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THE USE OF WETTING AGENTS IN CLAY BODIES

BY

NATHAN R. SEWELL Jr.

A

THESIS

submitted to the faculty of the

SCHOOL OF MINES AND METALLURGY OF THE UNIVERSITY OF MISSOURI

in partial fulfillment of the work required for the

Degree of

MASTER OF SCIENCE IN CERAMIC ENGINEERING

Rolla, Missouri

1947

Approved by Paul T. Herold
Professor of Ceramic Engineering

ACKNOWLEDGEMENT

The author is indebted to Dr. Paul G. Herold for his valuable assistance in this work.

CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

INTRODUCTION

It has been observed that one of the weak points in the present method of commercially preparing stiff mud bodies is the de-airing process, which involves passing them thru a vacuum chamber. Difficulties in maintaining a good vacuum, power costs, and work stoppages due to clogged vacuum chambers, are some of the problems. It was thought that perhaps a very definite contribution could be made in the field of ceramic engineering if some method could be devised for preparing a workable ceramic body of good dry and fired properties without the use of a vacuum chamber.

In attacking the problem, it was remembered that the ancient Chinese achieved the desired properties in their clay bodies through aging. It is now generally agreed that the advantages gained by aging a clay-water mass are due to the more complete distribution of the water, which is accomplished as a result of the long time interval involved. The problem is to find a way to eliminate both aging and de-airing, by adding compounds or mixtures which are better wetting agents than water, due to their lower surface tension.

REVIEW OF LITERATURE

Bartell[1] defines wetting as "that phenomenon which occurs when a solid phase and a liquid phase come into contact in any manner, so as to form a solid-liquid interface". He defines "degree of wetting" as "the amount of change in free surface energy which occurs when the solid and liquid are brought together". So with these definitions in mind we are no longer concerned with what is or is not a wetting agent, but rather the degree of wetting

(1) Bartell, F. E. Wetting of solids by liquids. Colloid Chemistry. Alexander, Jerome. Vol. III. N. Y., Chemical Catalog Co., 1931. pp. 41-58.

which we can expect from a liquid.

Whittemore and Bull[2] found that the use of an organic material commercially known as Plasticade improved the properties of three clay bodies. Specifically, it improved the plastic properties, increased the strength of both dried and fired ware, and decreased the water of plasticity, the pore water, the shrinkage, and the absorption.

Harrington[3] reviews the benefits to be derived from the introduction of soda ash into structural clay products. These include decreased water of plasticity, increased dry strength, decreased power consumption, and lower maturing temperature, with consequent decreased firing time.

Schurecht[4] improved the dry strength, drying shrinkage, fired strength, and absorption of a New York Chemung clay by pugging with steam and hot water, and by additions of soda ash in connection with steam pugging.

Schurecht[5] improved the drying behavior of several clays by the addition of 0.2% of various wetting agents, including iron shloride, sodium chloride, hydrochloric acid, and soda ash.

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(2) Whittemore, J. W., and Bull, F. W. Method for improving the physical properties of clays. Journal American Ceramic Society. Vol. 20, pp. 261-265 (1937).

(3) Harrington, H. W. Use of soda ash for structural clayware production by Barker-Truog process. Bulletin American Ceramic Society. Vol. 22, No. 3, pp. 57-60 (1943).

(4) Schurecht, H. G., McMahon, J. F., and Lampman, C. M. Effect of steam and hot water with soda ash and a wetting agent on properties of clay. Journal American Ceramic Society. Vol. 25, pp. 346-351 (1942).

(5) Schurecht, H. G., and McMahon, J. F. Testing and improving the drying behavior of clays. Journal American Ceramic Society. Vol. 25, pp. 422-424 (1942).

Lucas[6] has suggested that the advantages derived from a vacuum are not so much due to elimination of the air in the body as to an increase in the vapor tension of the water, due to the decrease in pressure. He points out that this increased vapor tension permits more thorough distribution of the water throughout the clay-water mass. Dr. Lucas found that essentially the same results were achieved in a chemical stoneware body by de-airing, aging for ninety days, and holding at a temperature of 90° Centigrade for twenty-four hours; with respect to porosity, dry strength, and fired strength. He proves through laboratory tests and plant observations that the product of vapor tension and time is the decisive factor in the development of maximum plasticity and workability.

DISCUSSION

CLAYS

In the selection of the clays for experimental work, an attempt was made, in a general way, to cover the field of ceramics. The first clay selected was a red surface clay from Jackson, Missouri, having small grain size and high plasticity, and maturing at about cone 4. The second test body was a semi-vitreous whiteware body maturing at cone 8-9, and having the following composition:

30% Potters' Flint
15 Keystone Feldspar
30 Georgia Kaolin
18 Florida Kaolin
5 Kentucky #12, A-F (Black Ball) Ball clay
2 Whiting

(6) Lucas, J. M. Deairing of clay. British Clayworker. Vol. 54, No. 647, pp. 254-257 (1946).

The third was a cone 14 fireclay refractory body of the following composition:

18% 4-10 mesh grog
49 semi-flint clay (through 6 mesh)
33 flint clay (through 3 mesh)

WETTING AGENTS

The four wetting agents selected were Oleic acid, Du Pont Product BC, Du Pont MP-189-S, and Du Pont Retarder LA. The investigation was not intended as an index to the comparative values of various wetting agents, but rather to determine whether or not wetting agents as a class of chemicals could effect improvement.

Oleic acid is a carboxylic acid having the formula $CH_3 \cdot (CH_2)_7 \cdot CH:CH \cdot (CH_2)_7 \cdot COOH$. It melts at 14° Centigrade, boils at 286° Centigrade, is insoluble in water and soluble in alkalies.

Du Pont Product BC is liquid at ordinary temperatures, and Retarder LA is a paste. Du Pont MP-189- S is a liquid consisting of saturated hydrocarbon sodium sulfonates and inorganic sodium salts. It has a pH of 9.1, a surface tension at 25° Centigrade of 25.7 dynes per centimeter, and is soluble in alkaline, acid, or distilled water.

