Title

COAL LIQUEFACTION ALLOY TEST PROGRAM. QUARTERLY PROGRESS REPORT FOR THE PERIOD 1 OCTOBER TO 31 DECEMBER, 1980

Author
Levy, Alan V.

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Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

Materials & Molecular Research Division

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A. Levy

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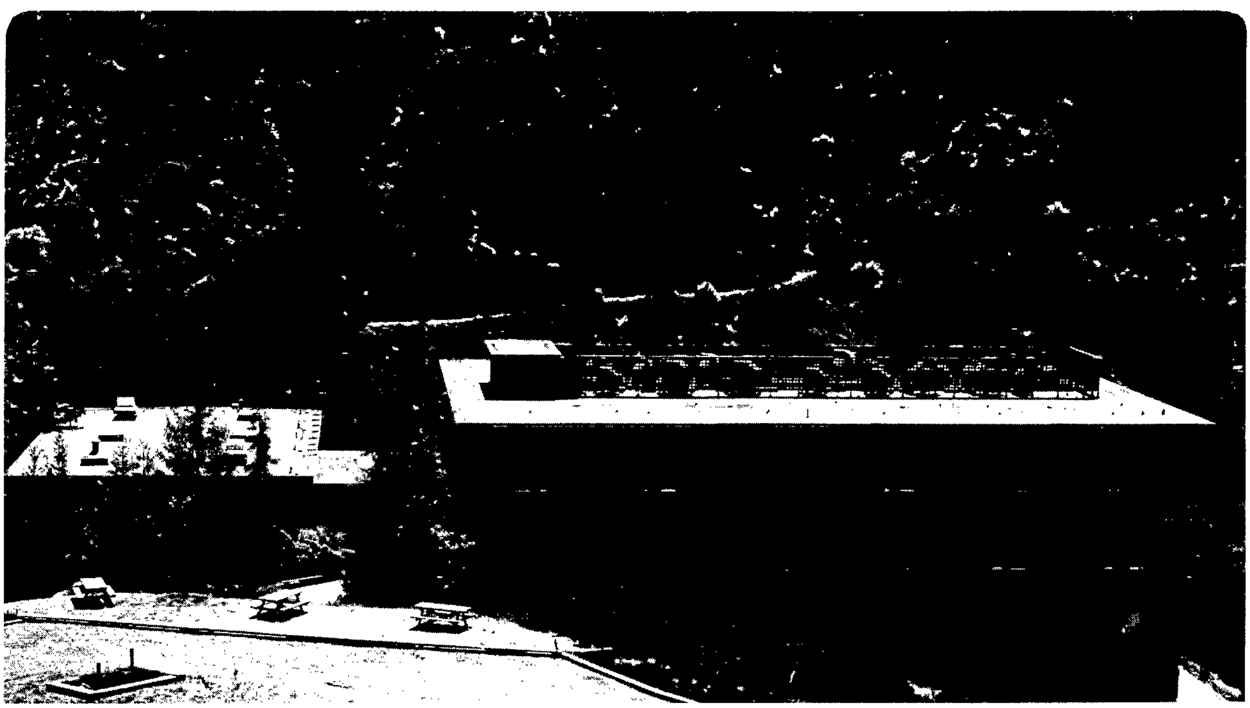

DISCLAIMER

COAL LIQUEFACTION ALLOY TEST PROGRAM

Quarterly Progress Report for the

Period 1 October to 31 December, 1980

A. Levy
Materials and Molecular Research Division
Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720

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INTRODUCTION

The objective of the program is to determine the erosion/corrosion behavior of materials used in the flow passages of liquid slurries under conditions representative of those in coal liquefaction systems. From the understanding gained from testing a number of different materials over a range of controlled operating conditions within and beyond those of currently acceptable operating practice, slurry flow operating parameter guidelines and improved performance materials selection and design criteria will be developed.

The program is being carried out by personnel from the Lawrence Berkeley Laboratory who are responsible for program management and for materials testing and analysis and from the Ralph M. Parsons Company who are responsible for slurry loop design and selection of loop operating conditions and who will contribute to behavior analyses. The Pittsburgh and Midway Coal Mining Co., SRC pilot plant at Tacoma, Washington, will also participate in the program as operators of a materials test side loop on a cooperative basis.

The program is structured to investigate the major variables inherent in the design and operation of non-aqueous liquid-solid particle slurry systems. These are:

1. flow passage geometry
2. materials of construction
3. slurry composition and properties
4. operating conditions.

Program Plan Summary

The program is being conducted in six overlapping tasks. These are:

1. state-of-the-art determination - completed
2. development and evaluation of test devices - completed
3. determination of the effects of flow passage geometry on erosion-corrosion of materials - in process
4. determination of the behavior of commerical and experimental materials - in process
5. development of an understanding of erosion-corrosion mechanisms - in process

6. establishment of system operating parameter guidelines and materials selection and design criteria - not begun.

Results from Prior Quarters

Task 1 - State-of-the-Art Determination

A literature review has been conducted and visits made to current slurry test facility and coal liquefaction pilot plant operators.

Task-2 - Development and Evaluation of Test Devices

Three different test systems have been designed and constructed at LBL. A fourth system, a 2" diameter pipe side loop being built and operated by PAMCO at the SRC pilot plant at Ft. Lewis, Washington, will be coordinated with the test program at LBL in some respects.

The three test devices at LBL are being operated and comparisons will be made of the erosion-corrosion data generated from each system in a series of coordinated tests on common materials using the same test conditions. The effect of the recirculation of the slurry on the change in size and configuration of the solid particles and on resulting erosion of the test materials has been determined. Two test systems at LBL will operate in a recirculating mode and one system in a once-through mode. The SRC side loop system will operate in a once-through mode.

Task 3 - Effects of Flow Passage Geometry

The erosion of A-53 mild steel and types 304 and 316 stainless steel have been determined as a function of passage geometry variations and operating conditions in this task.

The slurry used in the recirculating slurry loop is -200 mesh Illinois #6 pulverized coal bought to the same requirements and from the same source as that used at the SRC, Wilsonville, Alabama, pilot plant. The slurry liquid has been kerosene. Subsequently it will be SRC-Wilsonville pilot plant starter solvent, which is creosote tar distillate oil.

Viscosities of coal-kerosene slurries cover a range of solid loadings ranging from 10 to 50 wt% coal and temperatures up to 100°C have been determined.

Task 4 - Behavior of Materials

The effect of material composition of several plain carbon, low alloy, and stainless steels on erosion behavior at ambient conditions has been determined. Slurry operating conditions were varied over a range of velocities, solids loadings and low elevated temperatures. Other liquids, primarily water and other particles, primarily SiC, have also been used in the tests.

Task 5 - Erosion-Corrosion Mechanisms

The mechanisms of surface deformation and material loss by the impingement of solid particles in a slurry are being investigated in this task. Slurries varying the liquid, kerosene and water, and the particles, coal, Al_2O_3 and SiC have been tested on 1018 steel and 6061 aluminum to determine erosion behavior variations. Correlation analyses of erosion as a function of slurry and target material properties and flow conditions have been made.

Task 6 - Operating Guidelines and Materials Criteria

Activity in this task is awaiting the accumulation of sufficient data before it is begun.

DISCUSSION OF CURRENT ACTIVITIES

Task 3 - Effects of Flow Passage Geometry

A side loop, Fig. 1, was fabricated from A-53 mild steel of 1-1/2" and 1" I.D.piping with welded elbows and tested in the slurry loop for 253 hours using a 30 wt% coal-kerosene slurry. The smaller than 2" dia. pipe segments were used because after more than 2000 hr of operation in straight 2" ID pipe, no measurable amounts of erosion could be reliably measured. This was because of the low, 8-10 Fps velocity of the slurry. The 1-1/2" dia. piping increased the velocity to 25-30 Fps. At these velocities, wall thickness reductions could be made using the ultrasonic thickness gage.

