch box, and he should keep it with him at all times.

Check your batteries and safety light frequently to make certain they are functioning properly.

An electrical mechanism is only as good as the workmanship you put into it. Make sure that all wire leads are connected securely, that they are free of rust, and that there are no breaks in the insulation.

ILLUSTRATION NO. 65

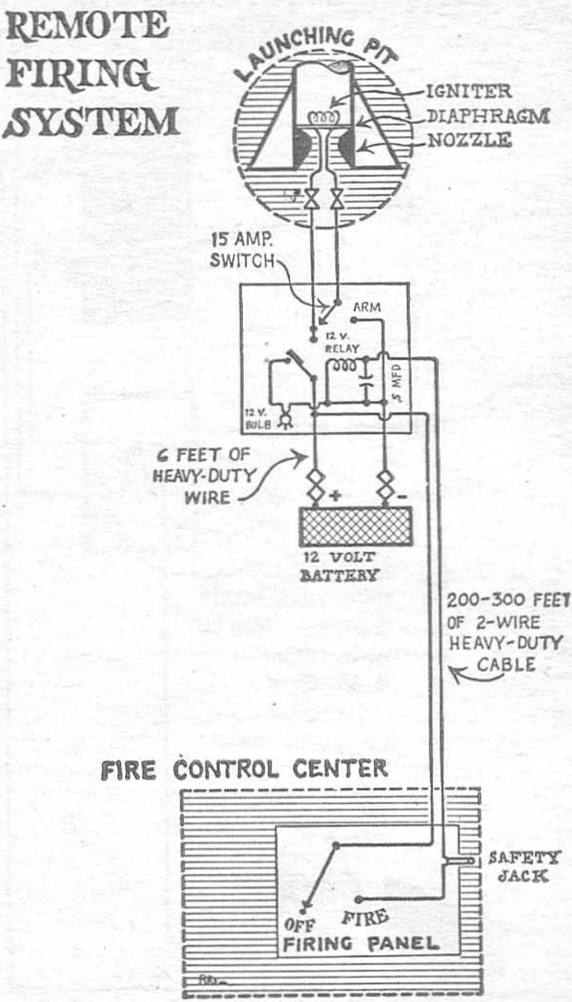
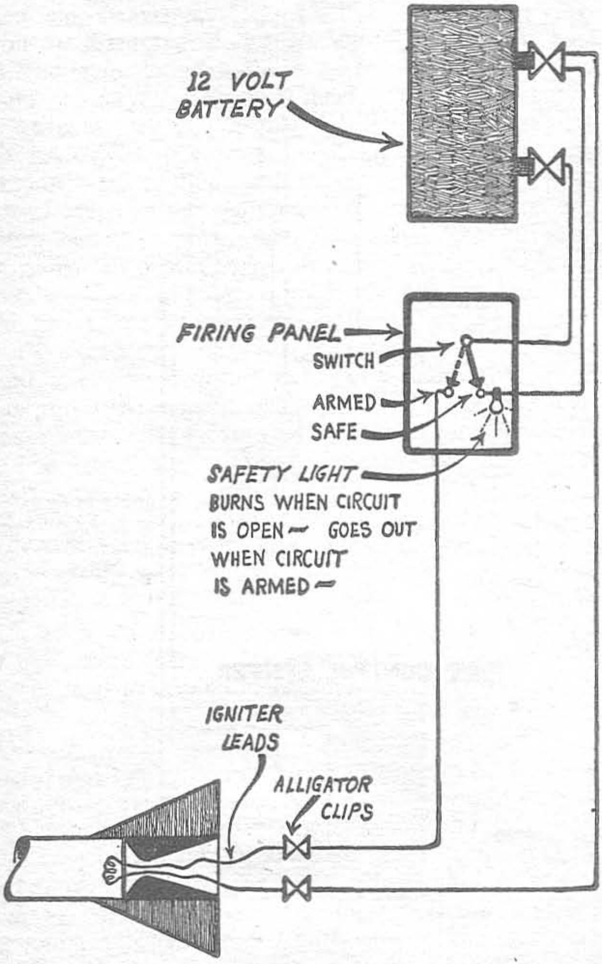


ILLUSTRATION No. 66

A SIMPLE ELECTRICAL CIRCUIT FOR REMOTE FIRING



Chapter 9

SAFE RANGE PROCEDURES AT THE LAUNCHING SITE

Assuming that you have a properly laid-out launching site constructed according to the principles outlined in the preceding chapter (though not necessarily as elaborate) and you have obtained the proper clearances and permissions of responsible officials, you now must learn how to use it effectively so as to take maximum advantage of the safeguards that have been built into it. You can blow yourself up on a so-called "safe" range just as easily as you can in your own basement, simply through carelessness and failing to establish simple and orderly routines that are easy to follow. Such routines are essential to the safety of all participants in a group project, and every individual assignment must be carried out to the letter, or failure—even disaster—may result. Any high school football player knows the importance of carrying out his individual assignment on every play, no matter how pointless it may seem in a hundred run-throughs. The time always comes when that particular assignment is the key to success or failure of the entire play—perhaps the game. Similarly, a driver, in order to qualify for a license and to avoid having accidents on the highway, must learn certain routines and get in the habit of taking certain actions by instinct, even though they may be wasted effort 99% of the time. As an example, the well-schooled driver automatically gives a signal before making a left- or right-hand turn. Probably only once in a hundred times does this signal serve a really useful purpose. But it is essential that it be given every time, as a matter of habit. For once in ten thousand times it may save the driver's life.

You must establish similar routines for the over-all operation of your launching site and for every individual who has an important assignment. And you must impress upon every member of your group the importance of following these procedures *every time* you conduct a test-firing or launching. What these procedures are, and the reasons they are important is the subject matter of this chapter. A complete operating procedure for conducting firings is outlined here as a model upon which you can base your own range regulations and step-by-step routine for launchings. It is not expected that you will duplicate this model procedure in every detail, for it has been designed for a hypothetical launching site and a hypothetical group. You must modify it to fit your own particular launching facility and the capabilities of your own group. What is important is that you understand the reason for each of the actions and safety checks taken, and follow the same principles in developing your own.

I POSITIONS AND RESPONSIBILITIES

Following are the positions and responsibilities to be assigned to individuals in your group. These are the essential positions necessary to assure the smooth operation of an "ideal" firing range. Your group may not be large enough to staff all of these positions. Your launching site may differ substantially from the one described in Chapter 8. Therefore, the organization of your range operation may be considerably different. Again, the important consideration is not whether you have supplied a man to fill each of the positions listed, but whether you have arranged to take care of each of the functions shown.

Range Officer—He is in complete charge of the launching site. No action is taken without his direction. He gives all orders, makes all decisions. His place should be at the control center.

Safety Officer—He is responsible for checking all critical points of the operation in advance to make certain that safety regulations are being followed. Responsible for instruction of all personnel in safety precautions. No firing takes place until he has given his clearance to the Range Officer.

Fueling Supervisor—He is responsible for establishing the procedures to be followed in the fueling pit and for supervising the actual fueling operation. Certifies the fueling area as clear before firing can proceed.

