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APPENDIX A

MISSILE TERMINOLOGY

ACCELERATION.	The rate of increase in velocity.
ACCELEROMETER.	An instrument that measures one or more components of the acceleration of a vehicle.
AERODYNAMICS.	That field of dynamics which treats of the motion of air and other gaseous fluids and of the forces acting on solids in motion relative to such fluids.
AFTER BURNING.	The process after the propellant was burnt out.
ALTIMETER.	An instrument that measures elevation.
ANGLE OF ATTACK.	The angle between a reference line fixed with respect to an airframe and the apparent relative flow line of the air.
BALLISTIC MISSILE.	A vehicle whose flight path from termination of thrust to impact has essentially zero lift. It is subject to gravitation and drag, and may or may not perform maneuvers to modify or correct the flight path.
BALLISTIC RANGE.	The range on surface of the reference sphere from the cutoff point to the point of reentry through the reference sphere.

BURNOUT. The time at which combustion in a rocket engine ceases.

CENTER OF GRAVITY. The point at which all the mass of a body may be regarded as being concentrated, so far as motion of translation is concerned.

DRAG. The component of the total air forces on a body, in excess of the forces owing to static pressure of the atmosphere, and paralled to the relative gas stream but opposing the direction of motion.

EXHAUST VELOCITY. The velocity of gases that exhaust through the nozzle of a rocket engine or motor relative to the nozzle.

FIN. A fixed or adjustable airfoil attached to the body of a rocket for the purpose of flight control or stability.

GRAVITATIONAL CONSTANT. The acceleration due to gravity.

GUIDANCE. The entire process of determining the path of a missile and maintaining the missile on that path.

GUIDANCE, FINSTABILIZATION. The simplest method of guiding a rocket or missile in flight where aerodynamics surface fins are mounted on the body of the rocket or missile for stabilizing its flight path and to prevent it from tumbling.

GUIDED MISSILE. An unmanned rocket moving above the earth's surface, whose trajectory or flight path is capable of being altered by a mechanism within the rocket.

GYROSCOPE. A wheel or disc, mounted to spin rapidly about an axis and also free to rotate about one or both of two axes perpendicular to each other and to the axis of spin. A gyroscope exhibits the property of rigidity in space.

IGNITER. A device used to initiate propellant burning in a rocket engine combustion chamber.

INTERCONTINENTAL BALLISTIC MISSILE (ICBM). A ballistic missile which has a range of approximately 5000 nautical miles.

INTERCONTINENTAL RANGE BALLISTIC MISSILE (IRBM). A ballistic missile which has a range of approximately 1500 nautical miles.

JET. An exhaust stream or rapid flow of fluid from a small opening or nozzle.

JET PROPULSION. The force, motion or thrust resulting from the ejecting of matter from within the propelled body.

LAUNCHER. A device which supports and positions a rocket to permit movement in a desired direction during takeoff.

LIFT. The aerodynamic force on a body measured perpendicular to the direction of motion.

MACH NUMBER. The ratio of the velocity of a body at that of sound in the medium being considered. At sea level in air at the Standard U.S. Atmosphere, a body moving at a Mach number of one (M-1) would have a velocity of approximately 1116.2 feet per second, the speed of sound in air under those conditions.

MASS(m). A measure of the quantity of matter in an object.

$$m = \frac{\text{weight}}{\text{gravitational constant}} = \frac{W \text{ (lbs.)}}{g \text{ (ft./sec}^2)}$$

MASS FLOW RATE. Propellant consumption rate in slugs per second.

MASS RATIO. Total weight of rocket divided by weight without propellant.

MISSILE. A self-propelled unmanned vehicle which travels above the earth's surface.

MOMENTUM (M) A quantity of motion measured by the product of the mass of an object times its velocity. $M = mV$.

NOZZLE. A duct of changing cross section in which the fluid velocity is increased. Nozzles are usually converging-deverging, but may be uniformly diverging or converging.

PITCH. An angular displacement about an axis parallel to the lateral axis of an airframe.

PROPELLANT. Material consisting of fuel and oxidizer, either separate or together in a mixture or compound which if suitably ignited changes into a larger volume of hot gases, capable of propelling a rocket or other projectile.

ROCKET. A thrust-producing system or a complete missile which derives its thrust from ejection of hot gases generated from material carried in the system, not requiring intake of air or water.

ROLL. An angular displacement about an axis parallel to the longitudinal axis of an airframe.

SUBSONIC. A velocity less than the local speed of sound, or than a Mach number of one.

SUPERSONIC. A velocity that is greater than the local speed of sound.

THRUST. The resultance force in the direction of motion, owing to the components of the pressure forces in excess of ambient atmosperic pressure, acting on all inner surfaces of the vehicle parallel to the direction of motion. Thrust less drag equals accelerating force.