Figure 2 records the amount of wall thickness reduction that occurred at various positions around the loop. The first number listed is the position number of the thickness gage measurement and the second number is the number of thousandths of material lost after 253 hours of operation. It can be seen that as the slurry velocity increased, the elbows underwent increased erosion. However, after the slurry had been turned, there was no erosion in the straight sections until the constriction from the 1-1/2" dia. pipe to the 1" dia. pipe occurred. Once the constricted area had been passed by the slurry, no erosion occurred in even the 1" dia. pipe where the velocity got up to 40 Fps. The pipe wall temperatures got up to 90°C during the test because of the frictional heating of the moving slurry.

It is interesting to note two particular geometry effects. The turbulence of the slurry upon entering the 2" elbow at the beginning of the side loop caused some measurable erosion of the elbow (position 2). However, the change from the 1" dia. pipe back to the 2" elbow at the end of the side loop created, in effect, a nozzle that directed the slurry at the 2" elbow in a manner that caused considerable erosion to occur (positioning 31, 32, 33).

The second geometry effect of note occurred at the transition of the entrance 2" dia. pipe elbow to the 1-1/2" dia. pipe. The turning slurry was directed in a manner that it impacted on one side of the 1-1/2" dia. pipe causing considerable erosion at positions 5 and 7 and none at positions 6 and 8.

Task 4 - Behavior of Materials

The slurry pot was used to determine the behavior of several types of steels that are candidates for use in coal liquefaction systems. The operation of the slurry pot has been described previously. It was 1/8" dia. tubular or solid cylinder specimens 2" long that are rotated through a slurry for 120 minutes to obtain erosion. The test rods are periodically removed from the pot and weighed to determine the amount of material that has been eroded.

A series of tests were run using A53 mild steel to establish the reproduceability of the slurry pot when the pot was completely filled with slurry and when a 1-3/4" air gap existed above the slurry. Figure 3 shows the results. Some of the air present above the slurry was eventually stirred into the slurry and apparently formed cushions around the coal particles, reducing their erosive potential and causing a spread in the data (lower series of data points). When the pot was full, the erosive coal particles were more effective in removing material and the spread in the data decreased. In all subsequent tests, the slurry pot was operated full.

Figure 4 compares the erosion behavior of 2 plain carbon steels and a low alloy steel. A 100% difference in the amount of erosion after 120 minutes of exposure occurred. The plain carbon steel had near the same hardness, A53-RB94 and 1075-RB98, but showed a 100% difference in erosion weight loss. The 2-1/4 Cr-1Mo steel was considerably softer, RB72, yet eroded midway between the other 2 steels. The lack of correlation between hardness and erosion in slurry erosion has been consistently observed.

Figure 5 compares the erosion behavior of 3 steels of different chromium content. A 65% difference in erosion occurred between the highest and lowest amount of erosion. Hardness of all 3 steels was near the same, ranging from

RB93 to RB97. As the chromium content increased, the amount of weight loss decreased. The reason for this trend is being investigated.

Figure 6 shows how 4 different 300 series stainless steels eroded compared to A53 mild steel. The mild steel eroded the most, but all but the 316SS eroded fairly nearly the same. The molybdenum containing 316SS eroded 39% less than the A53 mild steel.

A 67% difference in erosion occurred between representative samples of all of the types of steels that were tested. Again, no relation with hardness was evident. In fact, at this point, there is no basis for the distribution of erosion behavior among the alloys. Metallography is currently in progress on each of the eroded specimens to provide more information to aid in interpreting the data.

Task 5 - Erosion Mechanisms

The jet impingement tester, see Fig. 8, was used to determine the behavior of 1018 mild steel and 6061-T6 aluminum under various test conditions at ambient temperature. The slurry was directed out of 1/8" dia. nozzle at a flat specimen held at a pre-set impingement angle. The coal slurry and other slurries used in this test series were only used once, compared to the recirculating slurry flows in the other two test devices used to date in the program. The specimens were of sheet material, 0.75 in. x 1.25 in. x 0.125 in. A typical test directed approximately 20 gal. of slurry at the specimen in a ten to fifteen minute exposure period, depending on the velocity.

Figure 9 shows the effect of velocity on 1018 mild steel and 6061-T6 aluminum. The aluminum was selected to represent a medium strength material that would erode at a measurable rate using a comparatively low amount of slurry. While the jet impingement tester's slurry tank can hold 80 gal. of slurry, to use up that much slurry in a single test and have to dispose of it afterwards would be a problem. As it turned out, the 1018 mild steel could be eroded to a measurable amount with the same near 20 gal. of slurry that eroded the aluminum.

Both materials eroded at near the same rate at the lower end of the velocity range, 40 Fps, but a significant divergence occurred as the velocity was increased. The velocity exponent for both materials was approximately 2.0, indicating that erosion of ductile metals in liquid slurries relates to the kinetic energy of the eroding particles. In gas solid particle erosion of the same type, i.e., a stream of particles directed at a flat specimen surface, the velocity exponent varies from 2.3 up to greater than 3. This indicates that liquid-solid particle erosion differs from gas-solid particle erosion. Other evidence of a major difference in mechanism of erosion was also obtained in this test series.

The effect of the weight concentration of the coal in the kerosene had a significant effect on the erosion of the aluminum alloy. In Fig. 10 erosion rates are plotted for slurry concentrations ranging from 10 to 30 wt% coal in kerosene. In order to get a measurable amount of erosion at the lower coal concentrations, the velocity was increased to 75 Fps, which is somewhat high for slurry flows. The effect shown in Fig. 10 may be attenuated at lower velocities. The curve is flattening out at the 30 wt% coal and greater slurry concentrations that are used in liquefaction systems; this fact also lessens the importance of coal concentration differences on erosion behavior.

Figure 11 shows the effect of the angle of impingement on the erosion of the aluminum alloy. The results were very surprising and strengthened previous observations that the mechanism of erosion in liquid-solid particle erosion is different from that observed in gas-solid particle erosion. For comparison, a classic curve for gas-solid particle erosion of a ductile metal was put in Fig. 11. The liquid slurry erosion curve shows an increasing rate of erosion with increasing impingement angle up to a maximum at 90^{o}. The gas-solid particle erosion curve shows a peak at a rather shallow angle. Further tests are in progress to document this unexpected behavior further using different materials and test conditions.

One of the methods that was used to obtain more insight into the erosion mechanisms was to test the aluminum alloy with alternate slurries which would be more erosive and easier to handle so that more tests could be carried out in a reasonable time period. A series of slurries was prepared that used water for the liquid and various combinations of Al_2O_3 and SiC particles for the erodent. Figure 12 plots the results of these tests as a function of impingement angle. It can be seen that the same type of curve as was determined with the coal-kerosene slurry occurred in the mineral-water slurry series with maximum erosion occurring at 90^{o}. The increasing amount of erosion with increasing amount of SiC in the Al_2O_3-SiC mixture indicates that in liquid-solid particle erosion, different hard particles result in different rates of erosion. In gas-solid particle erosion, no difference in erosion potential was determined between Al_2O_3 and SiC particles.

Also, the harder mineral particles (than coal) and the less viscous, less lubricating liquid (water compared to kerosene) results in a second order of magnitude increase in the erosion rate of the 6061-T6 aluminum. The effects of changes in viscosity and lubricating of the slurries on erosion is currently being studied.