Spectator Control Officer—He is responsible for clearing the launching area of all personnel not assigned to specific posts and seeing that they are behind proper shelter before he gives his clearance to the Range Officer. If your group is short of personnel, this assignment may be handled by the Safety Officer.

As previously stated, the positions shown above are considered to be essential. If your group is small you must combine responsibilities wherever possible to ensure that every assignment is properly covered, with due regard for the fact that you cannot give one person too much to do. If you have a very large group, you may want to establish additional positions, such as a communications supervisor, photographic supervisor, etc., in order to give all members of your group something to do on each firing. All of these positions, of course, are either *supervisory* or *control* jobs. In addition you will have the people who perform the actual launching operation, and those who have a specific duty to perform not supervisory in nature. These are:

Key Man—He carries the key or the safety jack for the firing mechanism, and consequently is the only man on the range who can fire the rocket.

Fuelers—They perform the actual fueling operation.

Pit Men—They mount the rocket on the launcher in the launching pit under the supervision of the Safety Officer.

Range Guards—They are responsible for keeping by-passers out of the area, scanning the sky for aircraft, and certifying to the Range Officer that it is safe to fire.

Observers and Trackers—They are responsible for tracking the path of the rocket, taking observations on the azimuth and angle of elevation at the peak of trajectory and reporting them to the control center for plotting.

Recorders and Computers—They are responsible for recording all data received from observers and/or mechanical tracking devices for each firing, and for computing the path and performance of the rocket. They should be located at the fire control center.

First-Aid Man—A very important man who should have qualified for his job by completing a Red Cross first-aid course, or similar training.

The number of persons you choose to assign to each of these jobs in the second category will vary, of course, with the size of your group. It is important, however, that there be only one key man and only two fuelers and two pit men. Two men are sufficient to handle the fueling and the positioning of the rocket on the launcher. These are the most delicate operations, and any more than two people in addition to the supervisor would tend to create confusion and increase the likelihood of a mishap. Furthermore, and most importantly, if you are going to have an explosion it is far better to injure only two persons, rather than three or four.

Naturally, you should rotate assignments among the members of your group as frequently as possible. This is important, not only to relieve the boredom of always having the same job to do, but also from the standpoint of training the maximum number of people in each job. There are certain assignments, of course, requiring special skills which only a few members of your group will have. There also are people who like to do only one thing—such as photography or telemetering. But to the greatest extent possible, try to change the assignment of each individual on each firing and the group as a whole will become more proficient as a result.

II RANGE PROCEDURE

In setting up the procedures to be followed on your range, or launching site, you must be systematic and you must be logical. But above all be as simple as possible. Complicated procedures and unnecessary regulations only serve to increase the likelihood of a mishap. Simplicity is a basic rule of tactical planners in the Army, and very frequently maneuvers that are tactically sound in themselves are rejected because military men know that large groups of people in a coordinated effort become very easily excited and confused; and if the plan they are following is not the soul of simplicity itself, it will fail, no matter how well-conceived a plan it may be. If, after you have established a working procedure and tested it, you find that certain features of it are not really necessary, and serve no useful purpose, eliminate them. Nothing is more destructive of morale and efficiency among the personnel of an organization than regulations which appear to have no purpose. Eventually people will eliminate them or violate them on their own initiative. When this happens, and nothing disastrous occurs, they begin to have less respect for all regulations and procedures, and soon you will find that they are violating vitally important ones, because they think that they have discovered none of them are really necessary. At this point the whole fabric of your system of procedure will be threatened with collapse and you will find the morale of your organization very poor. If you would be a successful organizer and "run a tight ship," as they say in the Navy, then you must learn to apply two very simple, but inviolable rules:

Never establish a rule or regulation that is not entirely necessary.

Never establish a rule or regulation *which you cannot enforce,* no matter how necessary you feel it is.

The firing procedure which follows is intended to be comprehensive and all-inclusive. For that reason you may find it unwieldy, too elaborate, and much too ambitious for your group. Again, you must use your own judgment in determining which procedures are best suited to your own particular group and launching facility, using this procedure as a guide to ensure that you are not overlooking anything important. In a sense, you are a pioneer, and you must work out for yourself the procedure that is best and safest for *you* to follow. Amateur rocket groups have not been operating long enough for hard and fast procedural patterns to be established, and scarcely anyone is an authority on the subject.

But there is one consideration which you must always bear uppermost in your mind, and from which no deviation can be allowed. *You must base your firing procedure on the assumption that the rocket is going to explode.* To proceed upon any other assumption is foolhardy and an invitation to disaster. No person on earth can possibly predict what a specific rocket will do when it is ignited. It is therefore safer to pretend that you are setting off a bomb or a charge of blasting dynamite, and proceed accordingly.

Range procedure is divided into four separate operations. They are: *prefiring procedure, firing procedure, in-flight procedure* and *postfiring procedure.* Each of these periods has a definite end and a definite beginning. The *prefiring* period ends when all preparations for the launching have been made and all personnel are under cover ready for the blast off. The *in-flight* period ends with impact of the rocket on the ground. The *postfiring* period ends when all data have been reported and evaluated and a critique of the operation has been concluded. The step-by-step procedure for each of these four phases of a launching is provided for you in the following outline. The outline for the postfiring procedure includes the alternate patterns of action to be followed for successful and unsuccessful firings.

PREFIRING PROCEDURE

1. *Briefing:* Every group operation must start with a period of briefing, or orientation, in which the conduct of the operation is outlined to all participants, each individual is given his instructions, special actions involving a departure from normal procedure are explained, and questions of participants are answered. The Range Officer conducts this briefing and makes individual job assignments at this time. He may also call upon other members of the group, such as the Safety Officer, to explain certain phases of the operation, or to give emphasis to a particular phase. Every member of the group must attend this briefing, and every person who has a question about the procedure to be followed must be encouraged to ask it at the briefing. Once the operation has started, questions cause delays and it is frequently not possible to ask or answer them.

The briefing should be held on a prominent piece of ground from which the salient features of the launching site are visible to all members of the group. If such a piece of ground is not available, then the logical place to hold the briefing is at the fire control center. The Range Officer should have a blackboard available on which he can diagram the launching site and give graphic illustrations of points he wishes to cover. If a blackboard is not available, he should be provided with a suitable pointer and a sand table, or a sandy area, on which he can illustrate important points. The length of the briefing is entirely dependent upon the complexity of your launching procedure and other factors which will vary with each group. It will require at least fifteen minutes, however, and perhaps as long as an hour.

2. *Firing Stations—Scouts Out:* Immediately after the briefing is concluded all personnel move to their assigned stations. (Since range guards must normally traverse a considerable distance to their posts, and since fueling the rocket may sometimes be a time-consuming process, the fueling operation may be started as soon as all personnel in the immediate vicinity of the launching area have

reached their positions. Range guards at the most distant locations may not be able to report in to Control until second reports are called for in step 9.) The yellow range flag should be run up at this time.

