COO-4246-1

MICROSTRUCTURAL EFFECTS IN ABRASIVE WEAR

Quarter Progress Report
for Period 15 March 1977 - 15 June 1977

Nicholas F. Fiore
Department of Metallurgical Engineering and Materials Science
Notre Dame, IN 46556

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product or process disclosed or represents that its use would not infringe privately owned rights.

1 July 1977

NOTICE
This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

Prepared for

U. S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

Under Contract No. EF-77-S-02-4246

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

CONTENTS

ABSTRACT

This program is directed toward correlating the microstructural features of alloy cast irons and Co-base alloys to their wear resistance under room temperature low-stress and high-stress (gouging) abrasion. Low-stress abrasion resistance is determined on a dry-sand rubber wheel device, whereas high-stress abrasion resistance is measured in a grinding wheel test. The microstructures of the test materials are characterized by automated image analysis techniques. The cast irons, the two wear testers and the quantitative metallographic system have been acquired and are being calibrated during this, the first three months of the contract.

1. OBJECTIVE AND SCOPE

The objective of this program is to establish quantitative relations between microstructure and abrasive wear under gouging and low-stress conditions for a number of alloys used in coal mining, handling and gasification. The relations will not only provide an empirical ranking of the alloys, but they will also provide the designer and materials engineer with rules, based on the principles of physical metallurgy, for the specification of materials for wear resistance.

This contract was initiated on 15 March 1977, and the bulk of the progress to date has been by way of acquiring equipment and materials and beginning calibration tests. In the following section of this report each task will be briefly reviewed and the progress in the task will be described.

2. TASKS AND PROGRESS

2.1 Task 1 - Preparation of Test Matrix

The matrix describing the proposed test procedures, the test materials and their microstructural condition was prepared and sent to ERDA - Chicago Operations Office (COO) for approval on 6 June 1977.

The materials to be tested fall into two categories: wear-resistant cast irons and Co base superalloys. The salient features of each of the materials are listed in Tables I and II. The alloy

Table I. Wear-Resistant Irons

Type	Microstructural Condition
1. ASTM532 - Type I - Ni Hard 4	M_3C carbides in Tempered Martensite with a. 5% Retained Austenite
	b. 20% " "
	c. 45% " "
	d. 85% " "
2. ASTM532 - Type II-(15 Cr-3 Mo)	Cr_7C_3 Carbides in Tempered Martensite
3. ASTM532 - Type III-(27 Cr-2.5C)	Cr_7C_3 Carbides in Tempered Martensite
4. Pearlitic White Iron	Fe_3C Carbides in Pearlitic Matrix
	a. 3.5C- High Carbide Vol.Fract.
	b. 2.7C - Low Carbide Vol.Fract.

Table II. Co-base Powder Metallurgy Alloys

Type	Microstructure
1. #6	Low carbide vol. fract. - Low solid solution strengthener content.
2. #6KC-L	Moderate carbide vol. fract. - Low solid solution strengthener content.
3. #6KC-H	High carbide vol. fract. - Low solid solution strengthener content.
4. #19	High carbide vol. fract. - Moderate solid solution strengthener content.
5. #98M2	High carbide vol. fract. - High solid solution strengthener content.
6. #3	Very high carbide vol. fract. - High solid solution strengthener content.
7. #Star-J	Very high carbide vol. fract. - Very high solid solution strengthener content.

cast irons consist of alloy carbides of various volume fractions in tempered martensite matrices of various retained austenite contents. Their study will demonstrate the effect of carbide volume fraction and matrix toughness on low- and high-stress abrasive wear. Pearlitic white iron is a standard, inexpensive material used as baseline indicator of wear resistance. The Co-base superalloys are prepared by powder metallurgical (PM) techniques and consist of fine carbides in a fine-grained Co-rich matrix. They comprise a spectrum of carbide volume fractions and matrix strengthener contents and allow the study of the effect of these variables on low- and high-stress abrasive wear. Moreover, the micro-structures are simple and amenable to quantitative metallographic analysis.