FIGURES

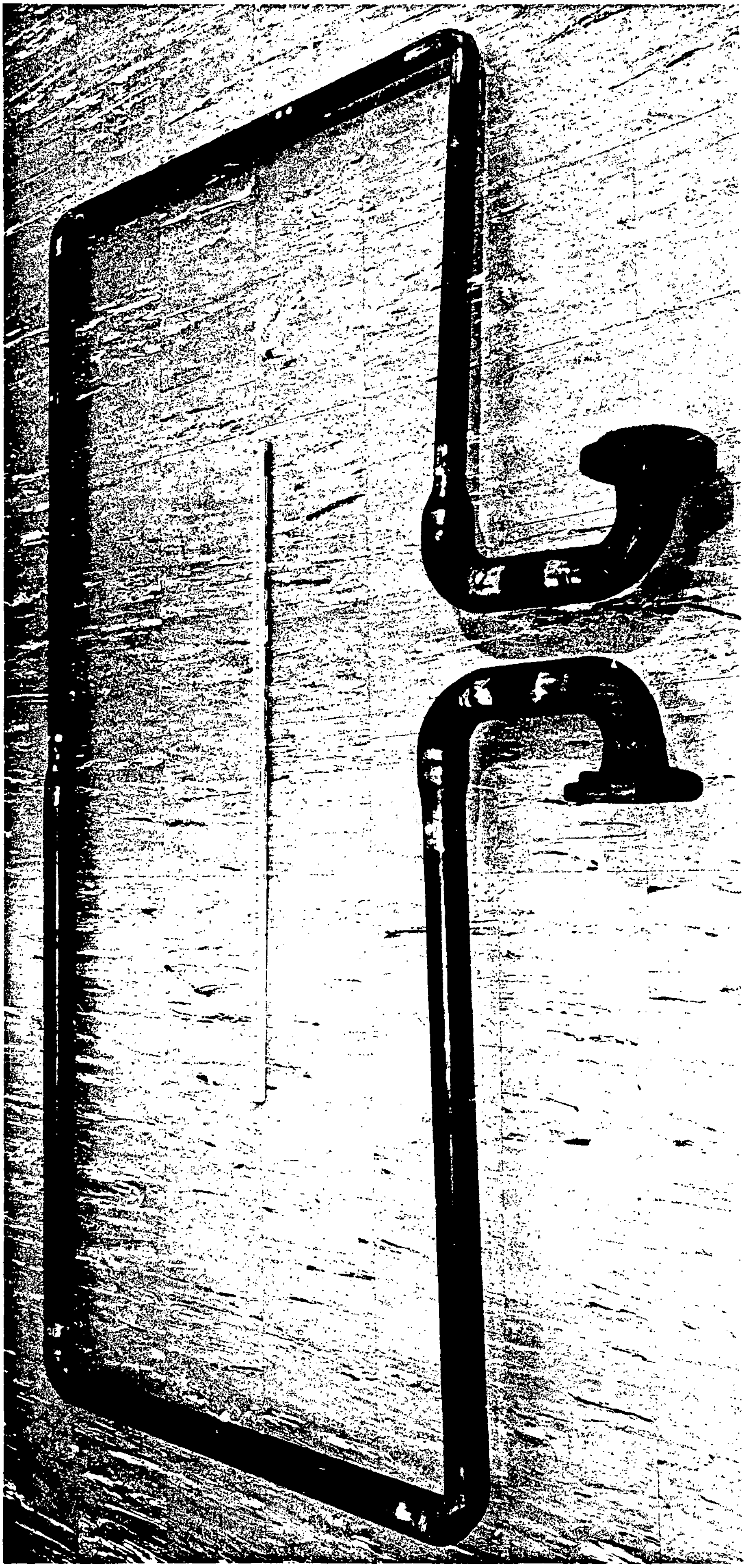

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Figure 1

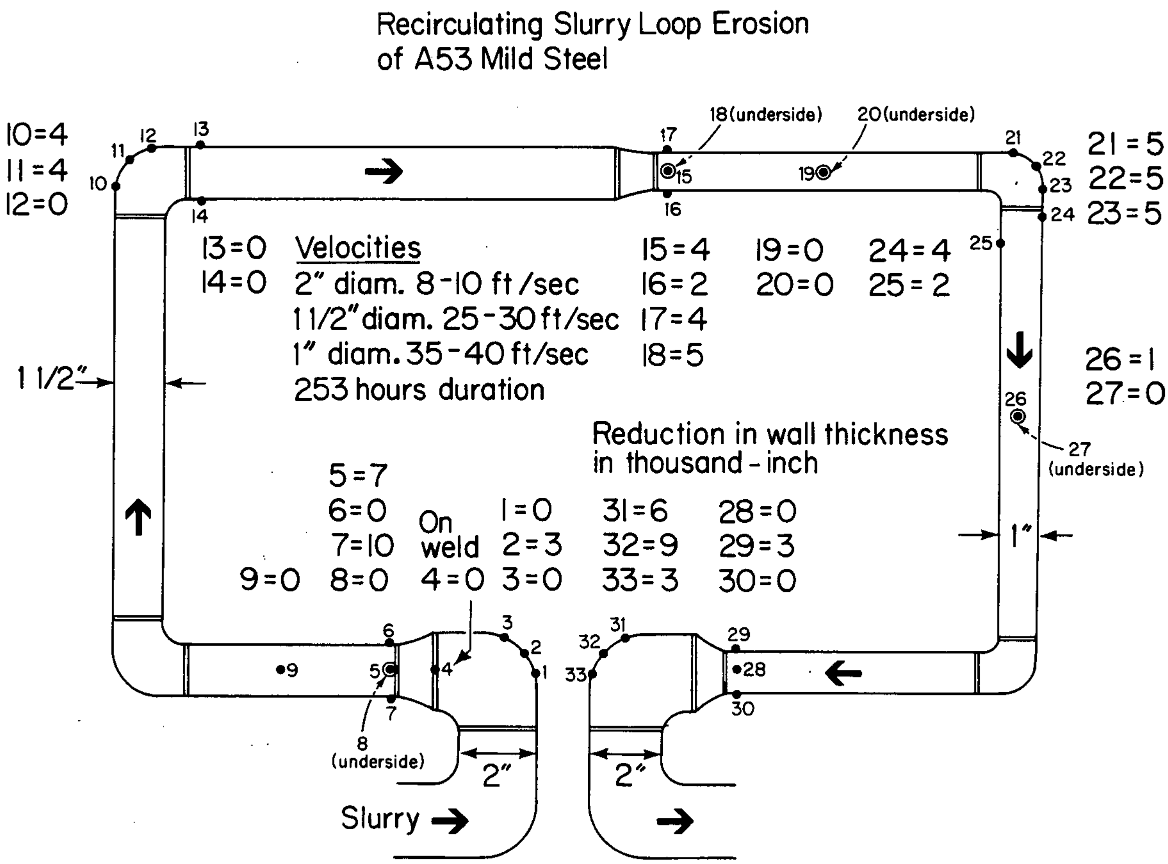

Figure 2