3. *First Reports:* As each person reaches his assigned station he must report in to the fire control center that he is in position and ready to perform his assignment. The method of reporting is dependent upon the type of communications you have, naturally. If you are not using a telephone or radio net, the report may be in the form of a signal, flare, hollering through a megaphone, or simply running up a small flag on a pole that can be seen from the fire control center. The Range Officer and his assistants must systematically check off each station on a chart as its report is received and initiate follow-up action in the case of stations not reporting in. Again, if you are not using telephones or radio, runners must be assigned to the Range Officer for the purpose of checking on delinquent stations.

4. *All Clear in the Launching Area:* When all stations except the more distant range guards have reported in the Range Officer announces, "All clear in the launching area," and gives the order for the fueling operation to start. "All Clear" in this instance means that all persons in the launching area are at their assigned stations, spectators are clear of the area and in a trench or behind barricades, only two persons are in the fueling pit with the Fueling Supervisor, and two pit men are in the launching pit. The only person who may move about at this time is the Safety Officer who must check the fueling pit, the firing mechanism, the position of the key man, the first-aid man, etc.

5. *Fueling:* Upon receiving the order to fuel the rocket the fuelers and Fueling Supervisor first run up a red flag in the fueling pit. This serves to warn all persons in the launching area that fueling is in progress. When fueling has been completed, except for insertion of the ignition device, the Range Officer at the fire control center (Control) is notified that the rocket is ready to be moved to the launching pit. This signal may consist of lowering and raising the red flag two or three times if other means of communica-

tion do not exist. When the signal is received from the fueling pit the Range Officer gives the order to clear the fueling pit of all unused fuel, and the fuelers and Fueling Supervisor retire to the spectator trench or other positions that have been assigned to them. The Safety Officer inspects the fueling pit to certify to the Range Officer that it is clear of unused fuel. The Range Officer then gives the order for the rocket to be moved to the launching pit.

6. *Positioning:* The rocket is moved to the launching pit by the pit men and the Safety Officer. The Safety Officer has the ignition device in his possession at all times. The red flag is lowered at the fueling pit and one is raised in its place at the launching pit. At the same time, the yellow flag on the main flag pole for the range is changed to a red one. The rocket is positioned on the launcher by the pit men and a length of wire long enough to reach outside of the barricade is attached either to the rocket or the launcher, depending upon the type of launcher you are using. (*See* Illustrations *54* and *63,* Chapter 8.) This wire is to be used to topple the rocket to the ground or into a water trough in the event of a misfire. The ignition device is then inserted. The Safety Officer makes a final check of the launcher and rocket, orders the pit men out of the pit, and sees that the wire leads to the ignition device are strung to the relay box which should be located *outside* of the pit or barricade. He checks to make certain the circuit is shunted at the relay box before he permits the wire leads to be connected to it. Leaving the relay box shunted he orders the pit men to the spectator trench, or to other positions assigned to them, and reports, "Ready in the launching pit!" to the Range Officer.

7. *Take Cover:* Upon receiving the "ready" report from the Safety Officer, the Range Officer announces, "Ready in the launching pit!" and "Take cover!" With this announcement all persons are required to get behind the protective barricades provided for them and stay there until the "All clear" signal is given by the Range Officer. This is the end of the prefiring procedure, and assuming that all personnel are accounted for and in protected positions, the firing procedure is about to start.

8. *Safety Check—Second Reports:* The Range Officer calls for a final safety check and second reports from all positions. It is not assumed that anyone is in a safe position simply because he cannot be seen. Positive reports are required from all stations by visual signal or telephone and each is checked off on the fire control chart by the Range Officer's assistants. By the time second reports are called for the more distant range guards should be in position and are included in the check-off procedure. Range guards carefully scan their areas of responsibility for persons or aircraft that may be within the limits of the range and report whether their sectors are clear for firing. Observers and trackers report that they are in position with instruments trained on the launching pit and that they are ready to track the path of the rocket. The Spectator Control Officer, or Safety Officer, certifies that all spectators are behind cover in the area designated for them.

9. *Ready on the Right—Ready on the Left:* When reports have been received from all stations on the right of the fire control center the Range Officer announces, "Ready on the right!" When all reports have been received from stations to the left of the fire control center the Range Officer announces, "Ready on the left!" When reports have been received from all points in the immediate vicinity of the fire control center and launching area, he announces, "Ready on the firing line!"

10. *Prepare to Fire:* The Range Officer then instructs the key man to check the firing panel. The key man checks to make certain that the firing panel switch is locked (or the safety jack is out) and reports, "Firing panel clear!" (This means that the circuit is open, the rocket cannot be accidentally fired, and it is safe to remove the shunt to close the circuit at the relay box.) The Range Officer then gives the command, "Prepare to fire!"

11. *Safety Officer Clears:* On the command, "Prepare to fire!" the Safety Officer proceeds to the relay box located outside of the launching pit barricade and closes the shunting switch. This closes the firing circuit so that the rocket

may be fired by the switch at the fire control center. He then returns to the control center or the spectator trench, whichever is his assigned station, and informs the Range Officer that it is clear to fire. The Range Officer announces, "Clear to fire!" and, "You may fire at the count of zero!"

12. *Countdown:* The Range Officer then announces "Fifteen seconds to blast-off!" The key man may then insert the key, or safety jack, after making sure that the firing switch is still open. At ten seconds the Range Officer begins to count down the seconds remaining until firing time, using the public address system or megaphone. "Ten seconds. . . .nine seconds. . . . . .three seconds. . .two seconds. . .one second. . .Fire!" At the command "Fire!" the key man closes the firing switch.

(NOTE: If at any time during the firing procedure or countdown a range guard, or any other member of the group, becomes aware of the presence of an aircraft or persons approaching the range area he should immediately halt the procedure by means of a prearranged signal, such as a flare or a blank cartridge being fired. Upon receipt of such a signal the Range Officer will immediately command "Hold! Cease firing!" until the reason for the interruption can be determined. If a considerable delay is to be involved, he must order the key or safety jack removed and the firing circuit shunted again at the relay box. When the range has again been cleared for firing, the firing procedure must be repeated, commencing with step number 8 (Safety Check —Second Reports), since many persons may have moved from their assigned positions during the delay.)

IN-FLIGHT PROCEDURE

13. *Maintain Cover—Open Firing Switch:* From the time of lift-off to the time of impact of the rocket onto the ground, all persons on the range must maintain their positions behind protective barricades, and, where provided, under overhead cover. (If you have ever seen an unbalanced rocket zig-zagging wildly through the air a few feet above the ground you can appreciate the reason for this. And such a flight is possible, even with well-designed rockets, due to slight variations in the density of the propellant and the resultant erratic burning.) Observers and trackers,

of course, must remain partially in the open to do their jobs (*see* Illustration No. *58*, Chapter 8) but they are generally more than a thousand feet away from the launching pit. As soon as the rocket has left the launcher, the key man opens the firing switch to prevent unnecessary drain on the battery.

14. *Observation and Tracking:* Observers and trackers, who have had their eyes and instruments trained on the launching pit since the beginning of the countdown, now follow the flight of the rocket. Methods of doing this are discussed in Chapter 10. Generally speaking, the trackers are responsible for obtaining elevation and azimuth readings at the peak of the trajectory; and the observers are responsible for timing the flight, noting the general behavior of the rocket, recording time of burn-out, if possible, and obtaining azimuth readings to the point of impact.

