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DETERMINATION OF THE COMBUSTION MECHANISMS OF ALUMINIZED PROPELLANTS

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) → This research project is concerned with determining the mechanisms governing the formation and combustion of metal/agglomerate/metal oxide particles throughout the solid rocket motor, that is, surface/near surface, cavity, and nozzle regions. Also of concern is the influence these particles have on propellant combustion characteristics and motor performance. The efforts of this past year were directed toward developing the experimental equipment needed for determining particle size distributions at and near -		

the propellant surface. A solid propellant strand window bomb with a servo-controlled positioning device was constructed and operated. Also, the interface of this equipment with data recording and reduction equipment was accomplished. The laser imaging device to be used to measure particle size distributions is undergoing calibration tests.

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I. INTRODUCTION

The use of metalized solid propellants may lead to decreased motor efficiencies due primarily to two phase flow losses. To be confident of the two phase flow loss prediction information must be obtained regarding the particle size and size distributions throughout the motor and nozzle.

II. RESEARCH OBJECTIVES

The long range objectives of this research program are:

- (a) To gain a thorough understanding of the various mechanisms influencing the combustion of metal; that is, an understanding of the physical and chemical characteristics of the burning metal/agglomerate/metal oxide particle as it leaves the propellant surface and traverses the motor chamber and nozzle. This knowledge will lead to an accurate determination of the metal/agglomerate/metal oxide particle size and size distributions throughout the motor and a detailed description of the changes a particle undergoes as it transverses the nozzle.
- (b) To predict (based on the knowledge gained from the first objective) motor performance and efficiency accurately and a priori based on propellant composition, grain geometry, and motor size and geometry.

While the long range goals listed above are the ultimate research objectives, the effort of this past year has been focused on the more immediate, short term goals. The work has been devoted to tasks that must be completed before accurate experimental data can be obtained.

More specifically, the goals of the fiscal year 1981 experimental program were:

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- (a) Design a medium pressure strand window bomb with two optical paths 90° apart - one optical path for taking data and the other to accomodate an optical sensing, laser source, servo positioning device for maintaining the burning propellant surface stationary relative to an inertial coordinate system.
- (b) Test the strand bomb and servo controlled positioning device for proper operation and determine the tolerances and capabilities of the servo positioning system.
- (c) Instrument the strand bomb and servo controlled mechanism and interface this equipment with a computer suitable for recording and reducing experimental data.
- (d) Demonstrate the capabilities of the laser imaging device that will be used to measure particle size distributions in the hostile environment of hot flow combustion products.
- (e) Perform an extensive literature review of small particle measuring techniques to include, sampling, high speed photography, and holography.

III. STATUS OF RESEARCH EFFORT

A solid propellant strand window bomb with a servo controlled propellant positioning mechanism has been designed, constructed and operated. A diagram of the strand bomb is shown in figure 1. Figure 2 shows a schematic of the servo system. The combustion bomb is a modified Crawford chimney bomb with two optical axes. A schematic of the associated optics is shown in figure 3. One optical axis is for observation of the burning strand and the other is for detecting the burning surface of the strand. The bomb has been pressure tested to 1000 psia.

The bomb and control system are in place and operational. The servo system can accommodate a maximum burning rate of 1.47 in./sec. The entire system has been operated at pressures up to 350 psia. The system has demonstrated the ability to accurately measure burning rate and to maintain a constant burning surface within ± 0.007 inches. Further improvements in position accuracy are expected when more experience is gained with the equipment.

Data recording and reduction are accomplished through the use of a Digital PDP 11V03-L computer system. During an experimental run, data are input to the computer through a Data Translation DT 1761 interface subsystem. The DT 1761 performs analog to digital conversion on the data with sixteen analog to digital channels available for inputting data to the computer. If necessary, the incoming data can be stored in analog form on magnetic tape or in digital form on floppy disk. The computer system itself has 32 k bits of main memory available and is supported by a Digital VT 100 CRT terminal and a Printronix line printer.