TRAJECTORY. The path that a rocket or missile travels from point of launch to point of impact, usually refers to ballistic missiles. Also the route of the course.

WARHEAD. That part of a missile that constitutes the explosive, chemical, or other charge intended to damage the enemy.

YAW. An angular displacement about an axis parallel to the normal axis of the rocket.

APPENDIX B

ROCKET TESTING

TYPE OF TESTS

Before liquid and solid propellant rockets are put into operational use; they are subjected to several different types of tests, all details about rocket testing can be seen on "ROCKET PROPULSION ELEMENTS" by George P. Sutton (second edition, March 1958). But for our short-range rockets, they were tested in the sequence below.

1) Manufacturing and assembly testing (pressure tests, leak checks, electromechanical checks)
2) Component tests (functional and operational tests on igniters, valves, injectors, structures etc.)
3) Static rocket system tests (with complete rocket on test stand)
   (a) Simulated rocket operation (for proper function calibration, calibration, ignition, operation - usually without establishing full combustion)
   (b) Complete engine tests (under rated conditions, off-design conditions, with intentional variations in environment or calibration)
4) Flight tests

After these tests bring us to perform three basic types of programs :

1) The research on and the development or improvement of a new rocket.
2) The evaluation of the suitability of this new rocket for a specified application.
3) The production of a rocket.

SAFETY PRECAUTIONS

This section is valuable to show because of the violence of explosion that may be happened any time bring us to elaborate safety precautions govern the method of testing. Almost all tests with actual propellants should be conducted by remote control from a protected barricade or blockhouse. In addition, precautions are usually taken to minimize the damage, in case of accident or explosion. The common safety features for our short-range rocket should be :

1) Operators are protected by barricades, which are located at some distance away from the test unit.
2) An automatic or hand actuated sprinkler system to extinguish possible propellant fires is almost always provided.
3) Individual test stations, propellant or parts storage locations, and control stations are never located adjacent to each other; they are usually

spaced sufficiently far apart so that an accident in any one establishment will not affect the remainder of the installation.

4) Warning signal are given to notify personnel to clear hazardous area prior to tests (siren, bell, flag, horn, or signal lights).

5) Separating of fuel and oxidizer storage reduces the fire and explosion hazard. The amount of propellant stored in any one installation is limited.

6) The test cell is usually barricaded on several sides so as to reduce sharpnel effect in case of explosion.

7) No smoking is permitted near a test station which use ignitable propellants. Sparkproof shoes are worn by all personnel.

8) Personnel are permitted to work on test installation only if fuel and oxidizer are separated and not pressurized.

9) Personnel handling dangerous propellants have to wear safety equipment such as gloves.

10) Establishment and rigid enforcement of safety rules will minimize carelessness.

Once a unit or a design has been proved or developed, it is possible to forego some of the safety precautions; for example, flight tests are usually performed only with proven and checked rockets.

APPENDIX C

THE THRUST

Let us consider an infinitesimal interval of time (t, t + dt) and a system of particles comprising the body of the rocket, the charge, and those particles of gas which are in the chamber and nozzle at the instant t. Then assuming that the motion of the gas in the chamber is "Stationary", we obtain the following expression for the increment in the momentum of the system during the infinitesimal interval of time

$$(t, t + dt) : \mu .dt.u, \qquad (1)$$

where μ is the rate of decrease of mass of the rocket and u the efflux velocity of gas from the nozzle, assumed constant in time. Equating equation (1) to the sum of the impulse of the external forces during the interval (t, t + dt), we obtain the equation

$$\mu udt = Tdt - (pa - Pn)\sigma adt \qquad (2)$$

where Pn is the atmospheric pressure, Pa the mean gas pressure over the exit cross-section and a the area of this cross-section. From equation (2) we obtain for Thrust T :

$$T = \mu u + (Pa - Pn)\sigma a \qquad (3)$$

which may be rewritten

$$T = \mu \left(u + \frac{Pa - Pn}{\mu} .\sigma a\right)$$

The expression in brackets is called the <u>effective efflux velocity</u> U_e :

$$u_e = u + \frac{Pa - Pn}{\mu} . \sigma a \qquad (4)$$

The magnitude of the second term in (4) is usually not greater than 10 percent of that of u.