15. *Impact Observation:* Impact of the rocket on the ground should be observed and noted by all who are in a position to see it, since the point of impact is frequently a very difficult thing to pinpoint. It is primarily the responsibility of the Observers at the tracking stations to attempt to fix this point as accurately as possible and report the azimuths from their stations to the fire control center when reports are called for. Methods of increasing the accuracy of impact observations are discussed in Chapter 10.

Postfiring Procedure

A. For a Successful Firing

16 A. *"All Clear."* Once the rocket has impacted on the ground the Range Officer announces, "All clear! Cease Firing!" Persons in the spectator trench may now leave the trench if they desire. Personnel at Observer and Tracker stations remain in position, however, to give required reports and to recheck data observed during the flight. Range guards should remain at their posts unless called in by the Range Officer, or unless firing has been completed for the day.

17 A. *Reset Safety Devices:* The Range Officer now orders, "Reset safety devices!" The key man (who has

already opened the firing switch immediately after lift-off) removes the key, or the safety jack, and reports this fact to the Range Officer. The Safety Officer proceeds to the launching pit and moves the shunting switch to the safe position, thus opening the circuit at the relay box. He reports to the Range Officer, "Relay box safe!" He then removes the wire leads and the spent igniter left behind by the rocket.

18 A. *Reporting of Data:* After the firing mechanism has been reset the Range Officer calls for reports from the Observation-Tracker stations. These reports are sent in telephonically or by runner, depending upon your communications, and are received and recorded by the Recorders and Computers at the fire control center. (Chapter 10 covers the details of this process.) From these reports the altitude, flight time and velocity of the rocket are calculated; and impact observations are reconciled to determine the probable point of impact.

19 A. *Recovery of Rocket:* After the probable path of the rocket and its impact point have been computed, the Range Officer dispatches a recovery team to the impact area while the recording and analysis of other data on the rocket's performance continues. It is best to attempt recovery of each rocket immediately after firing for many reasons discussed in Chapter 10. If and when the rocket is brought back to the fire control center, valuable additional data concerning its performance can be determined, which will be of interest during the critique which follows.

B. For an Unsuccessful Firing

An unsuccessful firing (firing in which there is no actual lift-off, or flight of the rocket) may result from any one of several causes. There may be a failure in the firing mechanism, a failure in the igniter, failure of the propellant to ignite after the igniter has burned out, failure of the rocket to develop sufficient chamber pressure, failure of the diaphragm to burst, etc. Whatever the reason may be, and whatever you may assume the cause to be, it is safest and wisest to follow the same procedure in all cases. Do not jump to conclusions as to the cause and expose yourself needlessly to danger. The procedure which follows is simple to put into effect, and provides maximum safety for you and your group, considering the fact that you have a potentially explosive article to deal with. It requires some prior preparation which should be a normal part of your firing procedure no matter how many successes you may have to your credit. (*See* step number 6, page 266.)

16 B. *Handling a Misfire or "Dud" Rocket:* If your rocket should misfire, do these things in the order indicated and at the times indicated. This procedure assumes that you have taken the precaution (step number 6) of attaching a length of piano wire to the rocket or launcher for use in toppling the rocket to the ground, or into a water trough. It also assumes that the type of launcher you are using, and the method of attachment of the rocket to it, will permit toppling to the ground. You must make one assumption yourself. You must assume that the propellant *is* burning slowly inside your rocket and that it is likely to explode at any moment.

All times are expressed in minutes. "0" represents the intended time of blast-off.

– 0 – Attempt to fire the rocket. If it fails to fire, open the firing switch after a few moments, wait about a minute.

0 + 1 Close the firing switch again. If rocket still fails to fire the firing circuit may be checked by simply bridging the lead wires from the panel with a light bulb assembly. This can be done at the fire control center. (This test is unnecessary if your firing circuit includes a light on the panel which lights up when the circuit is closed and current is flowing through it.) If the firing circuit functions and the rocket has still failed to fire, the Range Officer instructs all personnel to remain under cover and suspends all operations for fifteen minutes. The key or safety jack is removed from the firing panel at this time.

0 + 15 At the end of the fifteen-minute waiting period, the Safety Officer, or other person designated by the Range Officer, takes a length of wire or rope and *crawls* from the fire control center to the point outside of the launching pit barricade where he placed the end of the piano wire which is attached to the rocket, or launcher. He should be wearing a protective helmet, and it is important that he remain flat on the ground at all times. He first moves the shunting switch on the relay box to the safe position, then he attaches the end of the rope to the end of the piano wire. He then crawls back to the fire control center. (NOTE: If the piano wire is attached to the launcher itself, it obviously is not necessary for anyone to crawl out to the launching pit, because the wire or rope can be strung all the way to the Control Center initially (*see* Step No. 6). Crawling out is eliminated if your launcher is of the type shown in Illustration No. *63,* Chapter 8).

0 + 20 When the Safety Officer has returned to the fire control center the rope is pulled sharply in order to topple the rocket onto the ground. (This is done to precipitate an explosion or ignition of the rocket, if possible, while it is within the enclosure of the launching pit.) If no detonation takes place, the Range Officer orders all personnel to remain in position for another five minutes. If your launching pit is equipped with a water trough, of course, this procedure is much safer.

0 + 25 At the end of the five-minute waiting period the Range Officer designates two persons to disarm the rocket. The persons designated should be equipped with heavy padded clothing (preferably fire-proofed in some fashion), asbestos gloves, face shields and helmets. If the launching pit has been constructed according to the plan shown in Illustration *54* in Chapter 8, the entire rocket and launcher will have been plunged into the water. Care must be exercised by the two men to avoid exposing any more of their bodies than is absolutely necessary at any time. They should lie flat on the ground throughout the disarming operation and should make certain that the nozzle end of the rocket is completely immersed in water while the igniter is removed.

17 B. *"All Clear":* Once the igniter has been removed from the rocket the Range Officer announces, "All Clear!"

Following a misfire, however, nobody is permitted to enter the launching pit until the rocket has been removed from it.

18 B. *Reset Safety Devices:* The safety devices have already been reset during the process of handling the misfire. However, in order to ensure that there has been no slip-up, the Range Officer now orders a complete recheck of the firing mechanism.

19 B. *Reporting of Data:* Obviously no reports are required from Observer and Tracker stations following a misfire, but useful data may be obtained from examination of the igniter, the rocket itself after it has been rendered safe, and from persons who may have been in a position to observe the behavior of the rocket on the launcher. Any scrap of information which may be helpful in determining the reason for the malfunction should be recorded for later analysis.

20. *Critique and Evaluation:* Following each firing, whether successful or unsuccessful, there must be a critique of the operation and an evaluation of the performance of the rocket and the performance of the group as a team. Range guards may or may not be brought in for these critiques, depending upon their distance from the launching area and whether or not they are to be rotated. They should attend the final critique, however, at the end of the day's firing. The Range Officer conducts the critique, presents the data on the performance of the rocket, and calls for comments from other members of the group in supervisory assignments. At the conclusion of the critique new job assignments for the next firing are decided upon, and the briefing for the next firing begins.