The wetting agents were added on the basis of the water content of the body in the following percentages:

0.5%
1.0
2.0
4.0
8.0
16.0
32.0

EXPERIMENTAL METHOD

For each clay and every composition, ten pounds of

the clay were mixed dry for five minutes in a hotel food mixer, then the wetting agent added, followed by five minutes more of mixing. With the red clay and the whiteware body, two pounds (20%) of water were then added, and the mixing continued for fifteen minutes. In the case of the refractory body, one and one half pounds (15%) of water were added. Each batch was stored overnight and test pieces made according to specifications of the American Society for Testing Materials(7). The same method was followed for a de-aired body of each of the three clay compositions, with the exception that no additions of wetting agents were made, and they were de-aired in a vacuum chamber for fifteen minutes at 28.5 inches of mercury.

The pieces were then air dried for thirty hours and tested for linear drying shrinkage and dry transverse strength, according to American Society for Testing Materials specifications. At this time the dry volume measurements were made in a kerosene volumeter, after soaking under vacuum for two hours in kerosene.

The red clay pieces were fired to cone 5 in thirty-one hours. The whiteware body was fired to cone 8-9 in thirty hours and thirty minutes, and the firecla refractory body was fired to cone 14 in twenty hours. All pieces were fired in a "Globar" resistance furnace under the same conditions, and cones placed throughout the kiln indicated that the pieces in each body received exactly the same heat treatment. After firing, the linear firing shrinkage, volume firing shrinkage, fired transverse strength, apparent porosity, and per cent absorption were measured and calculated according to specifications of the American Society for Testing Materials.

(7) McNamara, E. P. Ceramics. Vol. 111. State College, Pa., Pennsylvania State College, 1939. pp. 300-324.

For all tests the results reported are an average of ten samples. The results are presented in the tables and graphs which follow.

MISSOURI RED SURFACE CLAY

DRY LINEAR SHRINKAGE

De-aired		4.0%	+0.1,-0.7
0.5%	Oleic acid	5.1	+0.7,-1.0
0.5	Du Pont Product BC	5.2	+0.6,-0.2
0.5	Du Pont MP-189-S	5.1	+0.7,-0.1
0.5	Du Pont Retarder LA	4.0	+1.0,-0.7
1.0	Oleic acid	5.7	+1.0,-0.7
1.0	Du Pont Product BC	5.2	+0.6,-1.1
1.0	Du Pont MP-189-S	5.3	+1.4,-0.3
1.0	Du Pont Retarder LA	4.3	+0.7,-0.2
2.0	Oleic acid	4.7	+0.3,-0.6
2.0	Du Pont Product BC	5.1	+0.7,-0.1
2.0	Du Pont MP-189-S	6.0	+0.7,-0.2
2.0	Du Pont Retarder LA	4.4	+0.6,-0.3
4.0	Oleic acid	5.7	+1.0,-0.7
4.0	Du Pont Product BC	5.2	+0.6,-1.1
4.0	Du Pont MP-189-S	6.1	+1.5,-1.1
4.0	Du Pont Retarder LA	4.6	+0.4,-0.5
8.0	Oleic acid	4.8	+1.0,-0.7
8.0	Du Pont Product BC	5.7	+1.0,-0.7
8.0	Du Pont MP-189-S	5.6	+1.1,-0.6
8.0	Du Pont Retarder LA	3.7	+0.4,-0.4
16.0	Oleic acid	5.1	+0.7,-1.0
16.0	Du Pont Product BC	4.1	+0.0,-0.0
16.0	Du Pont MP-189-S	4.3	+0.7,-0.2
16.0	Du Pont Retarder LA	3.9	+0.2,-0.6
32.0	Oleic acid	4.9	+0.1,-0.8
32.0	Du Pont Product BC	4.2	+0.8,-0.1
32.0	Du Pont MP-189-S	4.6	+0.4,-0.5
32.0	Du Pont Retarder LA	3.9	+1.1,-0.6

MISSOURI RED SURFACE CLAY

FIRED LINEAR SHRINKAGE

De-aired		2.7%	+2.2,-1.1
0.5%	Oleic acid	3.6	+1.4,-1.9
0.5	Du Pont Product BC	3.6	+1.4,-1.1
0.5	Du Pont MP-189-S	2.4	+1.4,-1.6
0.5	Du Pont Retarder LA	4.1	+3.3,-2.5
1.0	Oleic acid	6.2	+0.5,-1.2
1.0	Du Pont Product BC	2.2	+2.0,-1.4
1.0	Du Pont MP-189-S	4.1	+3.4,-2.4
1.0	Du Pont Retarder LA	3.5	+3.1,-3.5
2.0	Oleic acid	5.3	+1.3,-1.2
2.0	Du Pont Product BC	3.9	+1.1,-1.4
2.0	Du Pont MP-189-S	2.4	+1.5,-1.0
2.0	Du Pont Retarder LA	4.2	+2.4,-2.6
4.0	Oleic acid	5.7	+1.0,-0.7
4.0	Du Pont Product BC	3.6	+1.4,-2.8
4.0	Du Pont MP-189-S	1.7	+1.6,-0.9
4.0	Du Pont Retarder LA	1.7	+1.6,-0.9
8.0	Oleic acid	5.7	+1.0,-0.7
8.0	Du Pont Product BC	3.6	+1.4,-2.8
8.0	Du Pont MP-189-S	1.7	+1.6,-0.9
8.0	Du Pont Retarder LA	0.2	+0.1,-0.1
16.0	Oleic acid	4.4	+0.6,-1.1
16.0	Du Pont Product BC	3.9	+1.8,-1.4
16.0	Du Pont MP-189-S	3.3	+2.4,-1.4
16.0	Du Pont Retarder LA	3.2	+1.4,-1.6
32.0	Oleic acid	3.6	+1.3,-1.9
32.0	Du Pont Product BC	4.6	+1.2,-1.3
32.0	Du Pont MP-189-S	5.8	+1.6,-4.1
32.0	Du Pont Retarder LA	2.2	+1.9,-2.1