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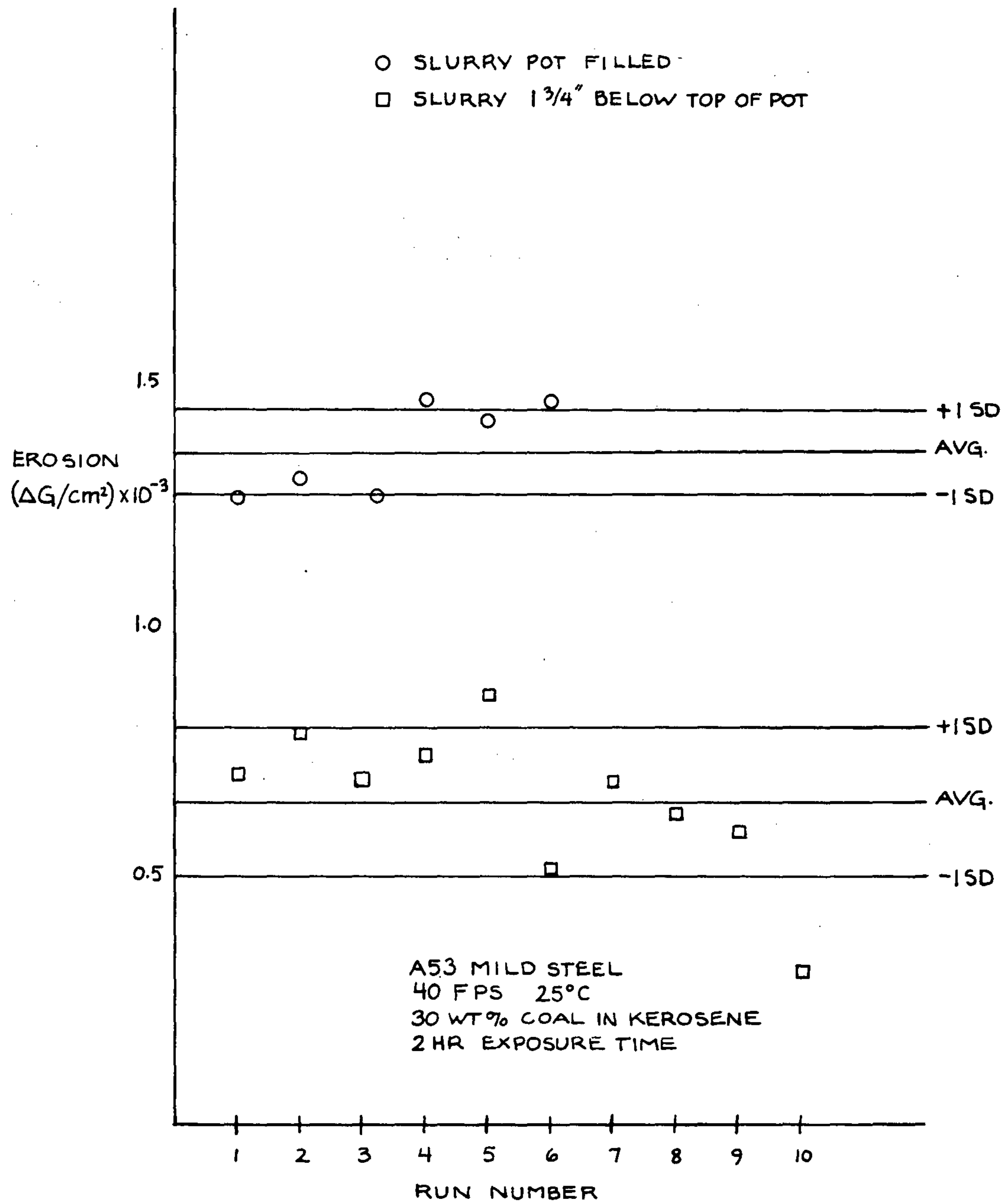

Figure 3

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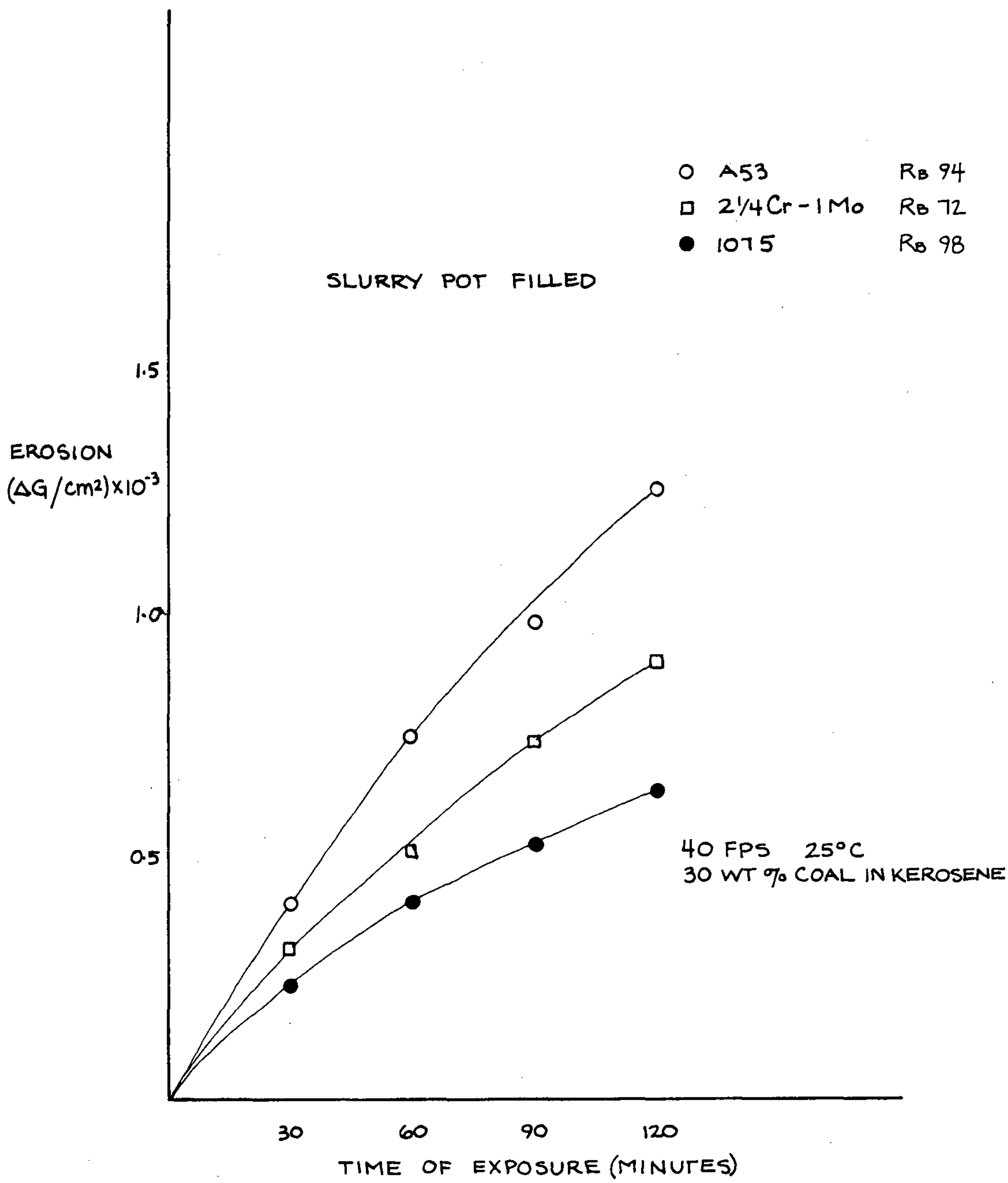

