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THE ROLE OF COMBUSTION RESEARCH IN ROCKET PROPULSION

By

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Summary

In spite of significant progress on the development of advanced propulsion techniques (i.e., of nuclear-thermal propulsion, nuclear-electric propulsion, and large air-breathing boosters), it appears quite certain that chemical rockets will remain the most widely used vehicles for missile and space exploration for some years to come and, furthermore, will continue to play a vital role for special missions in future years. For this reason, it is not inappropriate to discuss the extent to which basic research on combustion has contributed in the past to powerplant development and to what extent current and future studies are likely to facilitate new developments of chemical rockets.

The chemical rocket provides an almost classical example of a device that is too complex for detailed, quantitative description. Nevertheless, significant progress has been made in understanding the essential features of many of the steps involved in the utilization of propellant energy.

Reasonably simple models and descriptions are available for spray formation, droplet ignition, flame propagation, spray burning, and chemical changes in the nozzles of liquid-fuel rocket engines. Important aspects of the elusive processes responsible for unstable combustion are now understood and it is not inconceivable that proper utilization of these findings will ultimately lead to useful methods for engine scaling.

The development of solid-fuel rockets, like that of liquid-fuel engines, has been the result of intelligent empirical evolution, sometimes guided in qualitative terms by the findings and theories derived from basic studies. Although we do not yet know how to predict theoretically the burning rates of propellants from first principles, or to estimate the stability behavior of specified propellant formulations in particular engine configurations, it is nevertheless true that development of a quantitative theory of burning of ammonium perchlorate monopropellant, or of conceptually appealing pictures for the combustion of double-base and of composite propellants, has aided in the construction of useful models of resonance burning and has

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led to useful specifications of experiments which should, ultimately, help to define propellant and motor characteristics for completely stable engines.

It is not generally feasible to perform a demonstration of the close connection between basic combustion research and powerplant construction. For this reason, we shall content ourselves with a summary of representative basic studies in combustion that are motivated by engine development, which are of basic interest in their own right, and which may lead to useful pictures for the engine designer in the sense that they may help to clarify a significant approach for curing specific ills. These examples are illustrative of the work that is being done. They are not meant to be the "best" or "most pertinent" illustrations since they were selected primarily because the author has been involved in at least some aspects of the work discussed and because their use lessens materially the onerous task of writing a "survey." We choose the following combustion studies for further elaboration:

1. Burning of propellant droplets; flame propagation in arrays of liquid droplets; one-dimensional theory of combustion in liquid-fuel rocket engines.

2. The burning mechanism of pure ammonium perchlorate; combustion of solid composite propellants.

3. Correlation of mass burning rates of cylindrical plexiglass tubes in oxygen.

It is apparent that the specified studies have some bearing on combustion processes in liquid-fuel, solid fuel, and hybrid rockets, respectively.