WHITEWARE BODY

LINEAR DRYING SHRINKAGE

De-aired		2.9%+0.3,-0.5
0.5%	Oleic acid	2.6 +1.8,-1.0
0.5	Du Pont Product BC	2.6 +0.6,-1.0
0.5	Du Pont MP-189-S	3.2 +0.1,-0.8
0.5	Du Pont Retarder LA	3.1 +0.1,-0.7
1.0	Oleic acid	2.9 +0.8,-1.3
1.0	Du Pont Product BC	2.8 +0.4,-0.4
1.0	Du Pont MP-189-S	3.2 +0.0,-0.0
1.0	Du Pont Retarder LA	3.0 +0.2,-0.6
2.0	Oleic acid	2.6 +1.1,-1.0
2.0	Du Pont Product BC	3.2 +0.1,-0.6
2.0	Du Pont MP-189-S	3.0 +0.1,-0.6
2.0	Du Pont Retarder LA	3.1 +0.1,-0.7
4.0	Oleic acid	2.3 +0.1,-0.7
4.0	Du Pont Product BC	2.6 +0.6,-0.2
4.0	Du Pont MP-189-S	2.9 +0.3,-0.5
4.0	Du Pont Retarder LA	2.7 +0.5,-0.3
8.0	Oleic acid	3.2 +0.1,-0.8
8.0	Du Pont Product BC	2.7 +0.5,-0.3
8.0	Du Pont MP-189-S	3.2 +0.1,-0.8
8.0	Du Pont Retarder LA	3.2 +0.1,-0.8
16.0	Oleic acid	2.2 +0.2,-0.6
16.0	Du Pont Product BC	2.5 +0.7,-0.1
16.0	Du Pont MP-189-S	3.5 +2.0,-1.4
16.0	Du Pont Retarder LA	2.8 +0.4,-0.4
32.0	Oleic acid	2.9 +0.3,-0.5
32.0	Du Pont Product BC	2.5 +0.7,-0.9
32.0	Du Pont MP-189-S	3.2 +0.1,-0.8
32.0	Du Pont Retarder LA	3.1 +1.0,-0.7

WHITEWARE BODY

LINEAR FIRING SHRINKAGE

De-aired		5.9%	+2.2,-1.8
0.5%	Oleic acid	6.1	+1.9,-2.0
0.5	Du Pont Product BC	4.4	+2.0,-1.2
0.5	Du Pont MP-189-S	4.4	+1.2,-1.2
0.5	Du Pont Retarder LA	3.7	+0.1,-0.7
1.0	Oleic acid	5.7	+1.0,-1.0
1.0	Du Pont Product BC	4.4	+1.2,-1.2
1.0	Du Pont MP-189-S	4.0	+0.9,-0.8
1.0	Du Pont Retarder LA	4.5	+1.2,-1.2
2.0	Oleic acid	4.9	+0.1,-0.1
2.0	Du Pont Product BC	4.5	+0.4,-1.3
2.0	Du Pont MP-189-S	4.7	+0.9,-2.3
2.0	Du Pont Retarder LA	3.2	+1.7,-0.8
4.0	Oleic acid	4.3	+0.5,-0.3
4.0	Du Pont Product BC	4.8	+0.8,-0.7
4.0	Du Pont MP-189-S	3.8	+1.8,-1.4
4.0	Du Pont Retarder LA	4.2	+0.7,-0.9
8.0	Oleic acid	5.0	+0.7,-1.7
8.0	Du Pont Product BC	4.0	+0.9,-0.8
8.0	Du Pont MP-189-S	5.0	+2.3,-0.9
8.0	Du Pont Retarder LA	4.2	+0.7,-1.0
16.0	Oleic acid	5.2	+0.4,-0.4
16.0	Du Pont Product BC	4.0	+1.6,-1.6
16.0	Du Pont MP-189-S	4.8	+2.5,-2.3
16.0	Du Pont Retarder LA	4.8	+2.5,-1.5
32.0	Oleic acid	4.4	+2.1,-1.2
32.0	Du Pont Product BC	4.8	+1.6,-1.6
32.0	Du Pont MP-189-S	4.9	+1.6,-1.6
32.0	Du Pont Retarder LA	4.2	+1.5,-1.0