It should be mentioned that u depends only on the chemical composition of the propulsive charge and the configuration of the nozzle. It is independent of the chamber pressure. However, the rate of ejection of mass μ and the pressure Pa at the exit section are proportional to the pressure in the chamber; the ratio $\frac{Pa}{\mu}$ is therefore independent of the chamber pressure. Consequently, in the majority of cases, when the term $\frac{Pn}{\mu}\sigma a$ can be ignored, the effective efflux velocity is independent of the chamber pressure. We shall regard as independent of time. In the following and not with introducing the effective efflux velocity, we write the motor thrust in the form :

$$T = \mu ue \qquad (5)$$

Since μ is proportional to the chamber pressure, it follows from (5) that the thrust T(t) is proportional to the chamber pressure P(t). The value of u depends on the impulse j of the thrust T in the following manner. Let dm denote the increment in the mass of the rocket during the infinitesimal interval of time (t, t + dt). Clearly

$$\mu = - \frac{dm}{dt} \qquad (6)$$

Multiply both sides of equation (5) by dt and integrating from t = 0 (corresponding to the commencement of combusion of the rocket charge) to an arbitrary moment of time t, we obtain :

$$j(t) = u_e \{m(o) - m(t)\} \qquad (7)$$

where j(t) is the total impulse of the thrust during the first t sec of combustion, i.e.

$$j(t) = \int_o^t Tdt$$

m(t) is the mass of the rocket at the instant t; and m(o) = m_n is the initial mass (the sum of masses of the body of the entire propulsive charge).

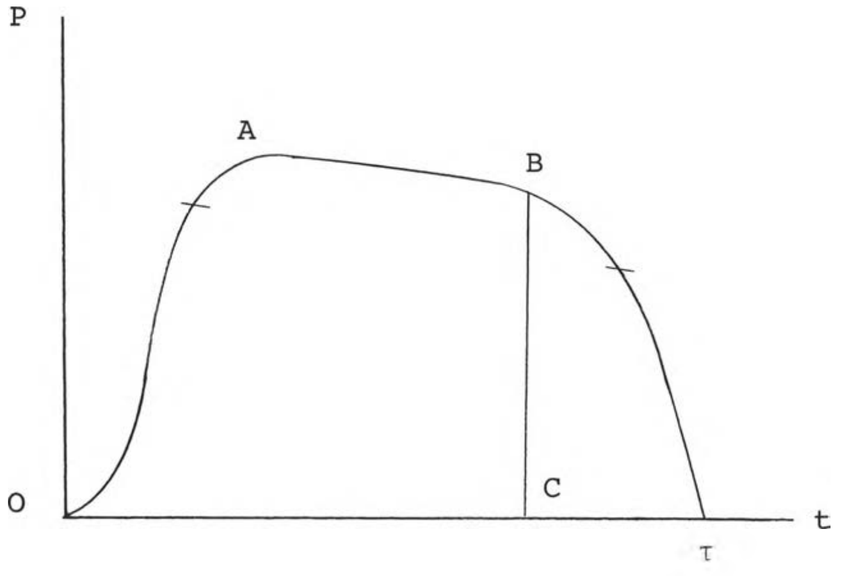

Figure 1.

The curve in Fig. 4 represent the thrust P as a function of time; Z is the total time for which the charge burns. The value of j(t) is the area OABC. The total impulse

$$j = j(\tau) = \int_o^\tau Tdt$$

is given by the total area under the curve.

Denote the weight of the rocket charge by w. Then, putting t = τ in formula (7) and noting that :

$$m(o) - m(\tau) = \frac{w}{g}$$

we have $u_e = \frac{jg}{w} = j_1 g$ (8)

where $j_1 = \frac{j}{w}$ is the specific impulse (S.I) of the propulsive system, and is the total impulse obtainable form unit weight of charge.

The magnitude of the specific impulse j_1, depends on the properties of the propellant charge, on the combustion conditions in the chamber and on the configuration of the nozzle. However, the magnitude of j_1 is in the vicinity of 200 kg.sec/kg for both solid and liquid propellant systems. Therefore, according to formula (8) the velocity u_e is of order 2000 m/sec. The impulse J can be measured on the test stand by means of an integrating thrust meter. Knowing J we can find u_e from formula (8).

It should be noted that the thrust varies substantially with the initial temperature of the propulsive charge (i.e. the temperature of the charge prior to the commencement of combustion). If the temperature of the charge changes from +40^{o}C to -40^{o}C, the magnitude of the thrust can be reduced by a factor of 2 or 3. However, it is shown by experience that the magnitude of the total impulse is practically independent of the initial temperature.

APPENDIX D

DRAG AND LIFT

DRAG

Whenever a body is moved through air, or other viscous fluid, there is produced a definite resistance to its motion. In aeronautical work this resistance is usually referred to as "Drag". Drag is usually distinguished by :

$$D = \tfrac{1}{2} \rho v^2 d^2 C_D$$

where: ρ = air density

d = diameter of the rocket

v = velocity

C_D = drag coefficient

$$C_D = C_{D_o} + \frac{C_L}{\P (AR) C}$$

C_D = zero lift drag

C_L = lift coefficient

(AR) = aspect ratio

= the ratio Span/Chord

LIFT

Lift is the Force perpendicular to the direction the air is flowing past a body. Lift is usually distinguished by :

$$L = \frac{1}{2} \rho v^2 d^2 C_L$$

where: ρ = air density

v = velocity

d = diameter of the rocket

C_L = lift coefficient

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