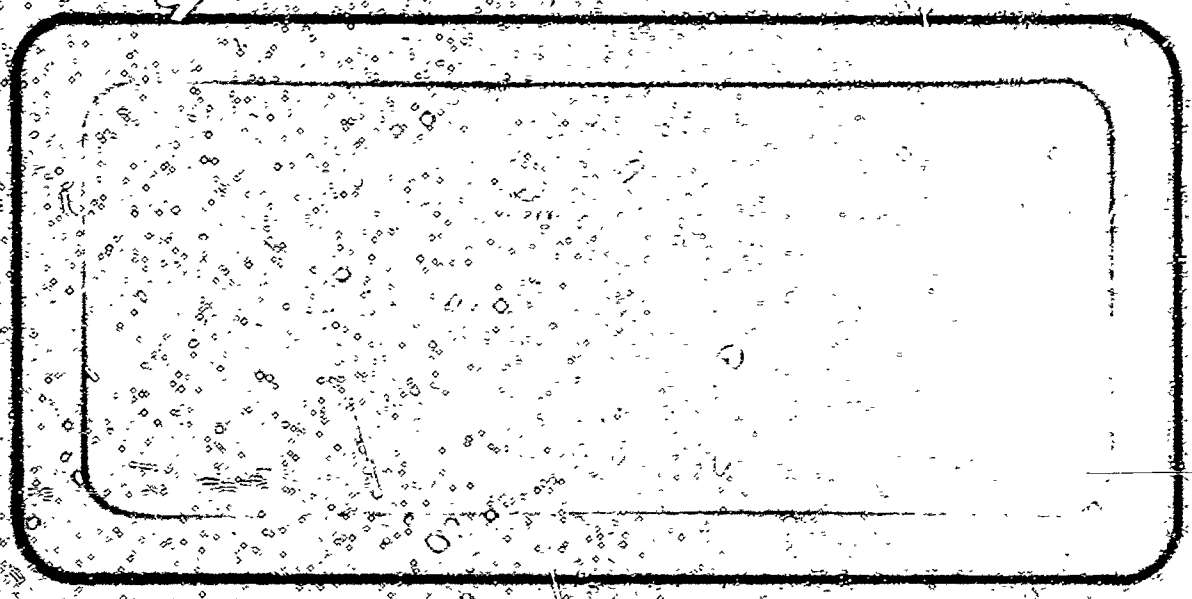
CALIFORNIA INSTITUTE OF TECHNOLOGY

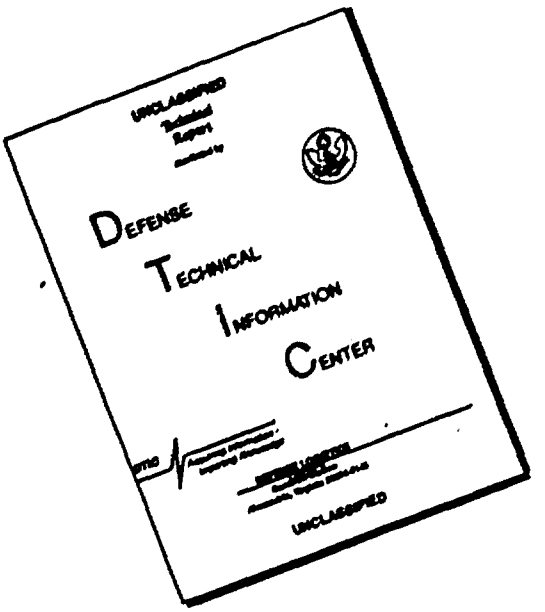
MATERIALS SCIENCE



W. M. KECK LABORATORY OF ENGINEERING MATERIALS

PASADENA

DISCLAIMER NOTICE



THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

MATERIALS SCIENCE
CALIFORNIA INSTITUTE OF TECHNOLOGY

Quarterly Report No. 1
1 November 1963 - 31 January 1964

A RESEARCH PROGRAM ON SOLID PROPELLANT PHYSICAL BEHAVIOR

M. L. Williams
Project Director

MATSCIT PS 64-1 FEBRUARY 1964

Contract No. AF 04(611)-9572
Air Force Rocket Propulsion Laboratory
Research and Technology Division
Edwards Air Force Base, California

W. M. Keck
Laboratory of Engineering Materials
Pasadena, California

A RESEARCH PROGRAM ON SOLID PROPELLANT PHYSICAL BEHAVIOR

The purpose of this research is to initiate and maintain an integrated program directed toward providing increased understanding of solid propellant physical behavior, and application of this understanding to analysis of solid rocket motors.

The major emphasis therefore will be to supplement existing knowledge in the areas of material behavior of polymeric and composite systems, and the refinement of solid rocket structural analysis procedures.