The laser imaging device which will be used to measure particle size distributions in the various experiments planned for this program is presently undergoing calibration tests. It has been tested using stationary test targets of known size distributions. Accurate interpretation by the device of these test target size distributions has been demonstrated. Further tests of this nature with moving targets is presently underway.

The literature survey of small particle size measuring techniques is nearing completion. Methods studied were sampling, photographic recording, and holographic techniques. Special interest was placed on holographic measuring of small particles because of the potential for obtaining accurate particle size distribution measurements using this method.

IV. PUBLISHED PAPERS FROM GRANT RESEARCH

1. Renie, J.P., Condon, J.A., and Osborn, J.R., "Oxidizer Size Distribution Effects on Pressure and Temperature Sensitivity," 14th JANNAF Combustion Meeting, CPIA Publication 292, December 1977, pp. 325-329.
2. Renie, J.P., Condon, J.A., and Osborn, J.R., "Combustion Tailoring of Propellant Composition to Satisfy Engine and Propellant Design Requirements," 1978 JANNAF Propulsion Meeting, 14-16 February 1978.
3. Renie, J.P., Condon, J.A., and Osborn, J.R., "Oxidizer Size Distribution Effects on Propellant Combustion," AIAA Paper No. 78-981, AIAA/SAE 14th Joint Propulsion Conference, July 25-27, 1978, also, AIAA Journal, Vol. 17, No. 8, August, 1979, pp. 877-883.
4. Renie, J.P. and Osborn, J.R., "Erosive Burning," AIAA Paper No. 79-0165, 17th Aerospace Sciences Meeting, New Orleans, January 15-17, 1979.
5. Renie, J.P. and Osborn, J.R., "The Implicit Flame Interaction Model," 15th JANNAF Combustion Meeting, CPIA Publication 297, Volume II, February 1979, pp. 217-240.
6. Barger, M.E., "Erosive Burning Rate Temperature Sensitivity," AIAA Midwest Regional Student Conference, March 29-31, 1979.
7. Renie, J.P. and Osborn, J.R., "Combustion Modeling of Aluminized Propellants," AIAA Paper No. 79-1131, AIAA/SAE/ASME Propulsion Meeting, Las Vegas, June 18-20, 1979.
8. Renie, J.P., Barger, M.E., and Osborn, J.R., "Effect of Erosive Burning on Pressure and Temperature Sensitivity," 16th JANNAF Combustion Meeting, CPIA Publication 308, Volume II, December 1979, pp. 153-169.

9. Renie, J.P. and Osborn, J.R., "Temperature and Pressure Sensitivity of Aluminized Propellants," AIAA Paper No. 80-1166, AIAA/SAE/ASME 16th Joint Propulsion Conference, June 30-July 2, 1980, Hartford, Connecticut.

V. PAPERS IN PREPARATION

1. Renie, J.P. and Osborn, J.R., "Comments on Aluminum Particle Size, Agglomeration, and Acceleration Effects on Solid Propellant Burning Behavior," to be presented at the 18th JANNAF Combustion Meeting, October 19-23, 1981. (A summary of the theoretical work conducted on the program).
2. Renie, J.P., Osborn, J.R., Corley, B.M. and Kobbeman, D.D., "Theoretical Analysis and Combustion Modeling of High Burn Rate Propellants to Obtain Low Pressure Exponent Compositions", to be presented at the 18th JANNAF Combustion Meeting, October 19-23, 1981. (The paper is concerned with using the aluminum PEM for predicting the burning rate behavior of a new family of propellants).

VI. STUDENT COMPLETING GRADUATE PROGRAM

M.E. Barger received her M.S. in the School of Aeronautics and Astronautics in May 1980 and is presently employed at the Air Force Rocket Propulsion Laboratory.