Using the foregoing procedure as a basis you can develop your own system for controlling the activities of your group at the launching site. You may find that certain steps can be eliminated or that others may have to be added because of the type of equipment you are using, the composition of your group, or the physical layout of your launching site. Whatever procedure you eventually develop, go over it very carefully, discuss it thoroughly with all members of your group, and actually rehearse it in a dry run several times. You do not have to be at the launching site to conduct these rehearsals. They can be held in your living room, if necessary, and you will be surprised to find how many defects in your procedure will be exposed when the members of your group actually go through the motions of conducting a firing.

When you are satisfied that you have a workable, fool-proof procedure that gives maximum assurance of safety, you should prepare a master check-list which outlines the entire procedure and includes every important step, order and safety check that must be made. A copy of this check-list should be furnished to the Range Officer prior to *each* firing so that he and his assistants can physically check off each step in the procedure as it occurs. Nothing should be left to memory or supposition. This check-list should become a part of the permanent record of each firing, and you can include space in it for written comments of the Range Officer so that he can make note of unusual occurrences or departures from the normal procedure.

Correct range procedure is important and vital to your safety. Do not neglect it or minimize it. No matter how good your equipment may be, no matter how expert the members of your group, you can still have an accident. For the greatest single cause of accidents is human error; and procedures are established for just one reason—to reduce human error to a minimum.

Chapter 10

TRACKING

HOW TO TRACK YOUR ROCKET
HOW TO EVALUATE ITS PERFORMANCE

Tracking your rocket, once it has left the launcher, is not easy. A frequent comment of amateurs, when asked how their rocket performed, is, "It went out of sight!" or, "We don't know where it went!" When this is the case, most of what you have been working toward is lost. For the behavior of your rocket throughout its entire trajectory, and the recovery of it, if possible, constitute your entire source of information. Virtually nothing can be told from the launching itself, except the fact that sufficient lift did, or did not, develop. For this reason there is really no point in observing the blast-off, except to experience the thrill that all rocketeers feel at the sight. If you are to gain the most from your experimentation with rockets, you must develop a reasonably efficient system for observing as much of the flight path as possible, and recovering the spent hull. It is the purpose of this chapter to help you develop such a system.

There are many techniques and methods used by amateur groups in tracking rockets, and many others that have been suggested. Some methods are workable, others are not. A great many of them appear to be sound in concept, but prove to be ineffective when put to a practical test. But no matter what methods you use, you must train yourself to use them effectively. No method will work automatically and without effort on your part.

For instance: it is possible for a man to follow the flight of a 155mm. artillery shell with the naked eye from the time that it leaves the muzzle until it impacts on the target —*but he must train himself to do it.* Such a shell travels at a speed close to 2000 mph and is even smaller than many amateur rockets, so you can see that it is entirely possible for you to track your own rockets visually.

Also, it is possible for a man to estimate ranges (longitudinal distances on the ground) with the naked eye and with reasonable accuracy, after he has practiced the technique long enough. Similarly, he can learn to estimate lateral distances and elevations, once the range is known, with even better accuracy.

All of this means that you can not only follow the flight of your rocket without the aid of expensive and delicate instruments, but you can also make a reasonable evaluation of its performance without all of the intricate equipment used by the military services and research agencies. The material which follows is designed to help you learn how to do this using only elementary equipment which should be available to any group. This equipment includes your eyes and fingers, binoculars, a simplified theodolite, home-made alidade, protractor, ruler, compass, drawing boards, graph paper, and telescopes (if you can use them effectively). Some of this equipment is optional.

First we will discuss a basic system for tracking which should form the basis for all of your tracking operations. Once the basic system is understood thoroughly, you can simplify it or elaborate upon it as you see fit, depending upon the capabilities of your group, the type of equipment you have at your disposal, and the physical characteristics of your particular launching site. Following that, we will discuss a variety of methods and alternate types of equipment that can be employed to improve your chances of reasonably accurate tracking.

The term "reasonably accurate" is used because there is no such thing as *absolute accuracy,* even in the professional field. If such were the case, many military and scientific development projects in the missile field would have ceased long ago, because the engineers and scientists concerned would have reached one of the objectives they are striving toward. A guidance systems engineer in a leading industrial firm once told me that in order to be certain of hitting a specific target the size of a city block at intercontinental ranges, they must have an accuracy in their calculations equivalent to one-hundredth part of the thickness of a piece of paper. Since the globe has not been mapped to anywhere near this degree of accuracy as yet, and probably never will be, you can appreciate the magnitude of the problems involved. Perhaps this will give you some idea of what the term *absolute accuracy* means, and what the chances are of achieving it.

Another point to consider on the question of accuracy is that the degree of accuracy you need must be related to the objective you have in mind. If you are trying to hit an intercontinental bomber which represents an almost imperceptible speck in the sky at an altitude of 60,000 feet you need one type of accuracy. If you are trying to put a satellite in orbit around the moon, you need another type. But if you are merely trying to measure the altitude reached by a rocket and determine its time of flight and point of impact, you can do with a much more rudimentary, and less demanding, type of accuracy. By and large, the requirements of amateur rocket groups for performance data on their rockets can be satisfied much more simply and easily than professional rocket experts realize; and although the more complex and comprehensive calculations of the professional will produce a more accurate result, it is questionable whether the degree of accuracy involved is of any significance. For instance, it is not important to the average amateur group to know whether the rocket they have just fired reached an altitude of 5,200 feet or 5,208 feet. What they are interested in knowing is whether it went up only 2,000 feet or as much as 10,000 feet!

For this reason, and for another which will be discussed shortly, the charts, diagrams and methods of computation contained in this chapter have been simplified in the interests of making them readily understandable, and in order to permit the rapid calculation of performance data. They are not intended to give highly accurate results which would conform to professional standards, and it would be misleading to present them in that light.

A third, and most important, point to be considered in determining the degree of accuracy which is valid and appropriate in your work is that the degree of accuracy you use in your computations must be related to the accuracy of the basic data with which you are working. If your basic data is only approximate, your answer, or end result, can only be approximate; and it is a waste of time to try and improve its accuracy by more refined computation. If you continue the study of mathematics in college (and you most certainly should), you should include some statistical analysis in your program. The study of statistical methods and their application to the evaluation of data will give you an understanding of the theory of significant numbers and of absolute and approximate quantities. You will learn and appreciate, for instance, that the result of any mathematical computation can only be as accurate as the basic data on which the computation is based. It cannot be *more* accurate (except by accident), and it is usually *less* accurate. In fact, when you are working with approximate basic data, it is even possible for a simple and short-cut method of computation to produce a result that is closer to the true answer.

A simple example will serve to illustrate this point. Let us assume that two men are asked to calculate the circumference of a circle which they are told measures 3 inches in diameter. The first man, striving for accuracy, multiplies by 3.1416 and comes up with an answer of 9.4248 inches. The second man, noticing that the diameter of the circle has been measured with a common ruler that could not be expected to give an accurate diameter, multiplies in his head by 3.1 and gives the answer of 9.3 inches. He then asks that the diameter of the circle be measured accurately and it is found to be not 3 inches, but only 2.97 inches. This means that the actual circumference of the circle is 9.330552 inches, and the second man has come closer to the true answer simply because he recognized that he was working with an approximation in the beginning.