Figure 4

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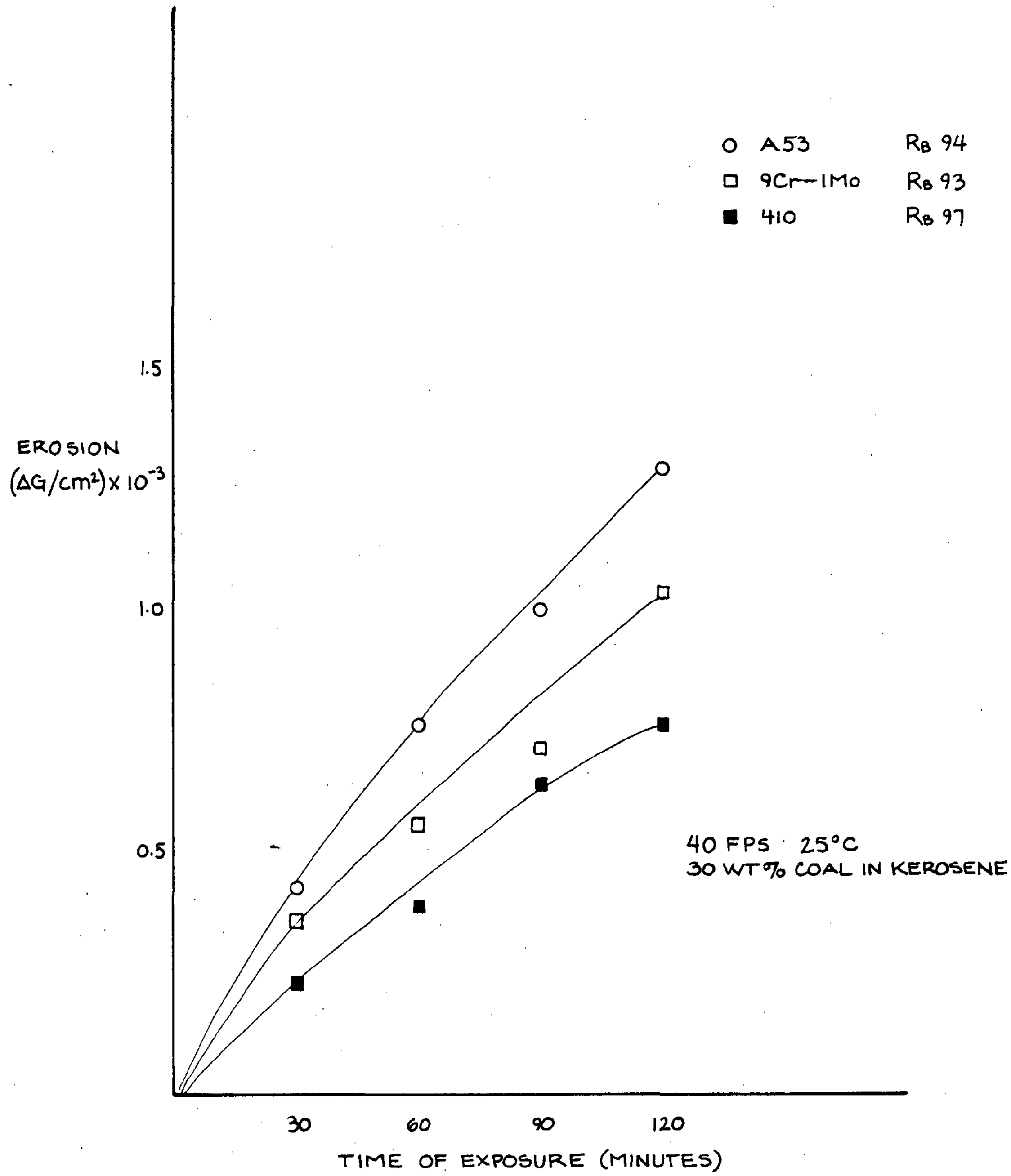

Figure 5

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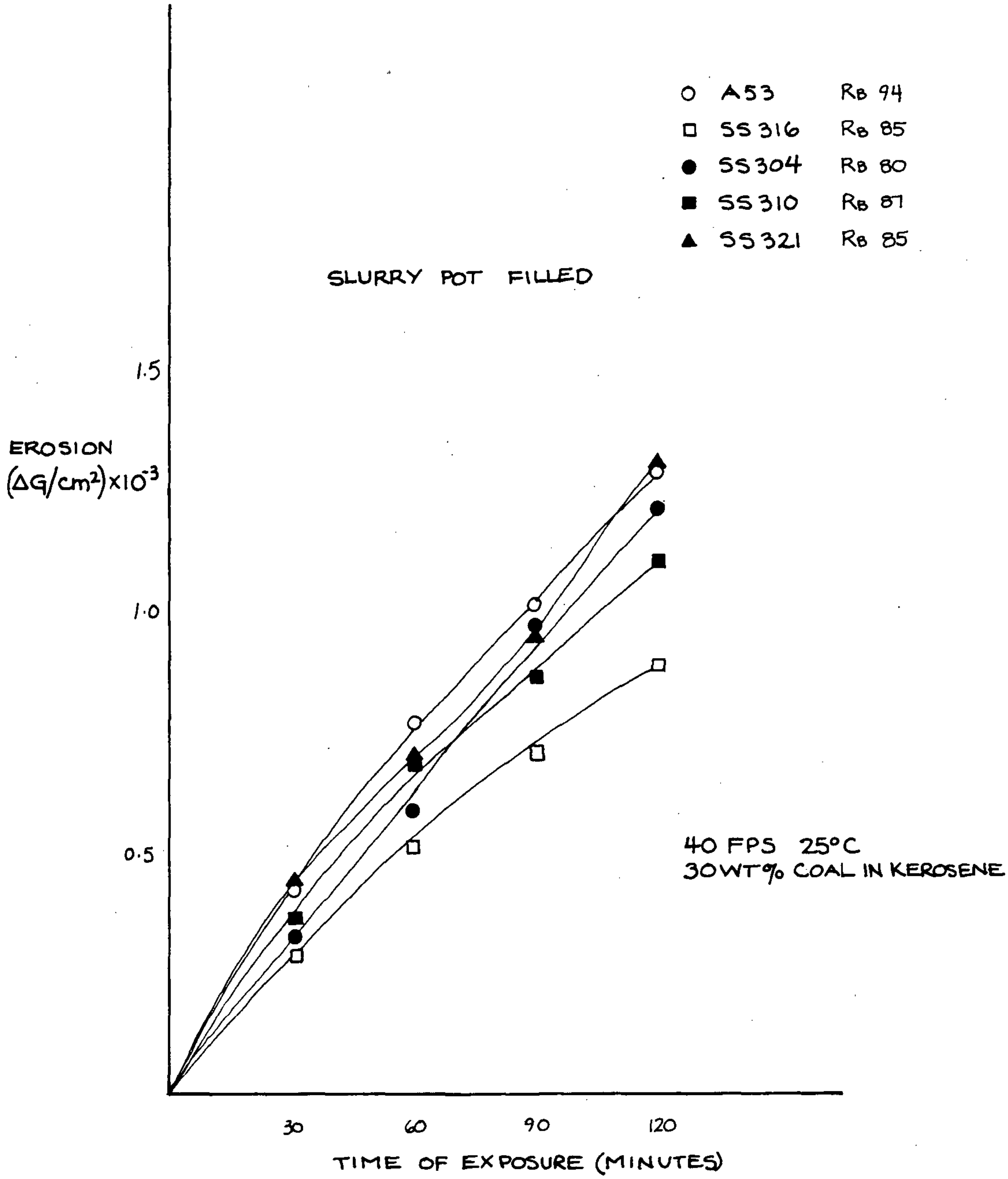

