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EXPERIMENTAL STUDY OF THE COMPOSITE  
SOLID PROPELLANT DEFLAGRATION PROCESS  
ON A FUNDAMENTAL LEVEL

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"EXPERIMENTAL STUDY OF THE COMPOSITE SOLID  
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1 October 1961 through 15 November 1972

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13. ABSTRACT <p>Investigations over an eleven-year period of the overall mechanism of composite solid propellant deflagration and its component processes are summarized. Experimental studies and techniques involving diagnostic measurements on analog burners (of several types) and characterizations of the linear pyrolysis of propellant ingredients (polymers and ammonium perchlorate) are included along with efforts at modeling the overall mechanism. All publications resulting from the work reported are cited.</p>			

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14 KEY WORDS	LINK A		LINK B		LINK C	
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This document represents the Final Report under Contract No. N00014-67-A-0202-0023 (Previously Nonr 263(48)), "Experimental Study of the Composite Solid Propellant Deflagration Process on a Fundamental Level", 1 October 1961 to 15 November 1972.

Certain activities initiated under this contract will be completed and reported upon under Contract No. N00014-67-A-0202-0035, 15 November 1972 to 15 September 1973.

#### SUMMARY

During the contract period experimental techniques were developed that permitted determination, for the first time under well controlled conditions, of the high-temperature surface decomposition/vaporization characteristics of both ammonium perchlorate (the propellant oxidant) and polymers (the propellant "fuel-binder"). Further, laboratory burners were developed that exhibited important deflagration characteristics identical to those of propellants, but with a much broader control of deflagration-rate-sensitive parameters (e.g., mixture ratio) than can be achieved with actual propellants. These were used in studies of the propellant flame structure and to illuminate the important mechanisms in the deflagration process. Finally, the new information was incorporated in an improved version of an established model of the deflagration process. It has resulted in better correlation of propellant deflagration characteristics (e.g., the dependence of burning rate on oxidant particle size, combustion pressure level, propellant mixture ratio and initial temperature) than previously possible.

#### DISSEMINATION OF INFORMATION

Information produced during the contract has been disseminated by means of publication in books, archive journals, technical reports and verbal presentation at symposia and technical meetings. The references cited include the total list of publications.

SURFACE DECOMPOSITION-VAPORIZATION OF PROPELLANT INGREDIENTS

During burning, the flame heats the propellant surface causing decomposition-vaporization of the ingredients. These vaporize to feed the flame, which in turn heats the surface, etc. At the outset of the program no reliable information existed concerning the behavior of propellant ingredients at the conditions existing of the burning propellant surface--e.g., fluxes approaching a hundred  $\text{cal/cm}^2/\text{s}$  produce surface temperatures of several hundred  $^{\circ}\text{C}$ , subsurface temperature gradients approaching a thousand  $^{\circ}\text{C}/\text{mm}$ , surface regression rates approaching a  $\text{mm}/\text{s}$ , and result in the subsurface material being heated to surface conditions at several hundred  $^{\circ}\text{C}/\text{s}$ . Thus, there was no reliable way to formulate the pivotal boundary conditions for the solution of the gas-phase flame equations.

New techniques had to be developed to obtain the information, as the classical laboratory apparatus for thermal decomposition studies, e.g. thermal gravimetric analyzers differential thermal analyzers, etc., produce conditions so far removed from those existing at the burning propellant surface to make extrapolation a futile exercise.

They were primarily combustive self-heating for the polymeric materials (Refs. 16-18,21,23-27), intense convective heating for both the ammonium perchlorate (Refs. 19-22), and the polymeric materials (Refs. 13-15). Surface temperatures were obtained both by an infrared spectroradiometric technique and an embedded thermocouple technique (which also yielded subsurface temperature gradients). In this way, the energetics and chemical kinetics of the surface degradation-vaporization of a variety of propellant ingredients were obtained. These were incorporated in formulation of appropriate boundary conditions for solution of the flame equations.

The role of catalysts is being studied under Contract N0014-67-A-0202-0035.

## DEFLAGRATION-MECHANISM INVESTIGATION

Intrinsic structural limitations of actual ammonium perchlorate composite propellants preclude experimental variation of deflagration-rate-sensitive parameters, such as mixture ratio, over a sufficiently broad range to permit meaningful mechanistic investigations. To overcome these and other limitations, laboratory burners were developed that had important deflagration characteristics which proved to be almost identical to certain of those of actual propellants. Thus it was possible to make experiments with the laboratory "analogs" that yielded results which served to illuminate important aspects of the propellant flame zone and deflagration mechanism of the actual propellants (Refs. 1-11). This approach was heavily exploited during the contract.

### THEORETICAL MODELING OF THE DEFLAGRATION MECHANISM

Information developed by the analog techniques, concerning mechanism, coupled with properly formulated boundary conditions when integrated with an established model led to an improved model of the ammonium perchlorate deflagration process. It has resulted in better correlation of deflagration characteristics (e.g., the dependence of burning rate on oxidant particle size, combustion pressure level, propellant mixture ratio and initial temperature) than previously possible. The basic work on the model has been presented (Ref. 12). Additional testing is being continued under Contract N00014-67-A-0202-0035.

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