2.2 Task 2 - Preparation of Materials

The cast irons have been produced at the Climax Molybdenum Research Laboratories, Ann Arbor, MI. Materials 2, 3, 4 of Table I are in hand, and cutting and grinding to appropriate sample geometry is underway at Notre Dame. Material 1, the series of Ni Hard 4 specimens, is in shipment. Each material has been subjected to testing at Climax before shipment to Notre Dame. It is of special interest to note that the irons have been subjected to the Climax pin-on-disk low-stress abrasion test and the Climax jaw crusher high-stress abrasion test. Similar tests are to be employed in another ERDA FER project (Contract W-7405-ENG-48), so the data on these cast irons should interface well with that obtained on the other ERDA project.

The Co-base alloys are to be prepared at the Stellite Division, Cabot Corporation, Kokomo, Indiana. Special dies for preparation of samples of the required geometry are being produced.

2.3 <u>Task 3 - Wear Testing</u>

The samples will be tested according to the scheme outlined in the flow chart in Figure 1. Mechanical testing will proceed wear testing and will be conducted according to standard ASTM procedures.

2.3.1 <u>Low-stress, Dry-sand Abrasive Wear Testing</u>.

These tests will be conducted on the low-stress machine constructed at Notre Dame by procedures described in ASTM STP 615. A schematic of the test device is shown in Figure 2. A significant feature of this test is the specially-formulated chlorobutyl rubber wear surface which resists softening and aging during sequential tests. A lot of 10 test wheels prepared from the same batch of rubber has been produced for the project.

Standard lots of AISI 1020 and AISI-VAR 4340 steel are currently being tested to document reproducibility of the test.

2.3.2 <u>High-stress Abrasive Wear Testing</u>.

This test was developed at the ABEX Corporation Research Laboratories, Mahwah, New Jersey. The test device (Figure 3) has been acquired by Notre Dame, and calibration tests with AISI 1020 and AISI-VAR 4340 steels are currently underway.

2.4 Task 4 - Wear Scar and Microstructure Characterization

2.4.1 Wear Scar Microtopography.

Attempts will be made to relate the wear scar microtopgraphy of the samples to microstructural parameters such as carbide size and spacing. The instrument which is proposed for these measurements is a computer-interfaced profilometer at the Inland Steel Research Laboratories, East Chicago, IN. The Inland instrument has the advantage of providing direct hard-copy read-out of surface feature mean amplitude and mean period, and of the distribution of these parameters.

2.4.2 Quantitative Metallography.

The microstructures of the samples will be characterized by automated quantitative metallographic techniques. The basic instrument for characterization is the Bausch and Lomb Omicron Alpha Image Analyser as interfaced to an Olympus PME metallograph. The analyser provides direct read-out of such parameters as precipitate dimensions and volume fraction. It includes a special module for determination of distribution of precipitate sizes.

The instrument has been received and is being installed and calibrated by the vendor.

2.4.3 Scanning Electron Microscopy (SEM).

The wear scars will be inspected by SEM in an effort to interrelate scar appearance, deformation and fracture processes, and microstructure. Standard SEM techniques will be employed, but in the event high resolution is required, a Scanning Transmission Electron

Microscope (STEM) with 30Å resolution in the SEM mode is available.