Figure 6

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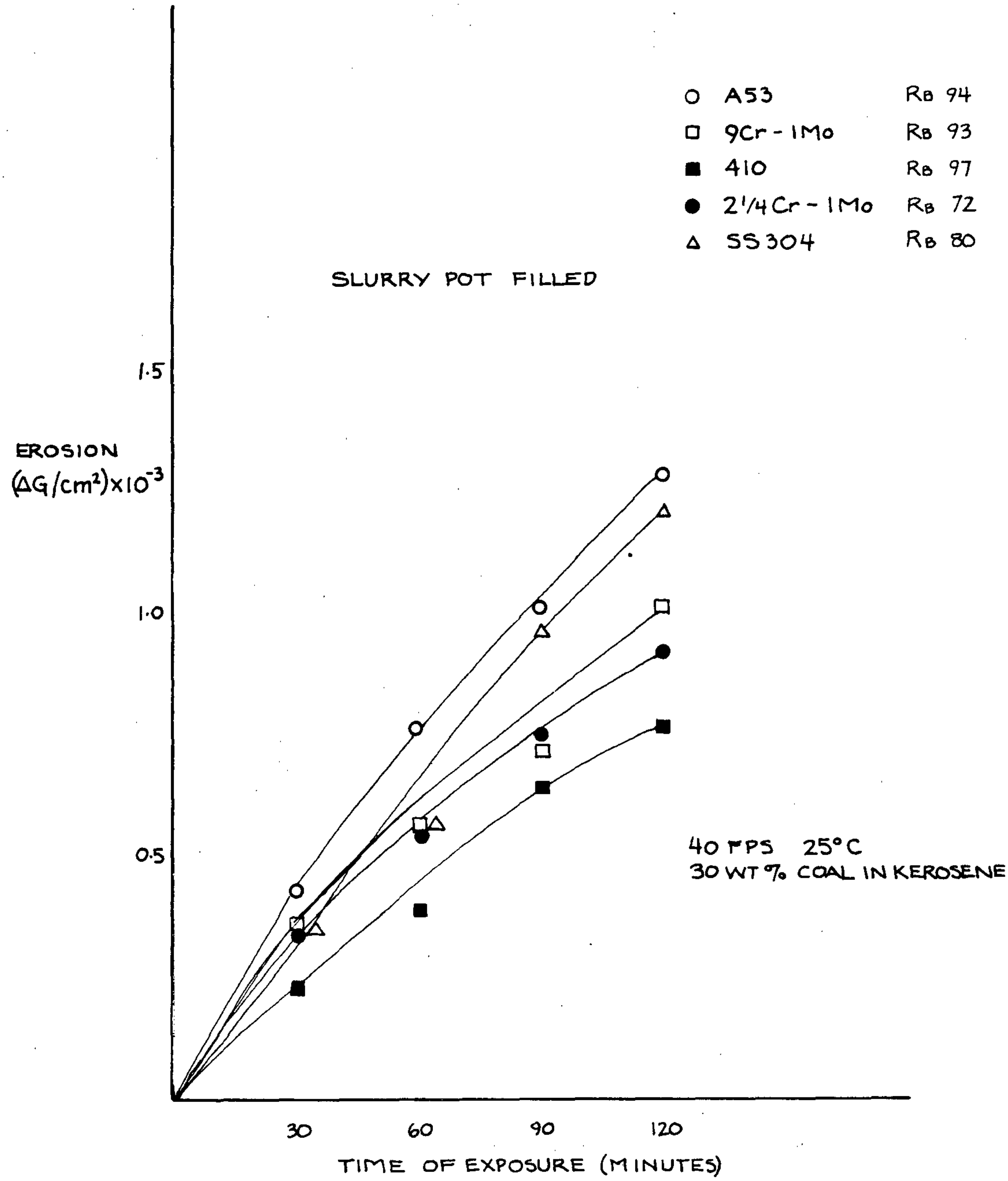

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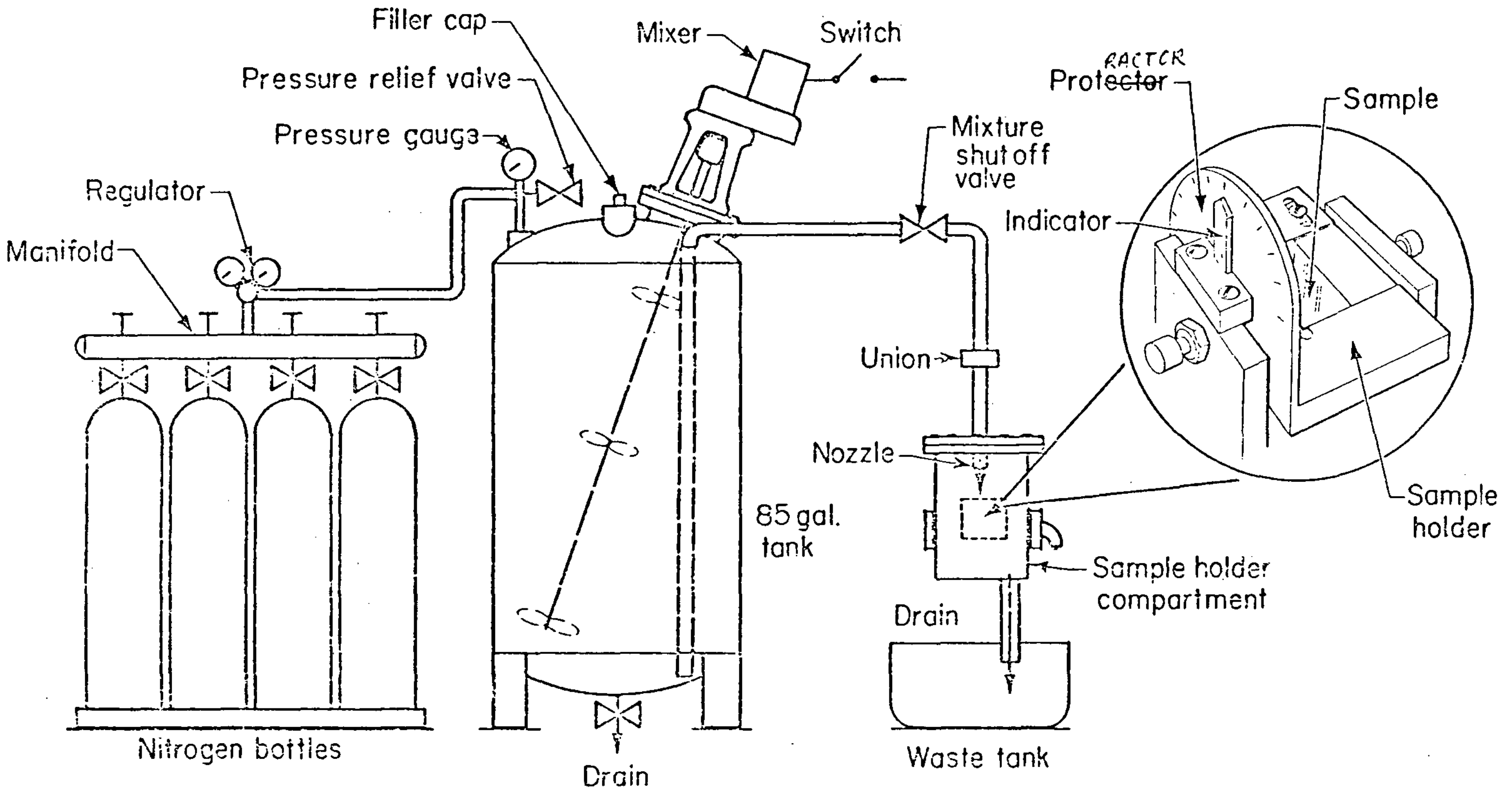