This example is cited, not to discourage you from taking the pains to be accurate in your work, but simply to emphasize the importance of recognizing the nature of the information with which you are working, and the futility of trying to get highly accurate results through laborious computation from very questionable basic data. To relate this lesson specifically to the subject at hand let us take the case of calculating altitude by the method of triangulation. The method itself is one hundred per cent accurate. But we must allow for the fact that the initial data on which we base the calculation is not one hundred per cent accurate. Therefore the altitudes themselves will only be approximate—but they will be within reasonable proximity to the true answer. As an example, an elevation reading must be taken from a visual sighting of the rocket as it reaches the peak of its trajectory. At a horizontal distance of 5000 feet a reading of 70 degrees gives an altitude of 13,737 feet. However, an error of only one degree in the elevation reading means a corresponding error of over 700 feet in the computation of altitude. This is a considerable amount; and it is very easy for an observer to make an error of one or more degrees in his reading. Given this great a possibility for error in the original data used for calculation, you can see how ridiculous it would be to waste time and effort in trying to calculate altitude to the nearest tenth of a foot —or even to the nearest hundred feet. At altitudes over 10,000 feet you are doing very well, indeed, if you can get an answer that is within 500 feet of the actual altitude. And in the final analysis, what purpose would be served by being any closer?

A Basic System for Tracking

The system of tracking outlined in this chapter is based on the use of three charts shown in Illustrations *67, 68* and *69*. Charts A and C are actually used continuously in the Fire Control Center for determining the altitude and impact point of the rocket. Chart B is a three-dimensional diagram illustrating the principle of triangulation as it is employed in this system. The method employed requires the stationing of at least two observer teams at points which are a known distance from the launching pit. What this distance should be has already been discussed in Chapter 8. The observer locations shown in Chart A (Illustration *67*) are equidistant from the launching pit. This is not necessary, but if it is topographically possible to do it on your particular launching site you will probably find it more convenient and less confusing when it comes to plotting and computing the performance of your rocket. Additional observer stations may be established if desired and if you have the personnel to man them. They can be useful in training additional observer teams and also in providing a check on the accuracy of readings taken from the two principal, or base, observer stations. These additional observer stations may be located at any point on the launching site that commands good observation, as long as they are located a safe distance from the launching pit and far enough away to enable the observers to get reasonably accurate readings, as pointed out in Illustration *59* in Chapter 8.

There is another advantage to be gained from establishing a third or fourth observer station. You will note on Chart A, Illustration *67,* that the point on the ground over which peak altitude occurs, and the impact point, can be determined by intersection of azimuths as long as these points do not fall on the base line which runs through the launching pit and the two observer stations. If you locate a third observer station at any point which is not on this base line then you can always get an intersection of azimuths from two observer stations no matter where peak altitude and impact occur. While we are on this subject it may be well to point out that it is not essential for the locations of the two observer stations and the launching pit to form a straight line. They are shown that way on the chart for the sake of clarity and simplicity. No matter where the two observation points are located, however, you will always be able to draw a straight line between them; and it is impossible to determine the location of any point on that line by intersection unless you have a third point from which to take readings.

Chart A illustrates the method of determining the location of specific points on your launching site, or range, by taking azimuth readings from two or more points of observation. An azimuth is simply a compass reading or a *line of direction* from one point to another expressed in terms of degrees, or in *mils* if you prefer to use the Army mil scale. We will discuss both the method of determining, or measuring, azimuths and the use of the Army mil scale in a moment. Chart A also functions as a small-scale map or diagram of your launching site. You will find such a map, or diagram, extremely useful for a great many purposes, and it will be your principal working tool in your fire control center.

To make up such a diagram of your launching site, get yourself as large a piece of graph paper as you can conveniently mount on a board in your firing bunker. The larger the better, generally, but the size you need for your particular operation will be determined somewhat by the size of your launching site and what you want to include on it. A piece of cross-sectional graph paper 36 by 48 inches mounted on a standard drawing board will probably prove adequate for most groups. If you want to be very fancy and professional, however, you can cover one entire wall of your firing bunker with graph paper and do your plotting there. The larger your diagram is, naturally, the greater the accuracy of your plotting will be. The paper you choose should be 10 or 20 squares to the inch.

Paper that is only 5 squares to the inch will give you less accurate results. Some graph paper is graduated in centimeters, so make sure you know what type of paper you are using. Chart A can conveniently be plotted on paper that is 20 squares to the inch and a scale of 1 inch = 1000 feet used. Such a scale used on paper that is 36 inches wide would enable you to plot peak altitude and impact points on a launching site 36,000 feet in diameter. This size launching site is adequate for rockets reaching 7000 to 7500 feet in altitude, but not much more.

From this point on we will refer to Chart A as the *plotting board,* because that is what it actually is. It is the chief tool which you will use to determine where your rocket went and to compute the details of its flight path.

First of all, plot the location of your launching pit in the exact center of your piece of paper (which is the point where it should be located in respect to the launching site itself, as pointed out in Chapter 8). Using this point as the point of origin for all your measurements, you can then indicate on your diagram the relative positions of the firing bunker, the fueling pit, the fuel storage shelter, the spectator shelter and any other facilities you care to, according to the scale you have determined to be most useful in your particular case. The facilities themselves do not have to be drawn to scale, naturally, as this would not be feasible on a small-scale diagram. Their relative positions, however, should be indicated as accurately as possible. In the case of the observer stations, the distance to them from the launching pit should be measured as accurately as possible on the ground and indicated on the diagram. This distance should be measured to the actual point from which readings of azimuth and elevation are to be taken, and not just to the nearest corner of the observer bunkers. This is important because all of your subsequent calculations will be predicated on this distance, which in Chart A has been labeled the *base line*. Similarly, the measurement should extend to the center of the launching rack itself, and not just to the wall of the launching pit.

Once you have plotted in the positions of the principal installations on your launching site you might then consider indicating also the locations of certain prominent terrain features, such as definable crests of hills, prominent trees on the horizon (or elsewhere), rock piles, scars on