2.5 Task 5 - Analysis of Data

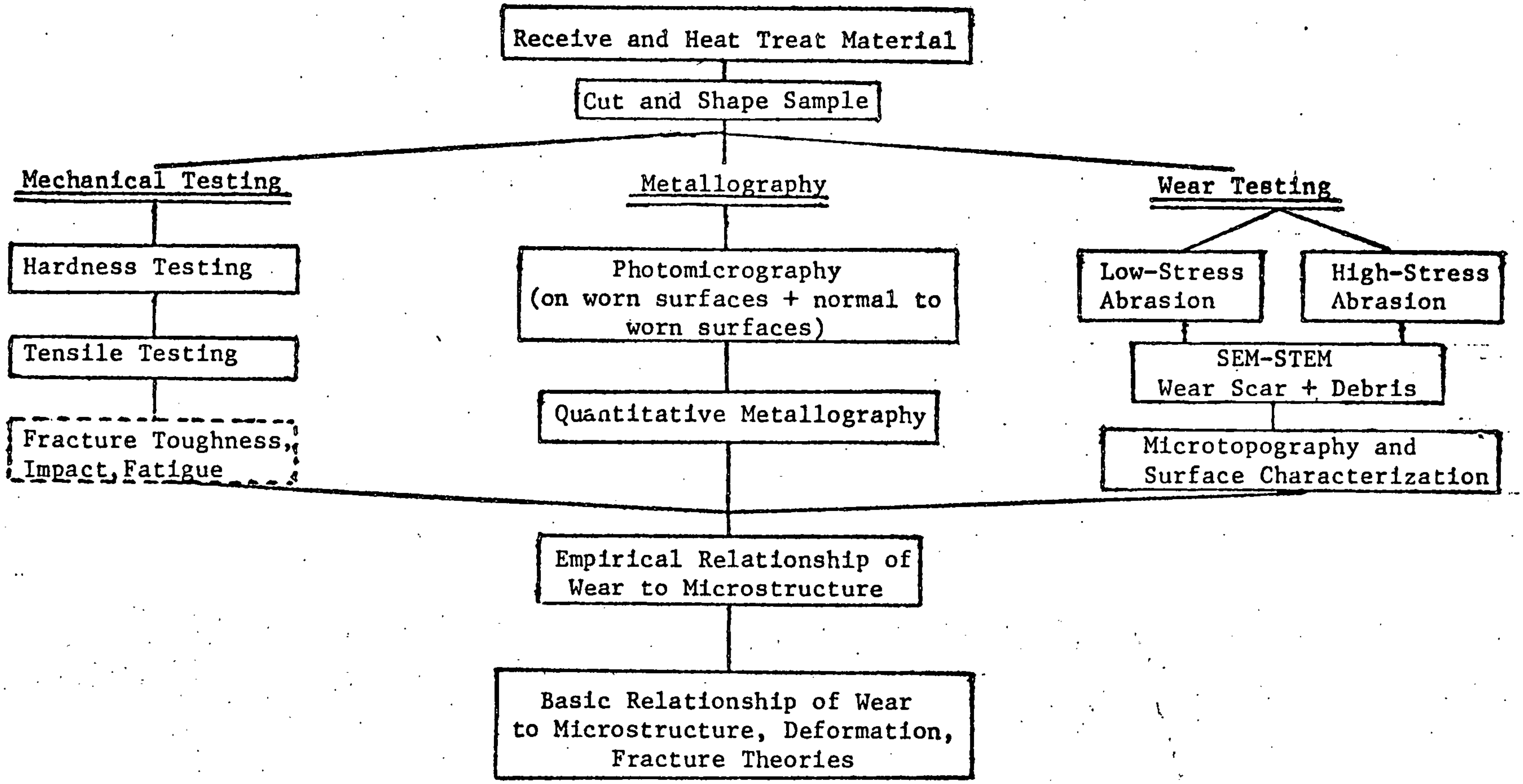
No progress has been made on this task to date.

3. PERSONNEL

The principal investigator, Dr. N. F. Fiore has spent approximately one-half time effort on the project in this quarter. The co-principal investigator, Dr. A. E. Miller has devoted about one-eighth time effort. Two graduate students, Jr. Joseph Coyle (Ph.D. candidate) and Mr. Steven Udvardy (M.S. candidate) began full-time work on the project on 1 June 1977. The principal investigator will devote comparable effort to the project during the next quarter.

Figure 1.