REFRACTORY BODY

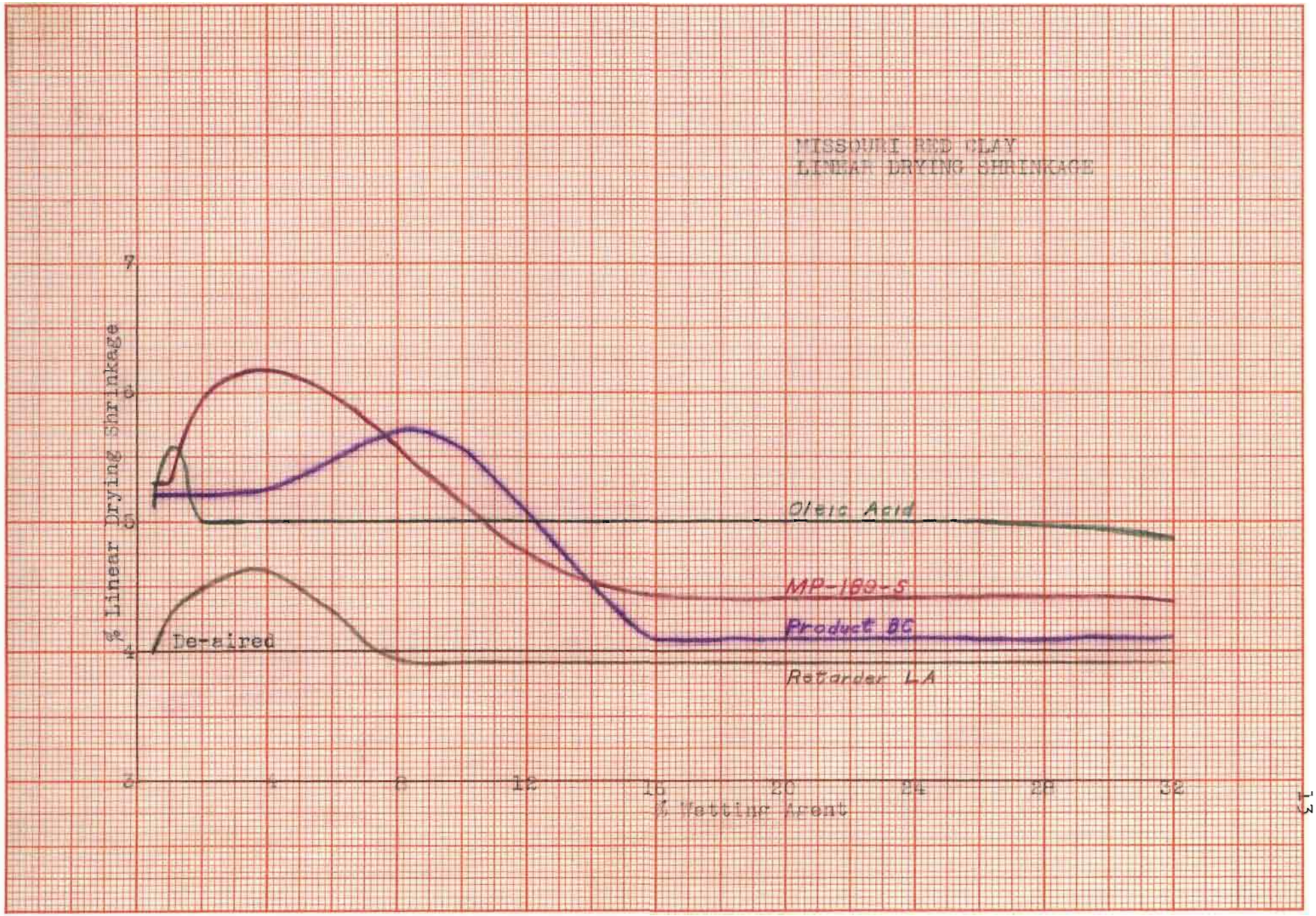
LINEAR DRYING SHRINKAGE

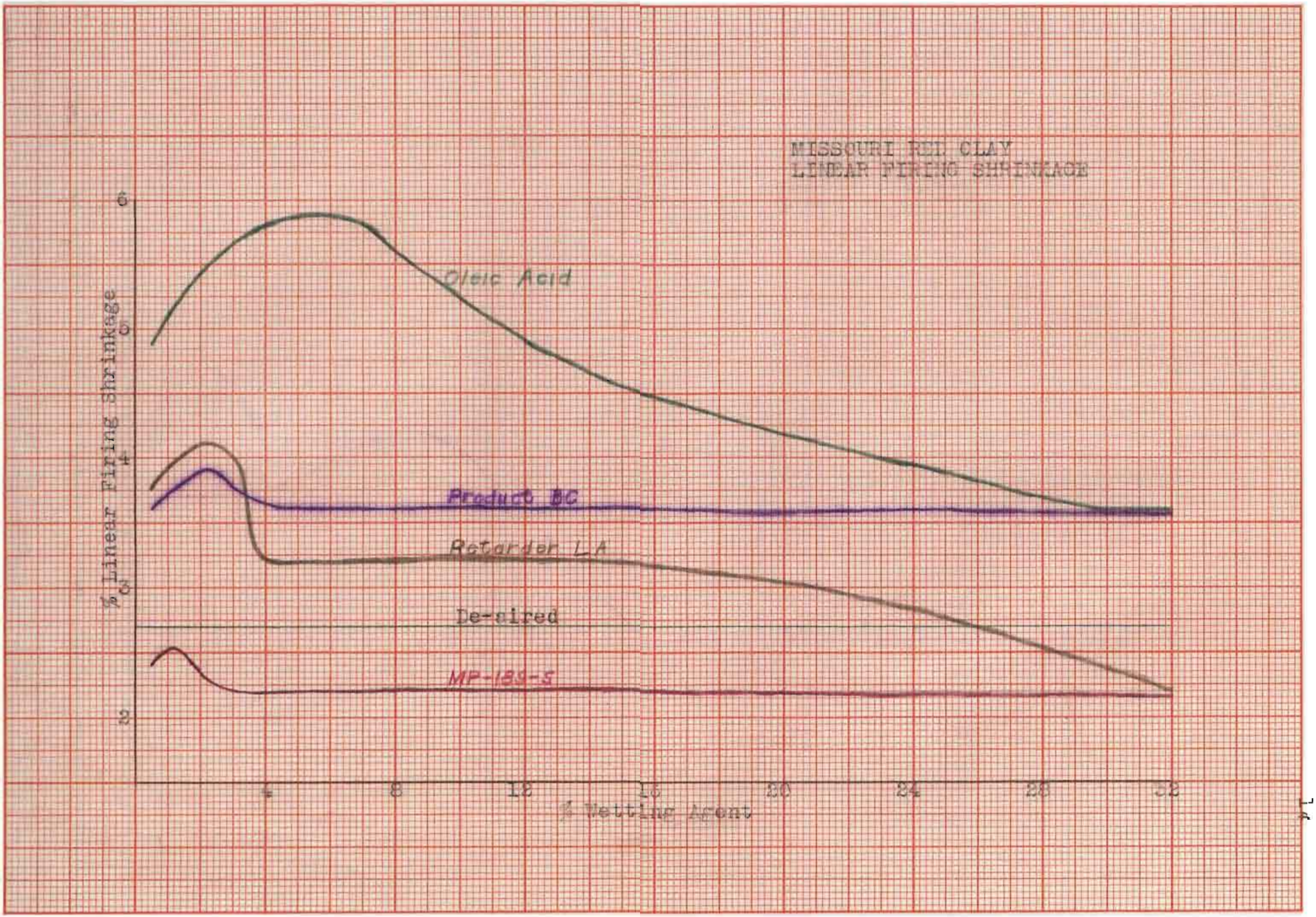
De-aired		2.4%	+0.0,-0.0
0.5%	Oleic acid	2.6	+0.7,-0.2
0.5	Du Pont Product BC	2.2	+0.2,-0.6
0.5	Du Pont MP-189-S	2.2	+0.2,-0.6
0.5	Du Pont Retarder LA	1.7	+0.7,-0.1
1.0	Oleic acid	2.3	+0.1,-0.7
1.0	Du Pont Product BC	2.4	+0.0,-0.0
1.0	Du Pont MP-189-S	2.3	+0.1,-0.8
1.0	Du Pont Retarder LA	2.2	+0.2,-0.6
2.0	Oleic acid	2.4	+0.0,-0.0
2.0	Du Pont Product BC	2.4	+0.0,-0.0
2.0	Du Pont MP-189-S	2.2	+0.2,-0.6
2.0	Du Pont Retarder LA	1.7	+0.7,-0.1
4.0	Oleic acid	1.5	+0.1,-0.7
4.0	Du Pont Product BC	2.4	+0.0,-0.0
4.0	Du Pont MP-189-S	1.6	+0.0,-0.0
4.0	Du Pont Retarder LA	1.7	+0.7,-0.1
8.0	Oleic acid	2.4	+0.0,-0.0
8.0	Du Pont Product BC	2.3	+0.1,-0.7
8.0	Du Pont MP-189-S	1.6	+0.0,-0.0
8.0	Du Pont Retarder LA	1.9	+0.5,-0.3
16.0	Oleic acid	1.9	+0.5,-0.3
16.0	Du Pont Product BC	2.4	+0.0,-0.0
16.0	Du Pont MP-189-S	1.7	+0.7,-0.1
16.0	Retarder LA	2.4	+0.0,-0.0
32.0	Oleic acid	2.2	+0.2,-0.6
32.0	Du Pont Product BC	2.4	+0.0,-0.0
32.0	Du Pont MP-189-S	2.3	+0.1,-0.7
32.0	Du Pont Retarder LA	2.2	+0.2,-0.6