ILLUSTRATION No. 67

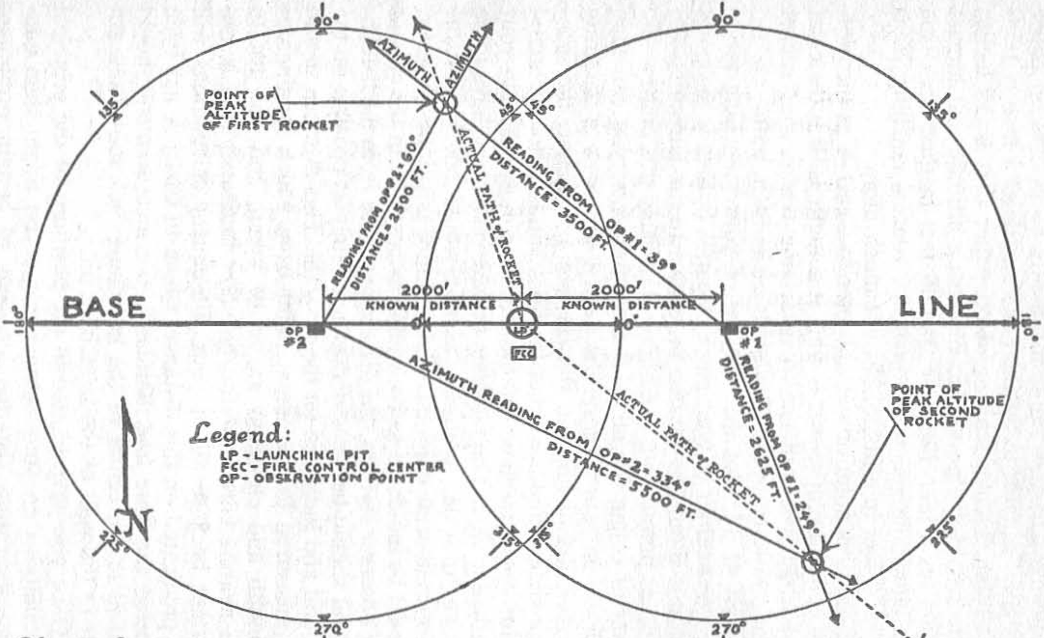


Chart A: DIAGRAM of LAUNCHING SITE USED for PLOTTING AZIMUTHS.

Theodolite at OP#2 is oriented so that zero or 360° points east toward the launching pit.

It is not necessary that OP#1, the launching pit and OP#2 be in a straight line, but if they are not, your diagram must reflect their relative positions.

Theodolite at OP#1 is oriented so that zero or 360° points west toward the launching pit.

Explanation: The chart shows the method of determining the location of point X on the ground by intersection of azimuths taken from two observation points equidistant from the launching pit. X represents the point on the ground over which the rocket reached its highest altitude (Z). The first rocket fired went to the north, the second to the south-east. All angles are measured from the base line which equals zero degrees. OP#1 reads angles clockwise, OP#2 reads them counter-clockwise. Intersection can not be used, of course, if peak altitude should happen to occur at a point directly over the base line.

the sides of hills, gullies, roads, paths, fences, telephone poles, distant water towers, or anything else that might serve as a useful reference point. The features selected for plotting, of course, should be observable from several points on the launching site, but most importantly from the firing bunker and at least one observation bunker. These reference points can serve several useful purposes, but their chief value lies in the fact that accurate azimuths and distances to them can be measured from each observation station and from the firing bunker. With this information indicated on the plotting board, the computers and recorders have a very good means of checking the accuracy of readings reported in from the observer stations, and of determining where the fault may lie in cases of readings from two different observation points which cannot be reconciled on the plotting board. The reference points selected can also be useful in visually estimating ranges, lateral distances and elevations. Their use in these operations will be discussed later in the chapter.

Once the basic information pertaining to the physical locations of permanent fixtures and landmarks on the launching site has been entered on the plotting board you may want to add certain refinements which can be of assistance in locating points rapidly and in speeding up the process of calculating performance. One thing that should certainly be included is a scale of distance in feet. This scale will prove most useful if it is superimposed on the base line which runs through the observer stations and the launching pit. It should be so devised that it is possible to measure distances either to the right or to the left, using either one of the two observer stations as the point of origin for the measurement. (*See* Illustration *70.*)

Another useful refinement is to devise a system of labeling the horizontal and vertical lines on your diagram so that you can identify any point on your launching site by coordinates. This is called a *grid system* or a *system of coordinates,* and it is the same system that is used on ordinary road maps to help you in locating towns from the index. Several systems of coordinates are used by mapmakers, depending upon how accurately points must be located. If you simply want to know the general area within which a specific point is located, you can identify only the heavy horizontal lines running across your paper by placing letters of the alphabet opposite each one down the left-hand margin of the paper. Then number the heavy vertical lines consecutively across the bottom. This will enable you to identify any large square on your paper enclosed by heavy lines (e.g., C10, or F11). If you want to be able to identify points more closely, such as the point of intersection of any two *fine* lines on your diagram, then use arabic numerals to number both the vertical and horizontal lines, and number all of them. When you use this method of numbering you must remember to always read the coordinate of the vertical line *first* by reading to the RIGHT across the scale at the bottom of the sheet. Then read UP the scale on the left margin of the paper to determine the horizontal coordinate. Always read the numbers off in this order with a dash inserted between them to avoid confusion between yourself and another person to whom you are trying to indicate a specific point on the plotting board or launching site. You can remember this rule by always repeating to yourself the phrase, READ RIGHT—UP, whenever you are reading coordinates off of your plotting board. (*See* Illustration *70.*) As an example, let us assume you are using a piece of graph paper 36 inches by 48 inches, 10 squares to the inch. There would be 480 vertical lines numbered across the bottom from left to right (it is sufficient to number every tenth line, actually), and 360 horizontal lines numbered up the left margin. The coordinates designating the center of your launching pit (which should be in the center of your paper) would then be 240-180—READING RIGHT and then UP. Assuming that your plotting board has a scale of 1 inch = 1000 feet, then an observer station located 4000 feet to the left of the launching pit, and on a line with it, would be designated by the coordinates 200-180—again READING RIGHT UP. A rocket which is observed to impact at a point 2000 feet in front of the launching pit and 1000 feet to the right of it, can be recovered by sending a search team to coordinate 250-200. If key members of your group, such as observers and range guards, are supplied with smaller-sized copies of the diagram used on the plotting board you can easily see how it would be possible to simplify many operations, and particularly the communication of information, by adopting a system of coordinates for designating specific points on your range.

A third refinement which should be added to your plotting board, by all means, is a method for readily plotting in the azimuths reported from each observer station to the point of peak altitude and the point of impact of the rocket. This can be done most simply by describing a circle of generous radius about the location of each observer station, as shown in Illustration *70*. This circle should be drawn accurately using the actual point of observation (as closely as it can be determined) as the center of the circle. Degrees from 0 to 360 can then be marked off around the perimeter of the circle (or mils, if you prefer) using a protractor of the same radius for the purpose. This will enable the plotter in the Fire Control Center to plot azimuths directly onto his board as they are reported in without the use of anything but a straightedge or a string. Naturally, these circles and the degree markings on them must be oriented in reference to the base line exactly as the alidade or theodolite of each observer is oriented. (Alidades and theodolites are both instruments for measuring angles.) This is not difficult to do, but it must be done carefully. It is not necessary that measuring instruments at different observer stations be oriented in the same direction (although it is obviously simpler and less confusing if they are), but it *is* essential that the orientation of each one be accurately reflected on the plotting board.