TEST PROGRAM FLOW CHART
Contract EE-77-S-02-4246



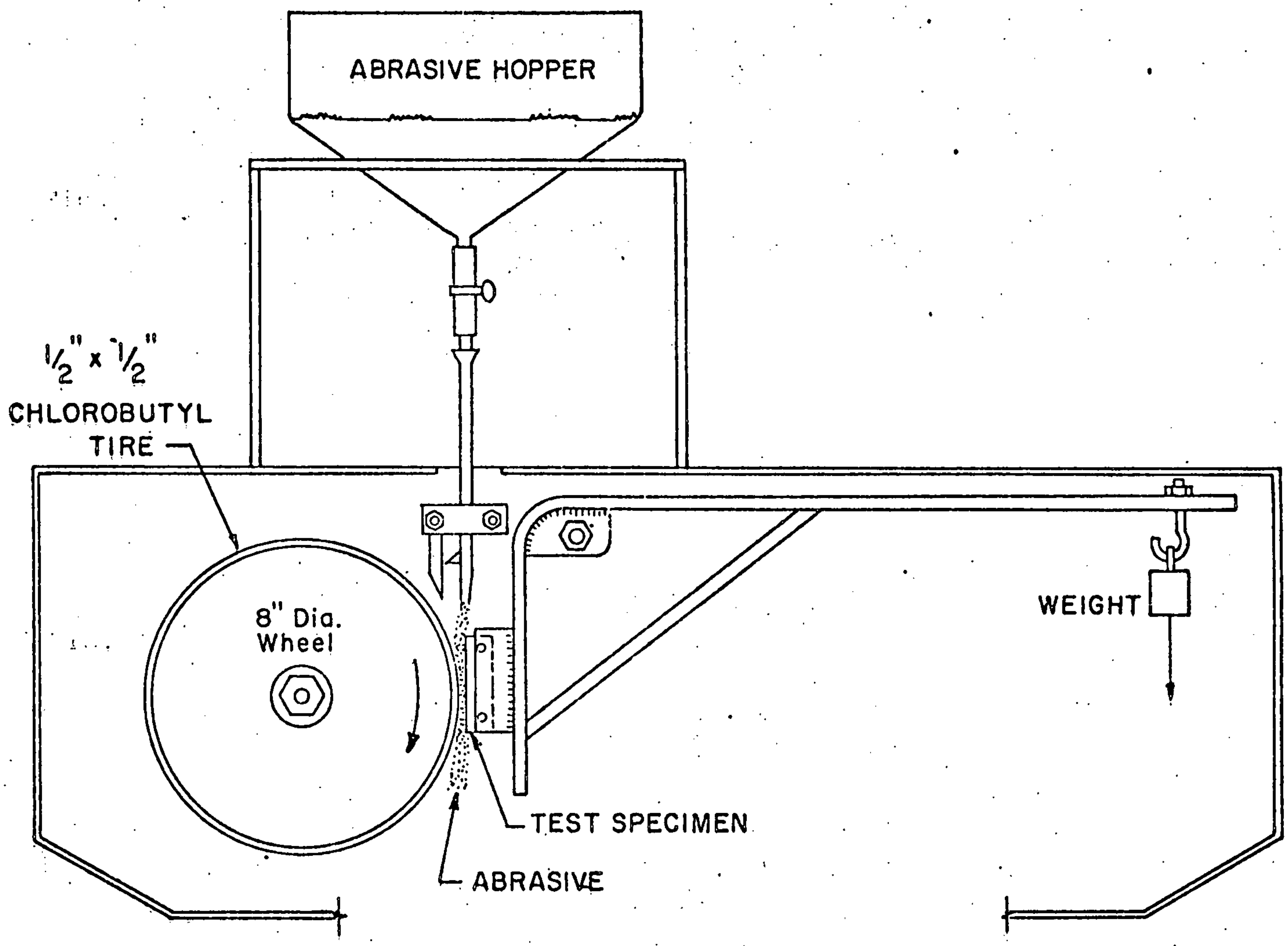


Fig. 2. Schematic Diagram of Dry-Sand Low-Stress Rubber Wheel Abrasive Wear Tester.