There are also two related subsidiary objectives. First, it is believed desirable to investigate the feasibility of generating basic physical and mechanical property data for one or more "standard" cross-linked materials. The purpose here would be two-fold: to provide a means for checking (a) internal consistency of data at various laboratories, and (b) to provide fundamental data against which to evaluate theoretical predictions. Second, it is the intent to establish and maintain a library facility for the consolidation of technical information relating to mechanical behavior and structural integrity analysis. Periodic abstracts and indexes of reports received from various research activities and from the open literature will be published and distributed according to procedures yet to be finalized.

Behavior of Polymeric and Composite Systems

Investigator, Dr. P. J. Blatz

This being the first in a series of quarterly reports on a proposed study of the physicomechanical behavior of polymers, it is appropriate to state the general aims of the program.

One goal is the understanding of the continuum behavior of several non-porous rubbers for strains out to the point of failure. In the case of equilibrium continuum behavior, it is well known that a complete description of response behavior is contained in the strain energy density function. This function usually contains two or three parameters, such as the shear modulus and the ratio of c_2/c_1. In addition to tabulating these parameters, one records the values of the

ultimate stresses and ultimate stretches in several stress fields and searches for a failure function which represents the criterion for global destruction of the material, as opposed to local fracture initiation. This type of information has already been accumulated by Ko[1] for polyurethane rubber. In the case of viscoelastic continuum behavior, the theory of Coleman and Noll[2] provides a frame work for the evaluation of time and temperature effects. Thus the first goal consists in the evaluation of the equilibrium and viscoelastic response behavior and failure behavior of several non-porous rubbers: SBR, EPR, Neoprene, and Natural Rubber.

A second goal is the understanding of the effect of microscopic structure upon the parameters investigated in pursuing the first goal. Thus an important step will be the correlation of these properties with variations in the microstructure: Primary chain length, cross-link density, plasticizer content, long-and short-chain branches, and swelling or solvent content. Of particular interest to this phase of the program will be the recording and understanding of the way the failure criterion changes with changes in microstructure.

A third goal of this program is an investigation into a particular type of electrogalvanic effect known as the inverse Wiedemann effect by which it is understood that a twisted conductor will develop an inductance. It is planned to build a bridge circuit and search for the imbalance in inductance between two similar samples of conductive silicon rubber when one is twisted. This work will be started in the immediate future.

Also underway in the immediate future is the investigation of the viscoelastic behavior of SBR. In a previous piece of work[3], Blatz and Ko investigated the form of the uniaxial stress relaxation function under the Coleman-Noll theory and showed that because of the glassy elastic limit imposed at zero time, five of the twelve relaxation functions proposed by Coleman and Noll are zero, four are non-zero, and three are indeterminate at the present time. In order to separate these three, both uniaxial and biaxial tests must be run. In the aforementioned previous piece of work, Ko and Blatz[4] investigated the stress relaxation behavior of SBR

at -25° F and evaluated certain linear combinations of the relaxation functions. It is proposed to complete the separation by investigating the biaxial relaxation of SBR, as well as the uniaxial and biaxial relaxation of cast polyurethane samples.

Standardized Material Characterization

Investigator, Dr. W. G. Knauss

Inasmuch as the material to be characterized is to serve as a material standard acceptable to a large number of investigators concerned with the properties of viscoelastic materials, it is intended first of all to obtain the opinion and suggestions on material choice of as many interested persons as possible. By pooling the experience and knowledge of people conversant with the problems of material production and characterization it is hoped to limit the number of possible material choices to two or three. Initial contacts in this matter were made during the AIAA meeting in Palo Alto, California, January 29-31, and at the Winter meeting of the Society of Rheology in Claremont, California, February 3-4. The major part of this opinion sampling is anticipated to be concluded by approximately June 1964.

The second direction of effort concerns the exploratory evaluation of a trial material, Solithane 113, for which considerable data is already available. The processing equipment for this material is presently being overhauled. Major effort will be spent on developing a composition with reproducible material properties as measured by

a) Dynamic Modulus
b) Birefringence
c) Swelling
d) Tensile strength.

These quantities will be determined in a simple but standard test for control purposes. Reproducibility of these properties is affected by

a) Mechanical mixing of catalyst and pre-polymer
b) Relative amounts of catalyst and pre-polymer
c) Cure temperature
d) Cure time
e) Post cure storage (humidity)
f) Time lapsed between mixing and casting

to mention the most obvious. A carefully controlled study of the property-sensitivity to variations in these parameters is therefore necessary.