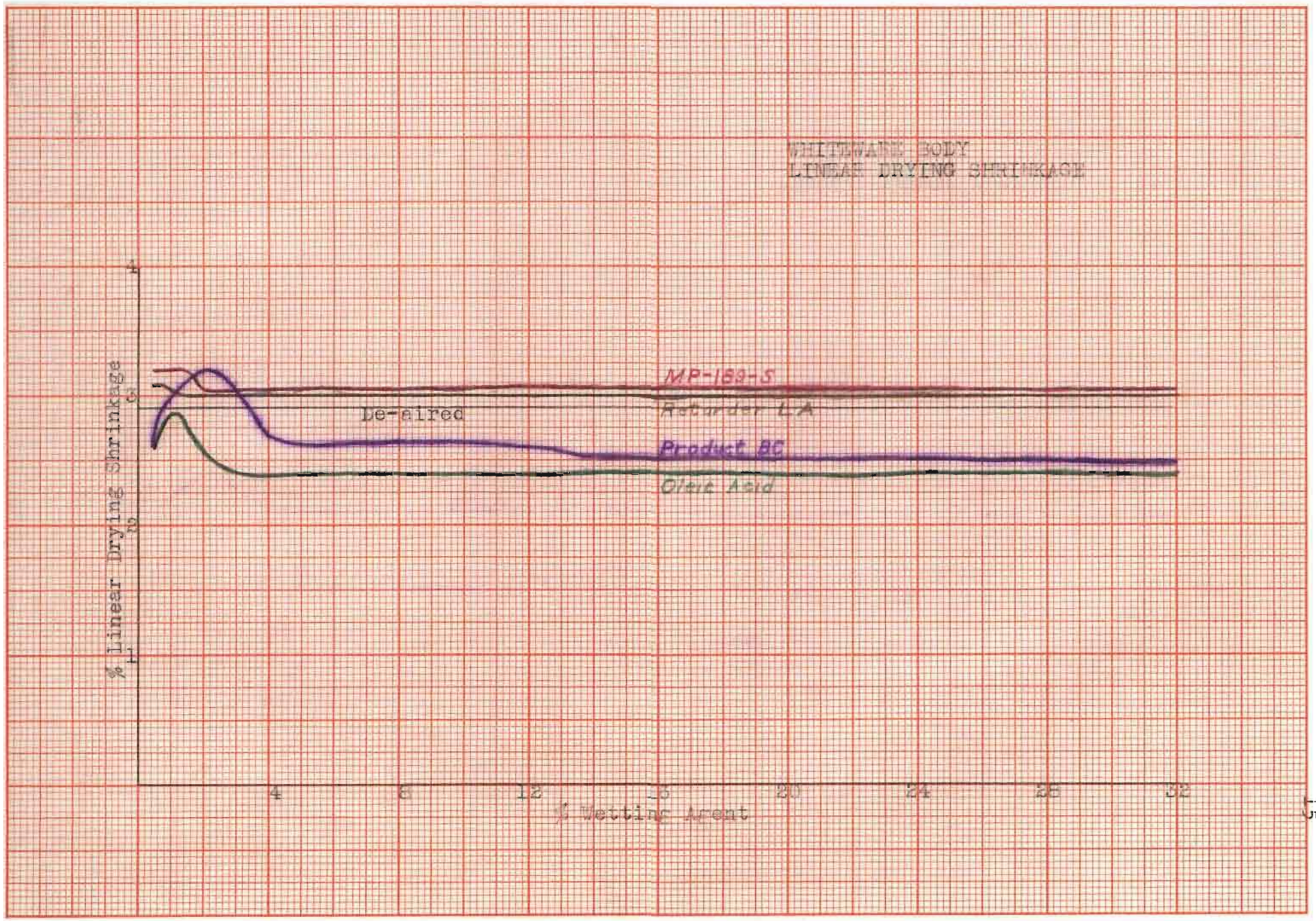
REFRACTORY BODY

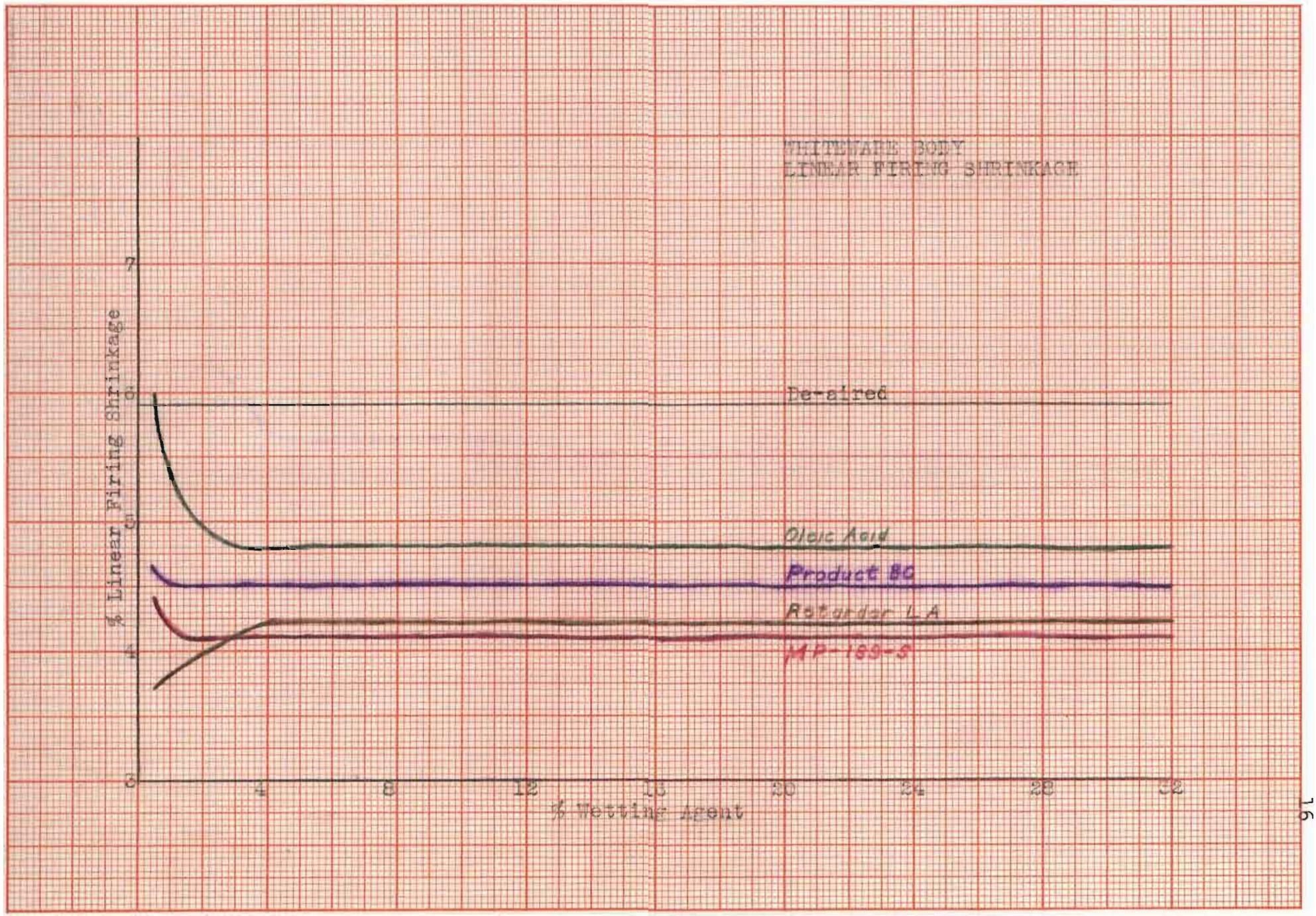
LINEAR FIRING SHRINKAGE

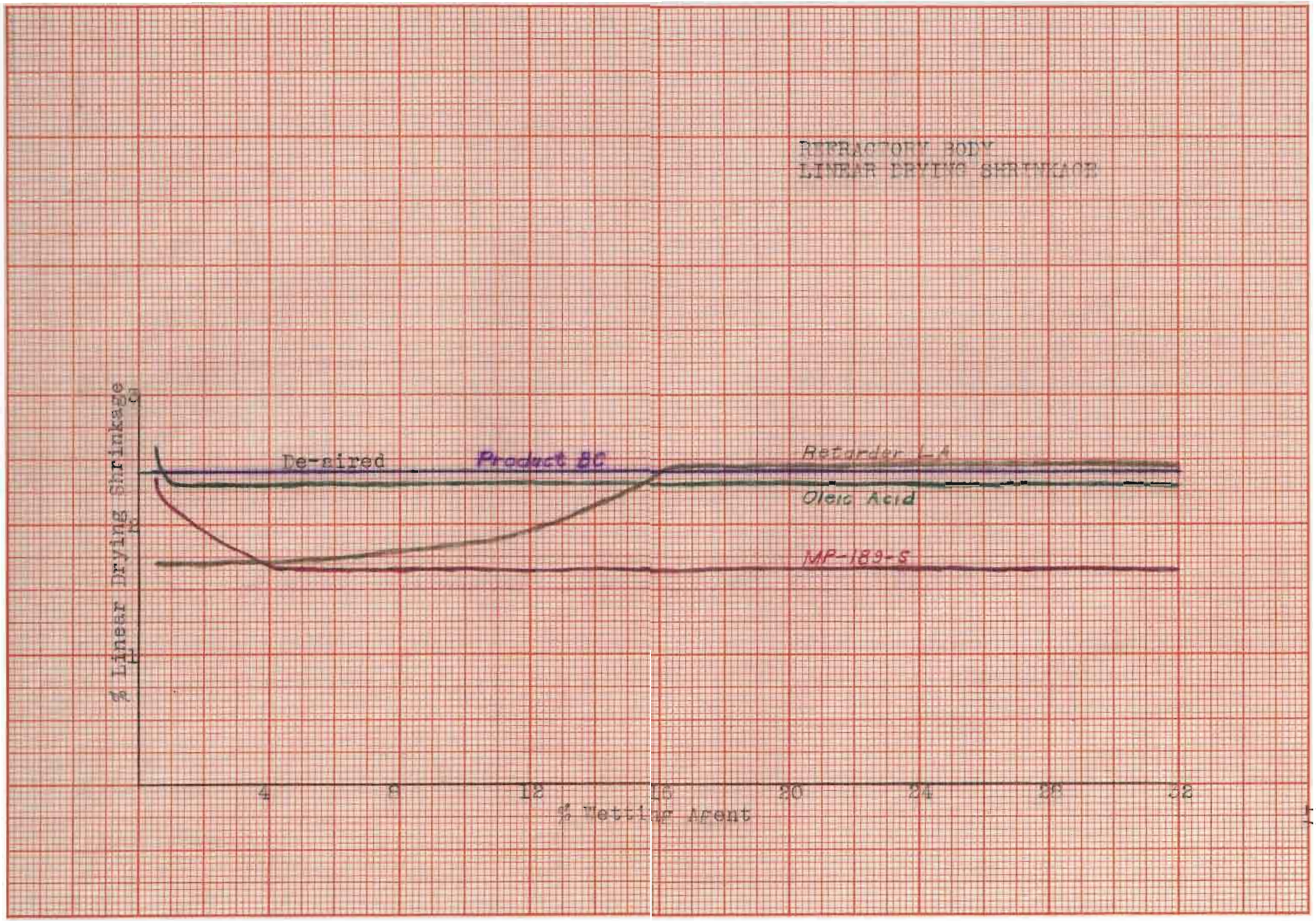
De-aired		4.1%	+0.7,-0.9
0.5%	Oleic acid	4.2	+0.6,-0.2
0.5	Du Pont Product BC	4.1	+0.7,-0.9
0.5	Du Pont MP-189-S	4.5	+0.1,-0.5
0.5	Du Pont Retarder LA	5.4	+0.2,-0.7
1.0	Oleic acid	4.9	+0.7,-0.9
1.0	Du Pont Product BC	4.2	+0.6,-0.2
1.0	Du Pont MP-189-S	3.5	+1.2,-2.3
1.0	Du Pont Retarder LA	3.8	+0.2,-0.6
2.0	Oleic acid	5.3	+0.3,-0.5
2.0	Du Pont Product BC	4.7	+0.1,-0.7
2.0	Du Pont MP-189-S	3.7	+1.0,-0.5
2.0	Du Pont Retarder LA	4.4	+0.3,-0.4
4.0	Oleic acid	3.7	+1.0,-0.5
4.0	Du Pont Product BC	4.2	+0.6,-1.0
4.0	Du Pont MP-189-S	3.8	+0.9,-0.6
4.0	Du Pont Retarder LA	3.4	+0.6,-0.2
8.0	Oleic acid	3.1	+0.1,-0.7
8.0	Du Pont Product BC	4.6	+1.0,-0.6
8.0	Du Pont MP-189-S	4.7	+0.0,-0.0
8.0	Du Pont Retarder LA	4.4	+1.2,-0.4
16.0	Oleic acid	3.5	+0.5,-1.1
16.0	Du Pont Product BC	1.1	+1.4,-1.1
16.0	Du Pont MP-189-S	4.6	+1.0,-0.6
16.0	Du Pont Retarder LA	3.5	+1.3,-0.3
32.0	Oleic acid	4.1	+0.6,-0.9
32.0	Du Pont Product BC	5.6	+0.0,-0.0
32.0	Du Pont MP-189-S	5.6	+0.0,-0.0
32.0	Du Pont Retarder LA	4.1	+0.6,-0.1