Figure 8

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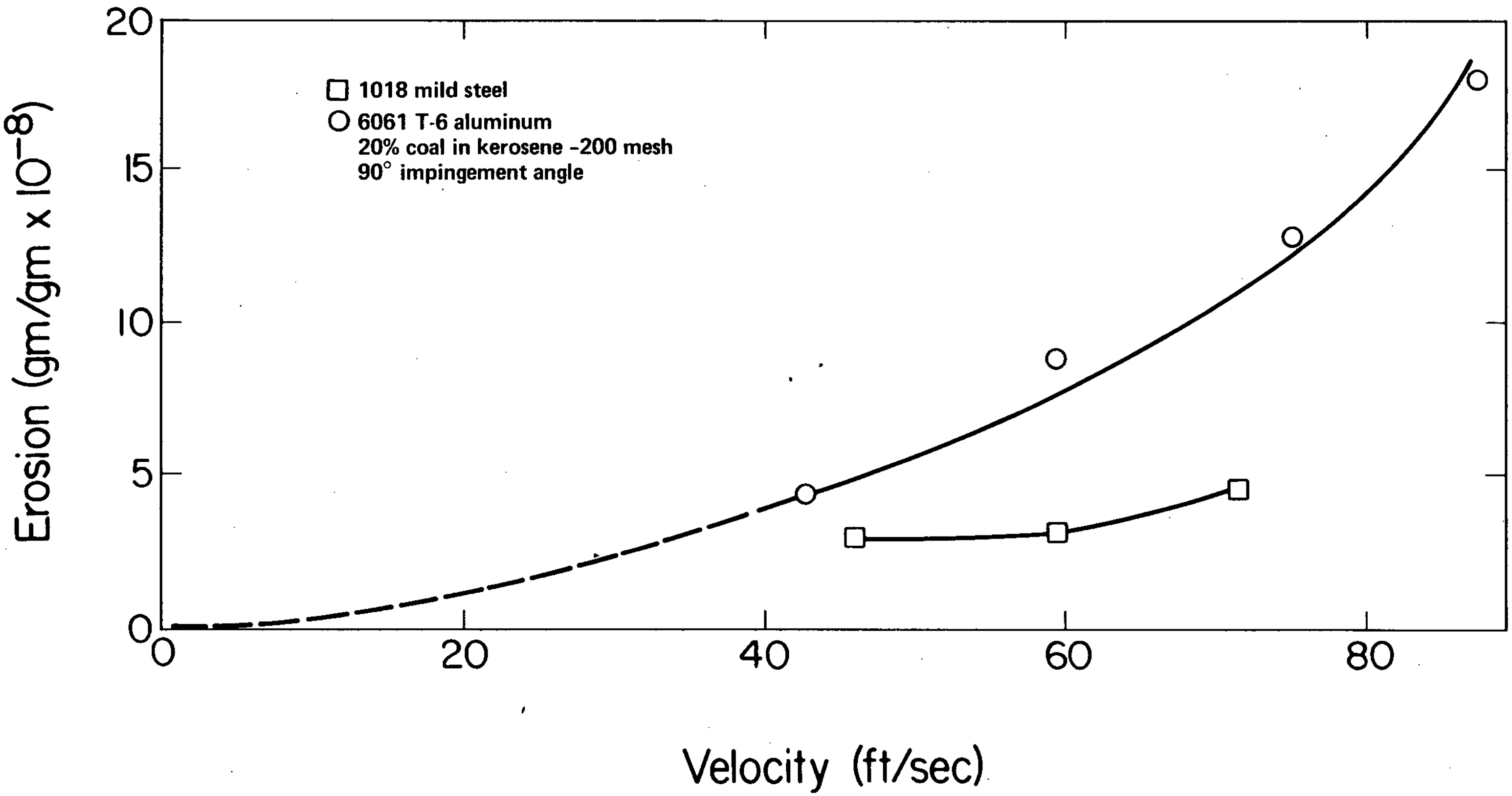