Presently a dye is being sought which dissolves in the catalyst (or pre-polymer). If the dyed catalyst mixes with the pre-polymer without striations mechanical mixing will be considered complete. After some further modification of the casting apparatus (more accurate dispensing of variable amounts of catalyst and pre-polymer) the effect of the parameters b) - f) will be explored. It is anticipated that the preliminary parameter study will be complete by the time sufficient information has been gathered under the opinion-sampling phase, and therefore assist in evaluating various other recommended materials.

Data Information Facility
Investigator, Dr. A. R. Zak

Objectives. - This program is designed to provide a systematic collection and abstraction of literature related to the solid propellant technology. The information on the collected literature will be published quarterly in the form of a "Library Addition List." This list shall contain the title of the publication, author, source and an abstract. There will be no attempt to review each publication, however the publications will be arranged according to subject matter. The publication date will be governed by the initial response to the literature request and the initial literature search.

Literature Sources. - The success of this program will depend on the procedures which will be used to gather the pertinent literature. There will be various sources from which the literature will be sought, these are:

a) Industrial and educational institutions which are performing solid propellant research sponsored by the various defense agencies. The literature solicitation from most of these sources could be automatic since it is recommended that the various contracts for such research provide that copies of all research reports be submitted to the California Institute of Technology. It is anticipated that this source will provide the bulk of the literature for the proposed information facility.

b) The second source will be provided by carrying out a systematic review of a number of scientific journals. The following will be typical:

J. of Applied Polymer Sciences
J. of Applied Mechanics
J. of Applied Physics
AIAA Journal
Review of Scientific Instruments
Applied Mechanics Reviews

Proceedings of various technical meetings will also be reviewed.

c) Quite an extensive library on the subject of the solid propellants has already been collected here at Caltech and will provide a large amount of the initial literature.

d) A large amount of the literature will be obtained through personal contacts with workers at other organizations. Also, literature information will be obtained by personal contact through visits to research laboratories and industrial organizations. Attendance at selected meetings will also be used for the purpose of collecting data.

e) It is expected that the facilities of the Aeronautical and General Libraries at the California Institute of Technology will be very helpful in the proposed abstraction program. For example the Aeronautics Library publishes a regular weekly listing of all articles and technical publications which are received, these lists will of course be checked for any pertinent solid propellant literature.

Format. - The articles and the literature will be arranged according to the subject matter. A numbering system will be used in order to facilitate the location and referenceing of any article. The list will contain the title of the article, the author, the name of the publishing institution and the abstract. Where possible the abstract will be taken directly from the article. In the case when no abstract is included in the article a short synopsis will be composed by the reviewer. In order to facilitate the collection of the large volume of the literature which has already been published in this area it is not intended to include any abstracts for articles published before January 1, 1963.

The subject matter into which the literature will be divided will be arranged in main groups, these will in turn be divided into sub-groups. The following is a tentative list of subjects:

A. Material Characterization

1. Elastic-Infinitesimal Theory
2. Elastic-Finite Theory
3. Viscoelastic

B. Analytic Methods

1. Elastic
2. Finite Elastic
3. Viscoelastic
4. Thermal Analysis
5. Miscellaneous (e. g. Ablation)

C. Engineering Analysis

1. Static (elastic)
2. Viscoelastic (no body forces)
3. Dynamic (elastic or viscoelastic and body forces)
4. Experimental

D. Failure Criteria

1. Elastic
2. Viscoelastic (rate effects)
3. Fracture Propagation
4. Problems in Filled Propellants (pull-away)

E. Special Test Procedures

1. Material Characterization
2. Fracture Studies
3. System Testing

F. Physico-Chemical Effects

1. Environmental Conditions
2. Curing Conditions
3. Binder-Filler Interactions

G. Instrumentation

Distribution of the "Library Additions List". - This publication will be primarily distributed to the research institutions who are actively engaged on the solid propellant work sponsored by contracts from the various defense agencies. Institutions other than these will also be qualified to receive the publication if they satisfy the following two conditions:

a) be actively supporting the abstraction program by sending to the California Institute of Technology pertinent research publications, and

b) be actively engaged in research directly applicable to the solid propellant technology. However, the distribution to these institutions will not be automatic, and will follow a request which will be reviewed and approved by the sponsor.

REFERENCES

1. Ko, W. L.: "Application of Finite Elastic Theory to the Behavior of Rubberlike Materials." Ph.D. Dissertation, California Institute of Technology, GALCIT SM 63-13, June 1963, p. 162, Figure II. 30.

2. Coleman, B. O.; Noll, W.: "Foundations of Linear Viscoelasticity," Rev. Mod. Phys. 33, 239, (1961).

3. Ko, W. L.; Blatz, P. J.: "Application of Finite Viscoelastic Theory to the Deformation of Rubberlike Materials: I. Uniaxial Stress Relaxation Data." GALCIT SM 64-4, California Institute of Technology, January 1964.

4. Ibid.