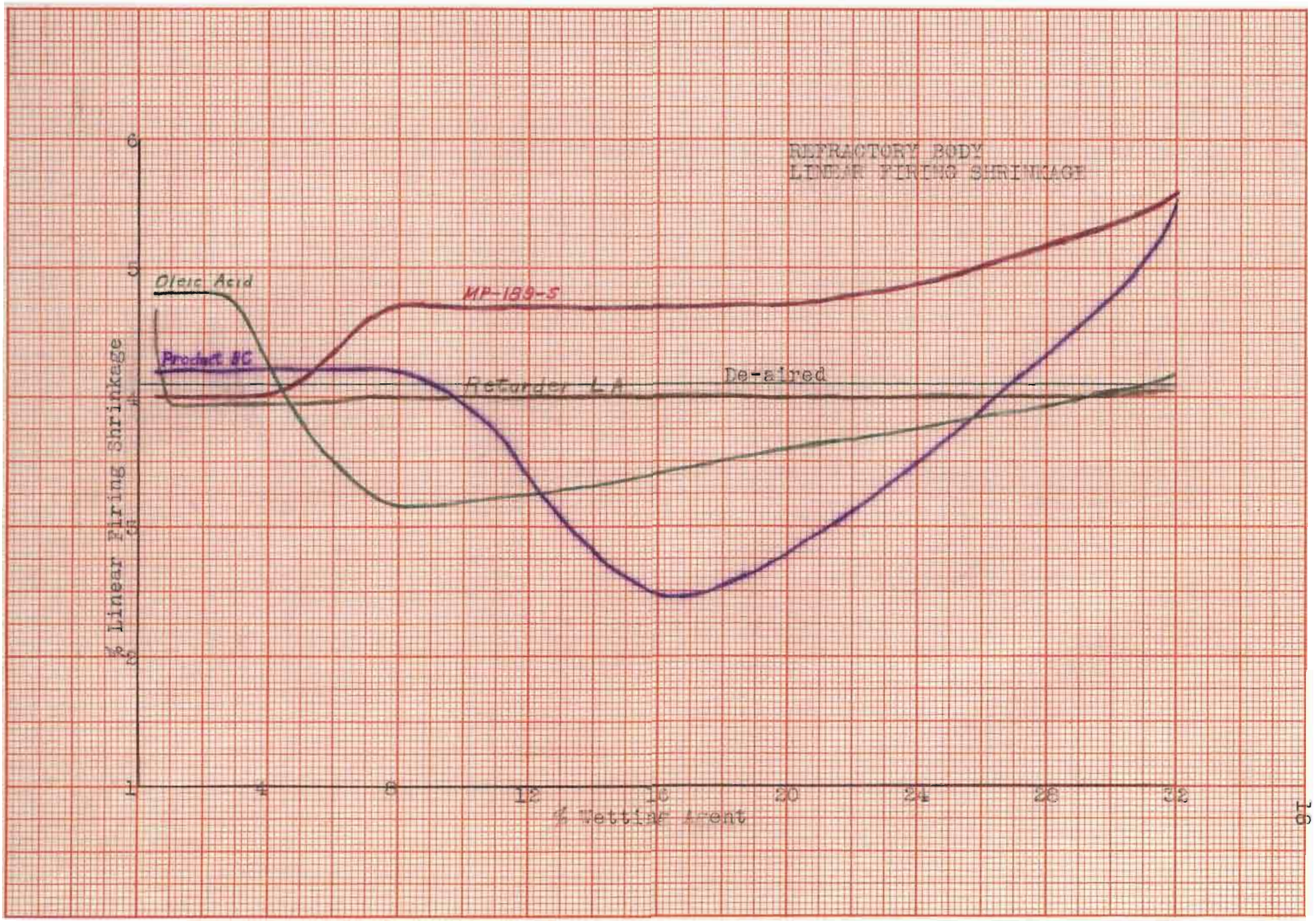

MISSOURI RED CLAY
LINEAR DRYING SHRINKAGE
% Linear Drying Shrinkage
7
6
5
4
Oleic Acid
MP-189-S
Product BC
Retarder LA
Deaired
0
4
8
12
16
20
24
28
32
% Wetting Agent


MISSOURI RED CLAY
LINEAR FIRING SHRINKAGE
% Linear firing shrinkage
6
4
2
0
Oleic Acid
Product BC
Retarder LA
De-aired
MP-189-S
4
8
12
16
20
24
28
32
% Wetting Agent


WHITEWARE BODY
LINEAR DRYING SHRINKAGE
% Linear Drying Shrinkage
MP-189-S
Retarder L.A.
Product BC
Citric Acid
Re-aired
4
8
12
16
20
24
28
32
% Wetting Agent


WHITEWARE BODY
LINEAR FIRING SHRINKAGE
% Linear Firing Shrinkage
0
4
8
12
16
20
24
28
32
% Wetting Agent
Deraired
Oleic Acid
Product BC
Retarder L A
MP-189-S


REFRACTORY BODY
LINEAR DRYING SHRINKAGE
% Linear Drying Shrinkage
De-aired
Product BC
Retarder L-4
Oleic Acid
MP-189-S
4
8
12
16
20
24
28
% Wetting Agent