Figure 9

XBL 8012-2450

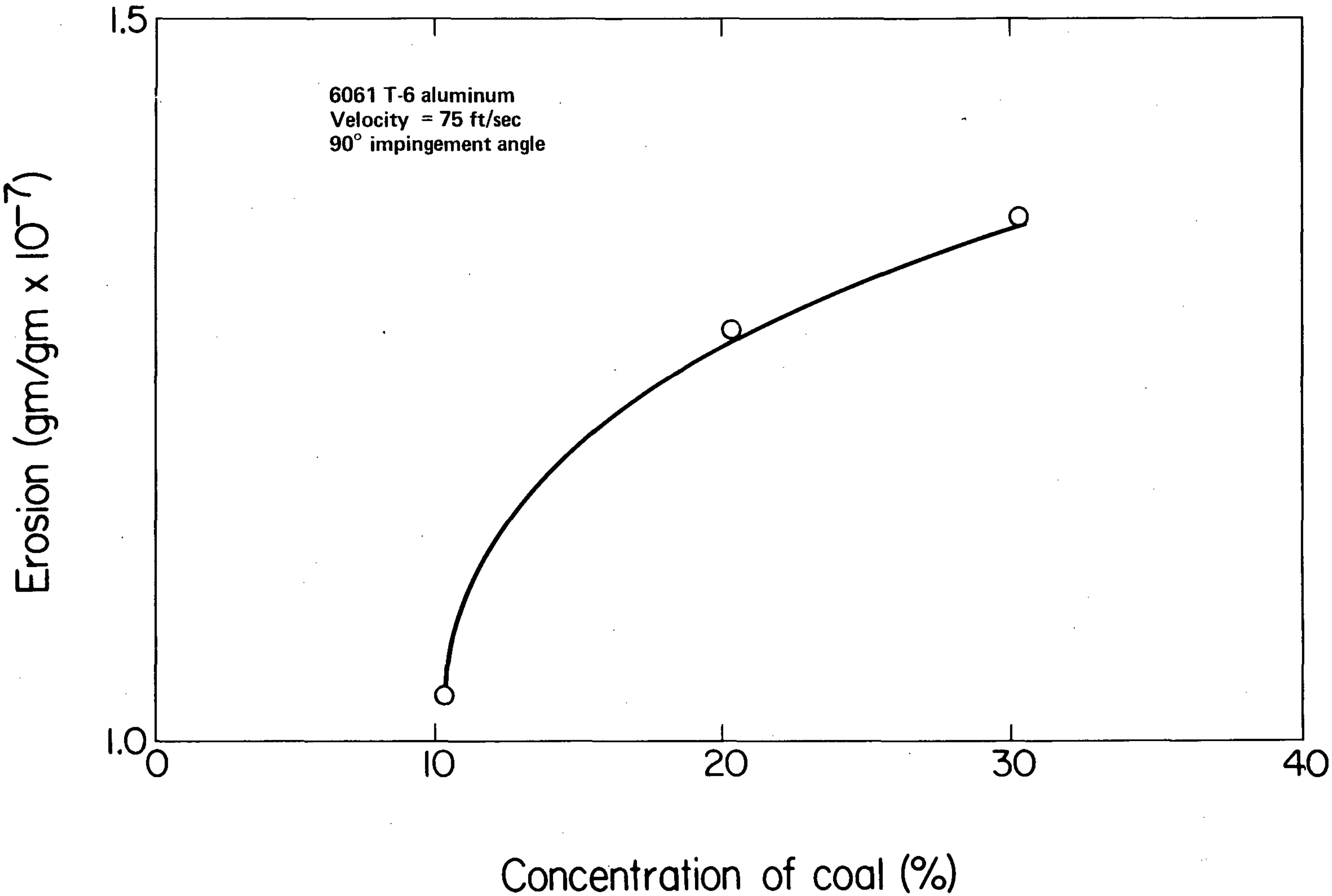

Figure 10

XBL 8012-2452

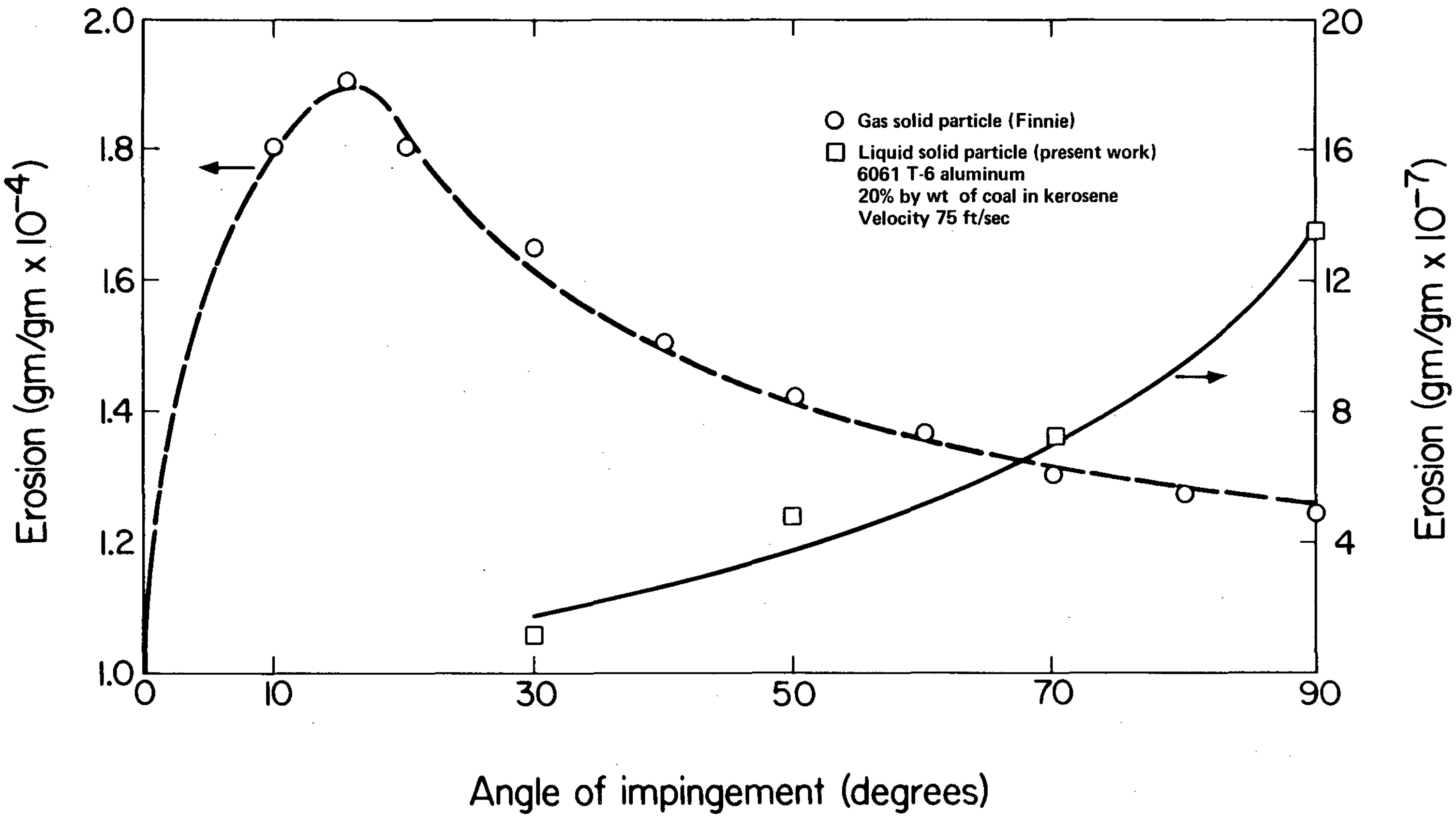

Figure 11

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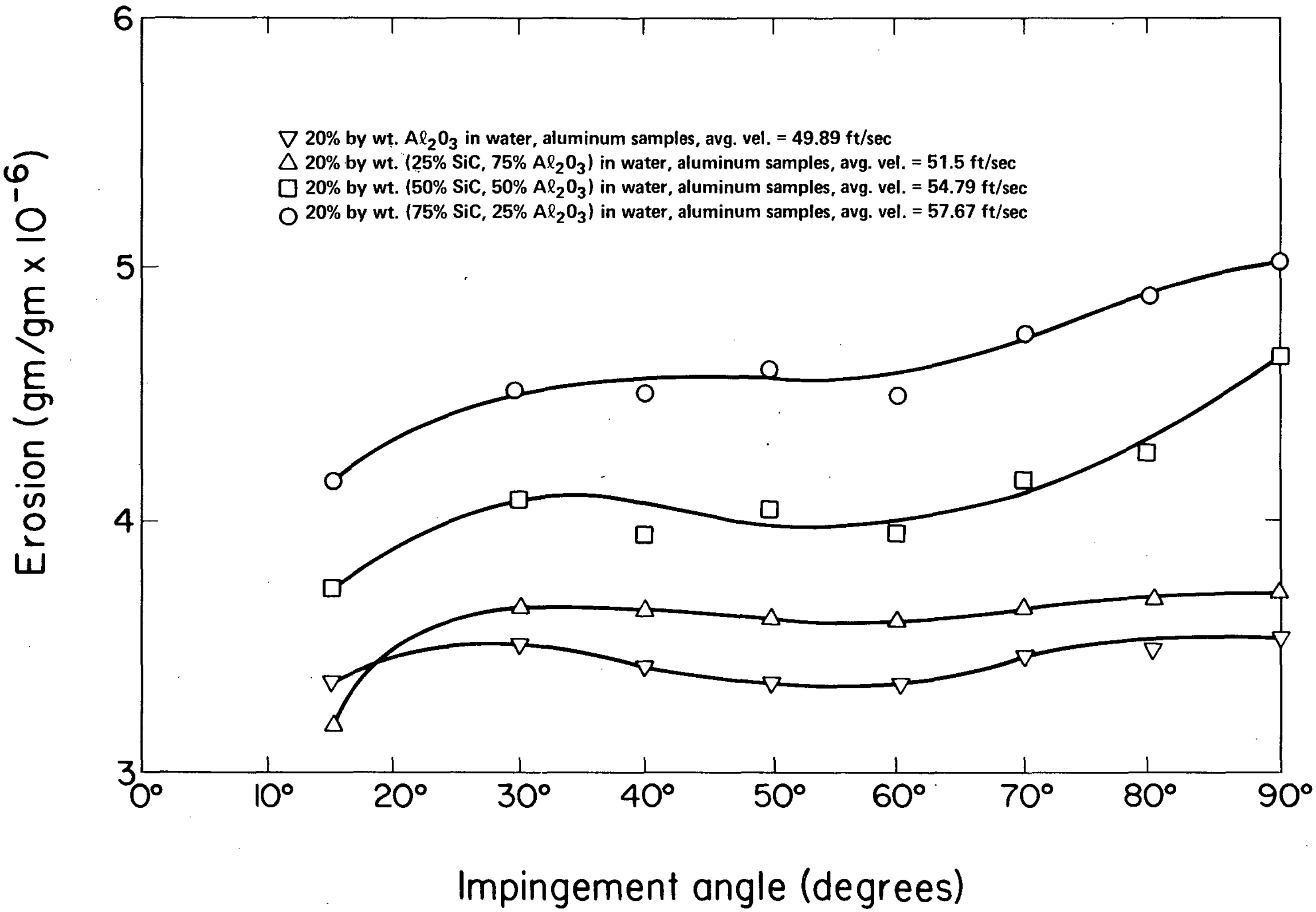

Figure 12

XBL 8012-2457

TECHNICAL INFORMATION DEPARTMENT
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720