ROCKET BASICS 1: THRUST AND SPECIFIC IMPULSE

In a liquid-propellant rocket, a liquid fuel and oxidizer are injected into the combustion chamber where the chemical reaction of combustion occurs. The combustion process produces hot gases that expand through the nozzle, a duct with the varying cross section.

In solid rockets, both fuel and oxidizer are combined in a solid form, called the *grain*. The grain surface burns, producing hot gases that expand in the nozzle. The rate of the gas production and, correspondingly, pressure in the rocket is roughly proportional to the burning area of the grain. Thus, the introduction of a central bore in the grain allowed an increase in burning area (compared to "end burning") and, consequently, resulted in an increase in chamber pressure and rocket thrust.

Modern nozzles are usually converging-diverging (De Laval nozzle), with the flow accelerating to supersonic exhaust velocities in the diverging part. Early rockets had only a crudely formed converging part. If the pressure in the rocket is high enough, then the exhaust from a converging nozzle would occur at sonic velocity, that is, with the Mach number equal to unity.

The rocket thrust T equals

$$T = \dot{m}U_e + \left(P_e - P_a\right)A_e = \dot{m}\left[U_e + \frac{\left(P_e - P_a\right)A_e}{\dot{m}}\right] = \dot{m}U_{\text{eq}}$$

where $\dot{m}$ is the propellant mass flow (mass of the propellant leaving the rocket each second), U_e (exhaust velocity) is the velocity with which the propellant leaves the nozzle, P_e (exit pressure) is the propellant pressure at the nozzle exit, P_a (ambient pressure) is the pressure in the surrounding air (about one atmosphere at sea level), and A_e is the area of the nozzle exit; U_{eq} is called the equivalent exhaust velocity. Rocket performance is often characterized by specific impulse I_{SP} defined as

$$I_{\text{SP}} = \frac{U_{\text{eq}}}{g_E}$$

where g_E = 9.81 m/s^2 (or 32.2 ft/s^2) is the gravitational acceleration on the Earth's surface. Specific impulse is measured in the units of seconds. For chemically based rockets, the higher specific impulse I_{SP} usually means the more efficient rocket. (This characterization is not applicable directly to electric propulsion thrusters.)

Specific impulse less than 100 s was typical for Congreve rockets. Modern solid-propellant rockets achieve I_{SP} = 250–300 s. For comparison, a high-performing liquid-propellant rocket engine, such as the space shuttle main engine (SSME) using liquid oxygen and liquid hydrogen, would have I_{SP} = 410–450 s. Specific impulse and thrust usually increase with the increasing altitude as the ambient pressure decreases.

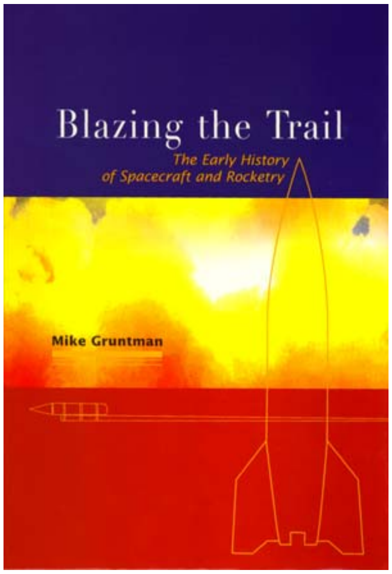
Congreve rockets had only a converging nozzle. At the exit of such a rocket, the exhaust velocity was thus typically equal to the local speed of sound, with exit pressure approximately one-half of the pressure inside the rocket, and the temperature 10–25% smaller than the gas temperature inside the rocket case.

A typical Congreve rocket would burn its propellant in a few seconds. During this time interval, the rocket thrust would accelerate the missile. After that, only forces of gravity and air drag would affect rocket flight on a ballistic trajectory.

Winner of the *Luigi Napolitano Book Award* (2006) from the International Academy of Astronautics

Blazing the Trail

The Early History of Spacecraft and Rocketry



Mike Gruntman

AIAA, Reston, Va., 2004
ISBN 156347705X; 978-1563477058
505 pages with 340 figures
Index: 2750+ entries, including 650 individuals

This book presents the fascinating story of the events that paved the way to space. It introduces the reader to the history of early rocketry and the subsequent developments which led into the space age. People of various nations and from various lands contributed to the breakthrough to space, and the book takes the reader to far away places on five continents.

This world-encompassing view of the realization of the space age reflects the author's truly unique personal experience, a life journey from a child growing on the Tyuratam launch base in the 1950s and early 1960s, to an accomplished space physicist and engineer to the founding director of a major U.S. nationally recognized program in space engineering in the heart of the American space industry.

Most publications on the topic either target narrow aspects of rocket and spacecraft history or are popular books that scratch the surface, with minimal and sometimes inaccurate technical details.

This book bridges the gap. It is a one-stop source of numerous technical details usually unavailable in popular publications. The details are not overbearing and anyone interested in rocketry and space exploration will navigate through the book without difficulty. The book also includes many quotes to give readers a flavor of how the participants viewed the developments. There are 340 figures and photographs, many appearing for the first time.

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Book details (including **index** and **reviews**) at: **http://astronauticsnow.com/blazingthetrail/**

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