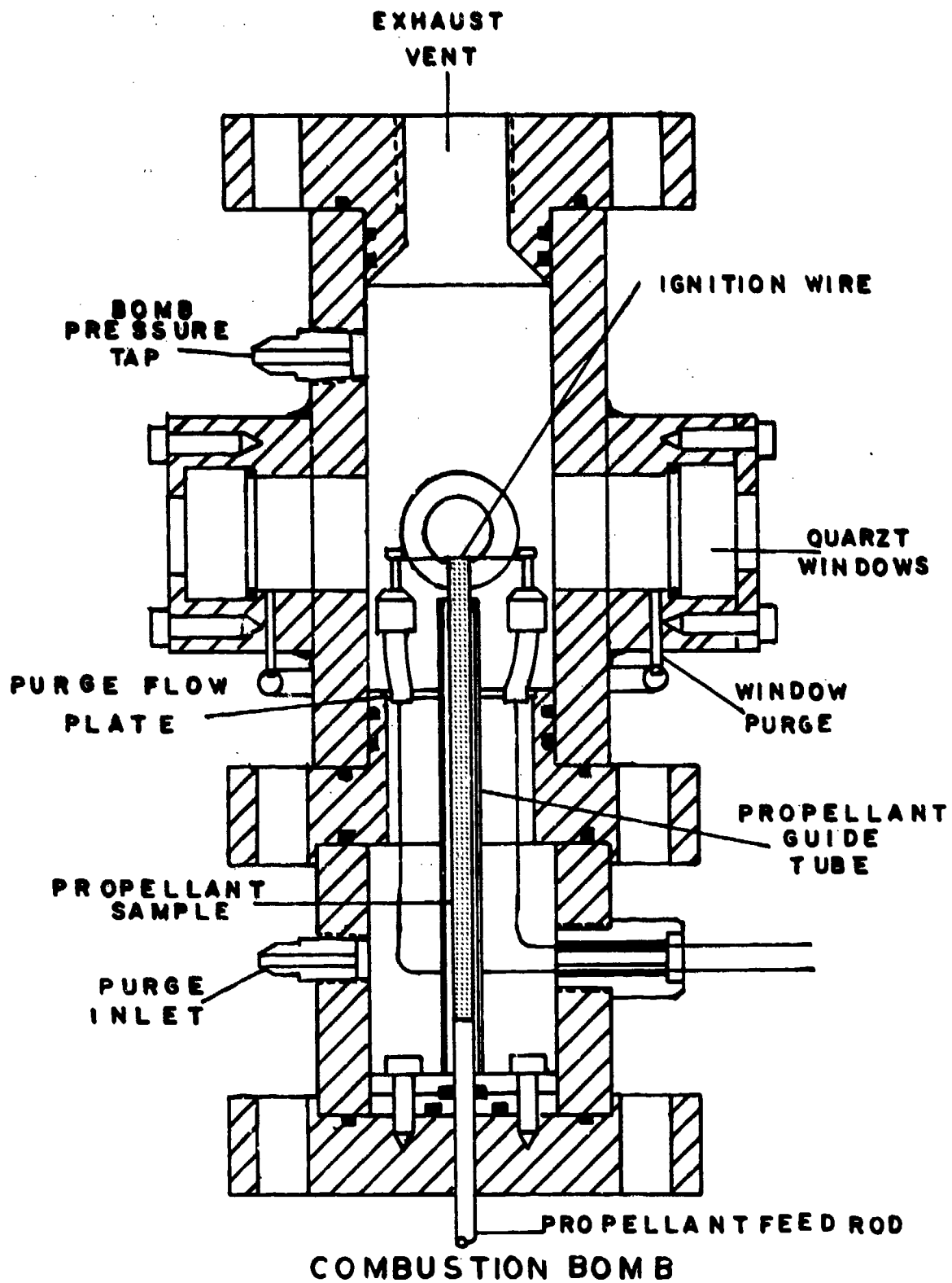
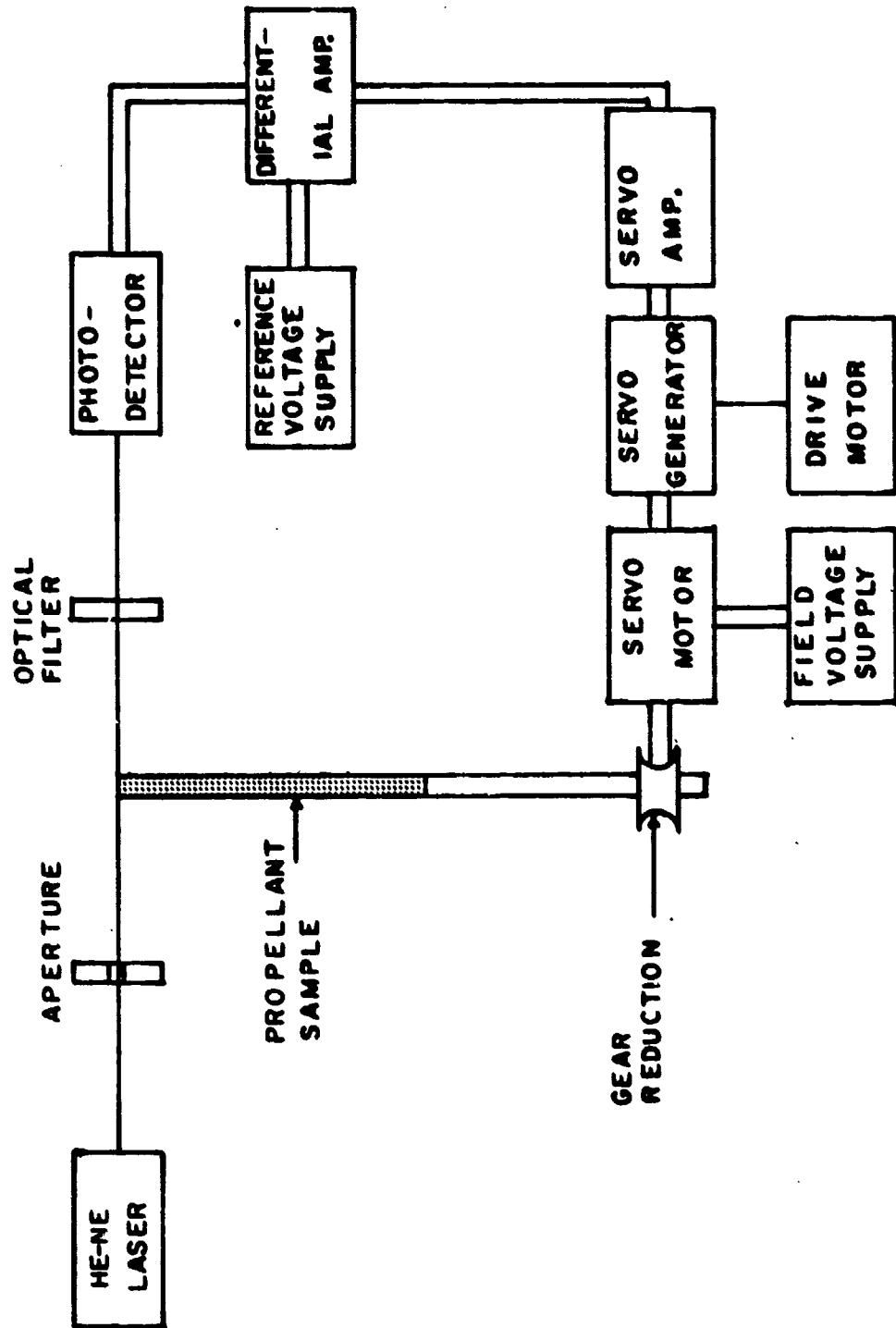