Use of the Plotting Board: You can, if you wish, plot azimuths and other data directly onto your plotting board in ink or pencil so that the sheet can be kept as a permanent record of firings. If you do this, however, you are faced with the problem of making up a new plotting diagram after every few firings. If you do not want the plotting diagram itself as a permanent record, you can place a sheet of pliofilm or other plastic covering over it and mark in the data with a grease pencil. Probably a better method, however, is to tack a sheet of tracing paper as an overlay on your plotting board and use a fresh sheet for each firing. This gives you a permanent record without destroying your permanent diagram. Also, you can do away with straightedges and pencils entirely and use string and thumbtacks for laying in azimuths. This is a very good method and it also simplifies measuring. Simply place a thumb tack in the center of the circle at each observer point and attach

ILLUSTRATION NO. 68

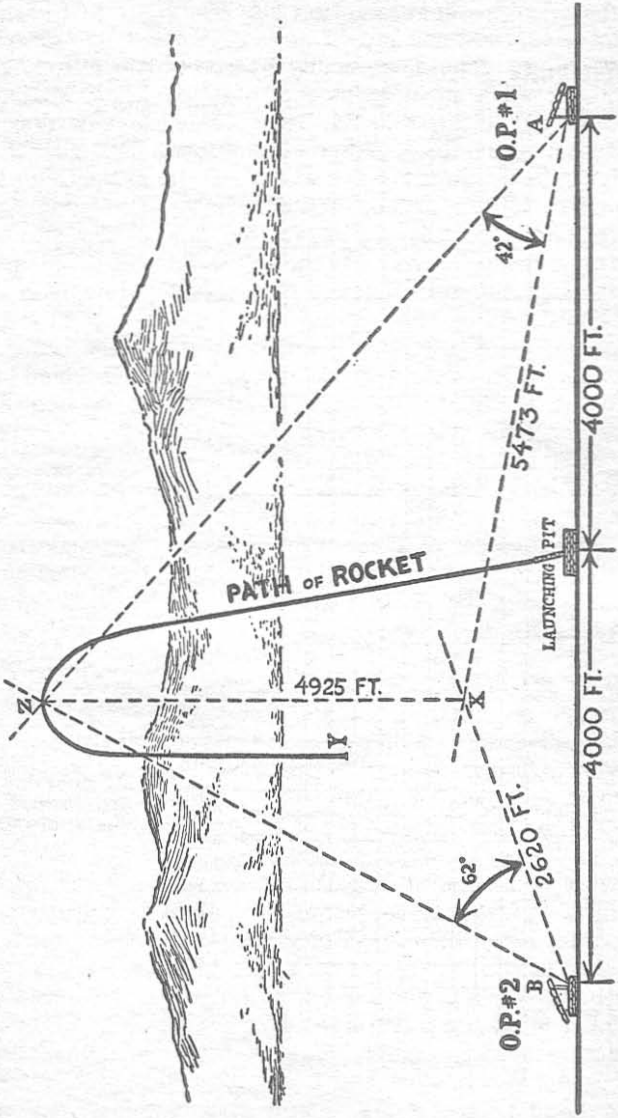


ILLUSTRATION No. 69

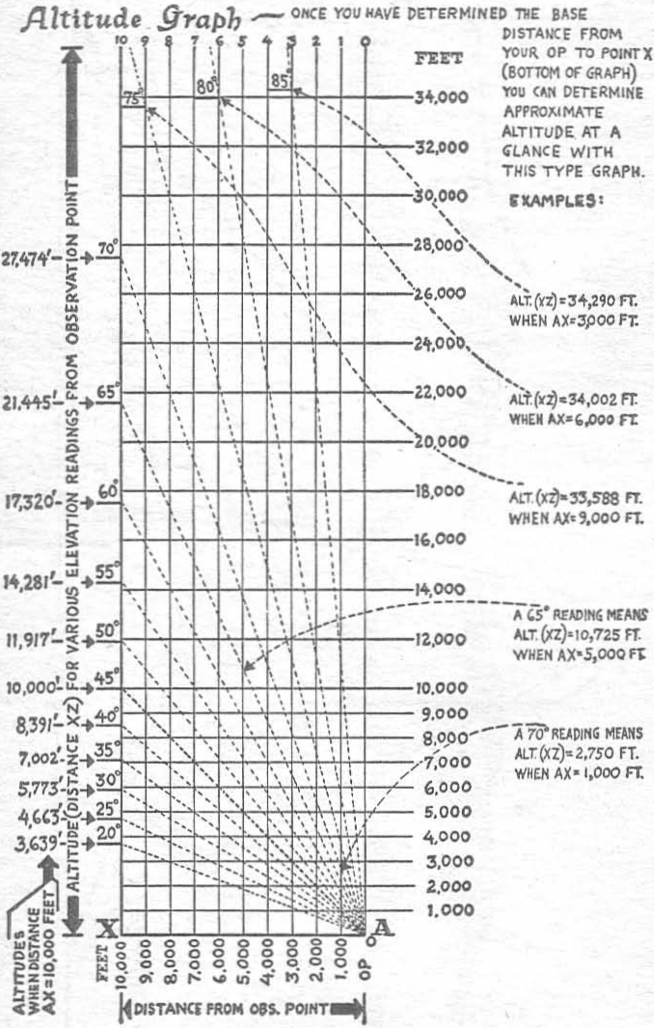
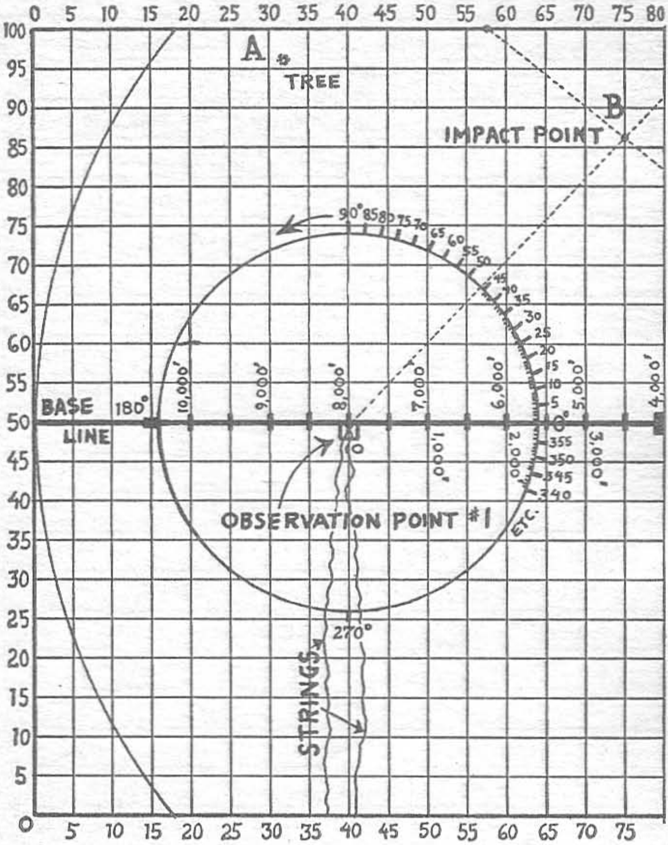


ILLUSTRATION No. 70



Point "A" shows the location of a prominent tree which has been plotted on the board at coordinates 32-96. This means the tree is located on the ground 4600 feet in front of, and 800 feet to the left of observation point #1 which is located at coordinates 40-50. The location of this tree is determined first by ground measurement and then checked by shooting azimuths to it from each OP.

Point "B" shows the plotting for the impact of a rocket (coord. 75-86) which landed 3600 ft. in front of, and 500 ft. to the