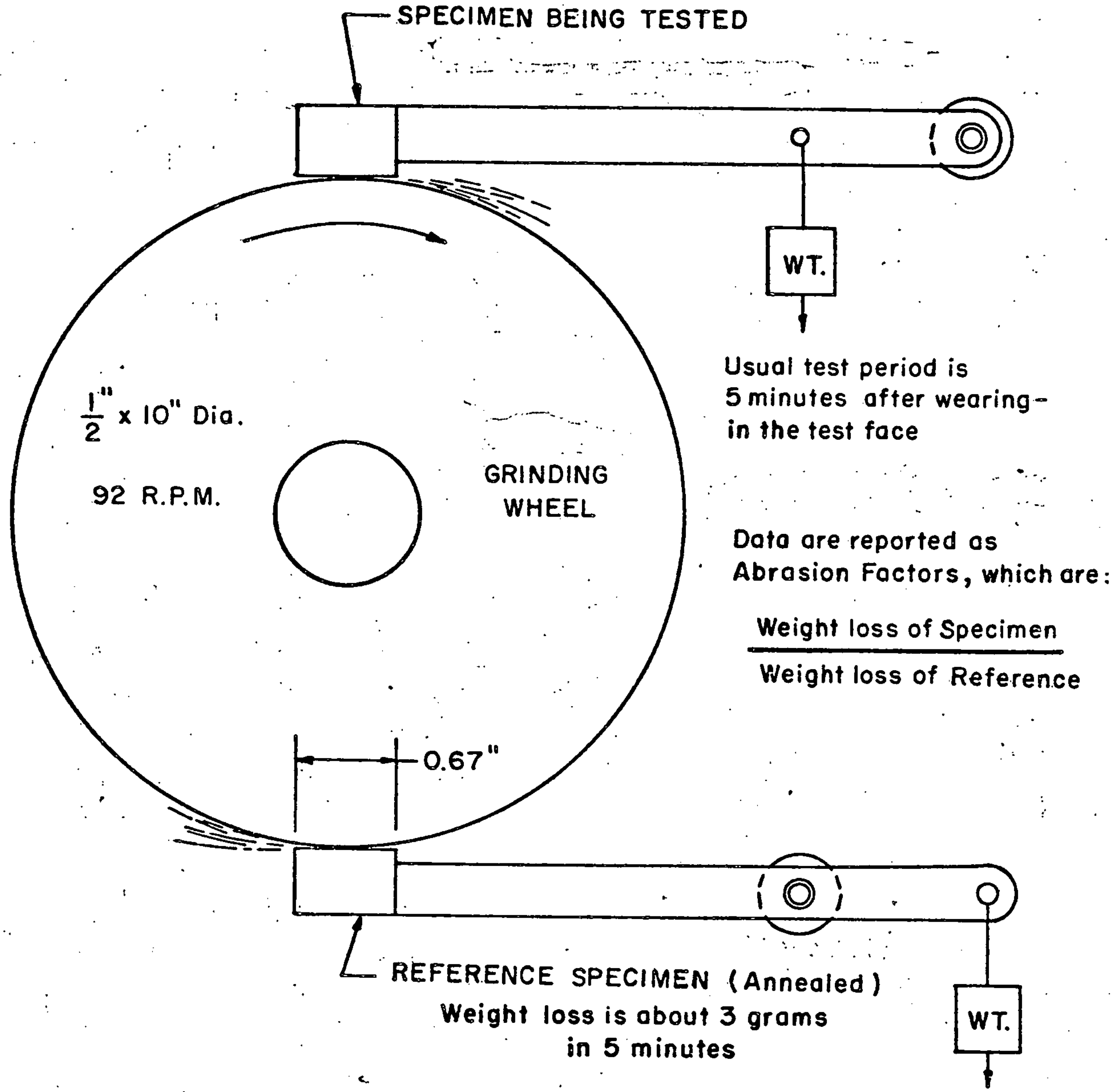


Fig. 3. Schematic Diagram of High-Stress Wear Tester.