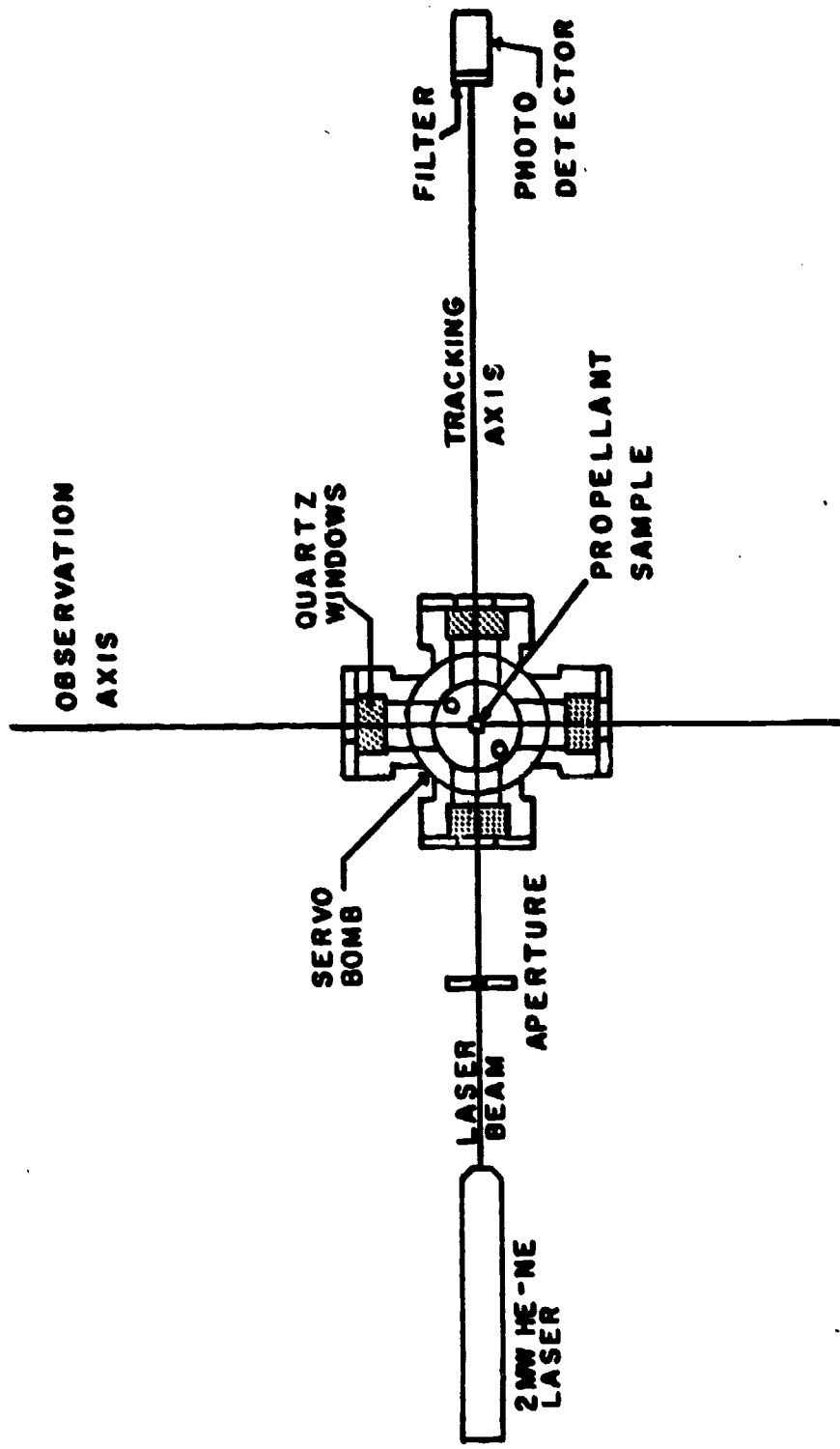


Figure 1



SCHEMATIC OF SERVO SYSTEM

Figure 2



OPTICAL SCHEMATIC

Figure 3