REFRACTORY BODY
LINEAR FIRING SHRINKAGE
Oleic Acid
MP-189-S
Product BC
Retarder L.A
Desired
% Linear Firing Shrinkage
% Wetting Agent
0
4
8
12
16
20
24
28
32

MISSOURI RED SURFACE CLAY

FIRED VOLUME SHRINKAGE

De-aired		17.9%	+2.9,-5.1
0.5%	Oleic acid	18.3	+2.8,-3.1
0.5	Du Pont Product BC	13.7	+5.8,-4.6
0.5	Du Pont MP-189-S	17.0	+1.3,-1.4
0.5	Du Pont Retarder LA	20.0	+4.2,-6.2
1.0	Oleic acid	18.8	+2.8,-3.4
1.0	Du Pont Product BC	14.6	+3.4,-2.0
1.0	Du Pont MP-189-S	16.2	+3.2,-6.0
1.0	Du Pont Retarder LA	18.4	+3.8,-7.4
2.0	Oleic acid	18.4	+6.2,-9.9
2.0	Du Pont Product BC	13.9	+5.2,-4.4
2.0	Du Pont MP-189-S	18.1	+3.1,-9.1
2.0	Du Pont Retarder LA	16.7	+5.4,-10.0
4.0	Oleic acid	19.8	+2.4,-3.4
4.0	Du Pont Product BC	13.2	+10.8,-6.1
4.0	Du Pont MP-189-S	20.4	+5.7,-7.1
4.0	Du Pont Retarder LA	18.4	+2.5,-6.5
8.0	Oleic acid	20.3	+6.5,-12.2
8.0	Du Pont Product BC	14.5	+2.2,-4.3
8.0	Du Pont MP-189-S	20.9	+2.1,-4.7
8.0	Du Pont Retarder LA	17.3	+2.9,-3.5
16.0	Oleic acid	20.4	+6.4,-10.6
16.0	Du Pont Product BC	12.2	+3.8,-10.6
16.0	Du Pont MP-189-S	17.5	+8.0,-13.0
16.0	Du Pont Retarder LA	20.8	+5.1,-2.7
32.0	Oleic acid	17.3	+2.8,-2.2
32.0	Du Pont Product BC	14.7	+7.1,-5.6
32.0	Du Pont MP-189-S	19.4	+4.3,-17.3
32.0	Du Pont Retarder LA	19.5	+3.5,-3.5

WHITEWARE BODY

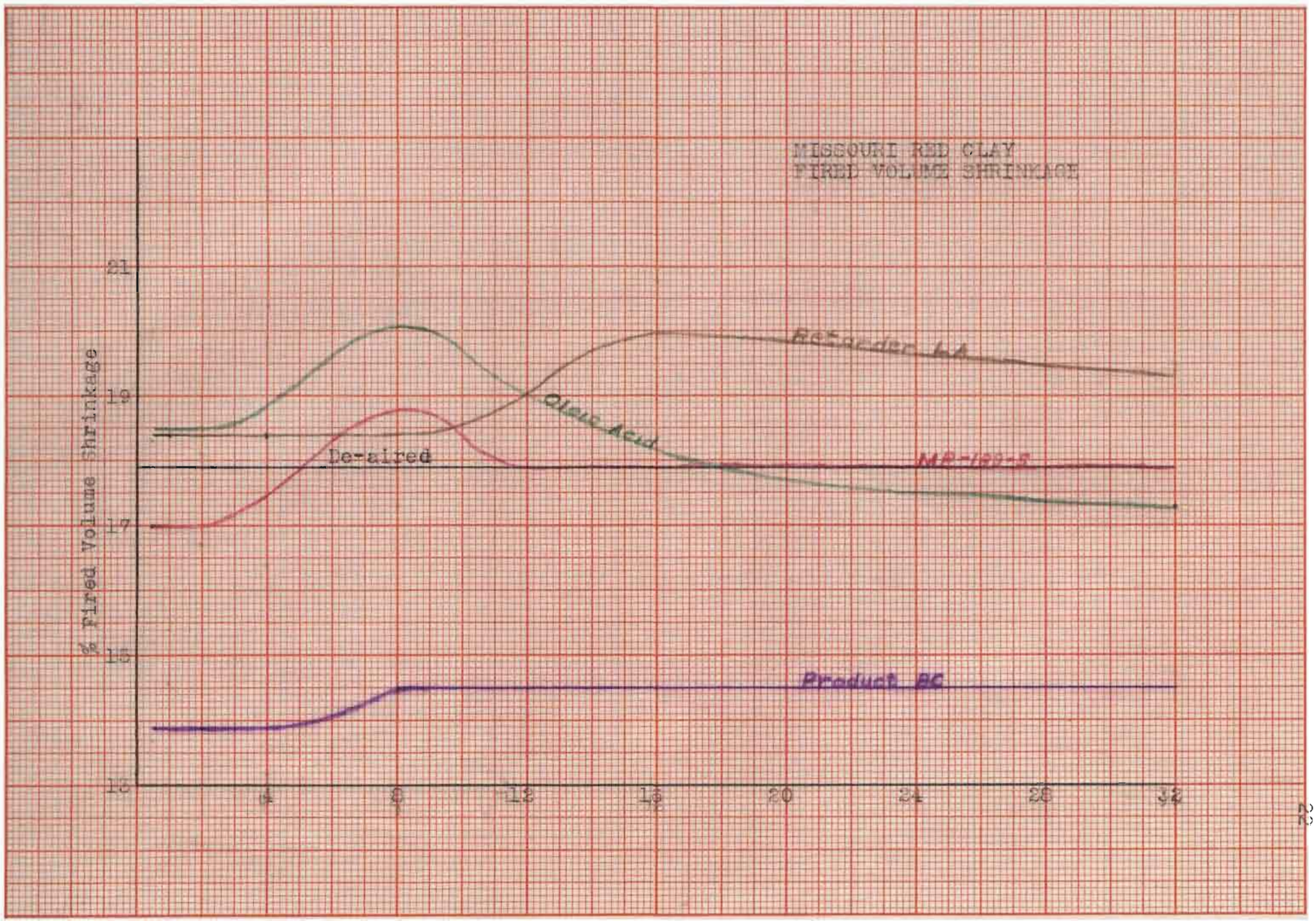
VOLUME FIRING SHRINKAGE

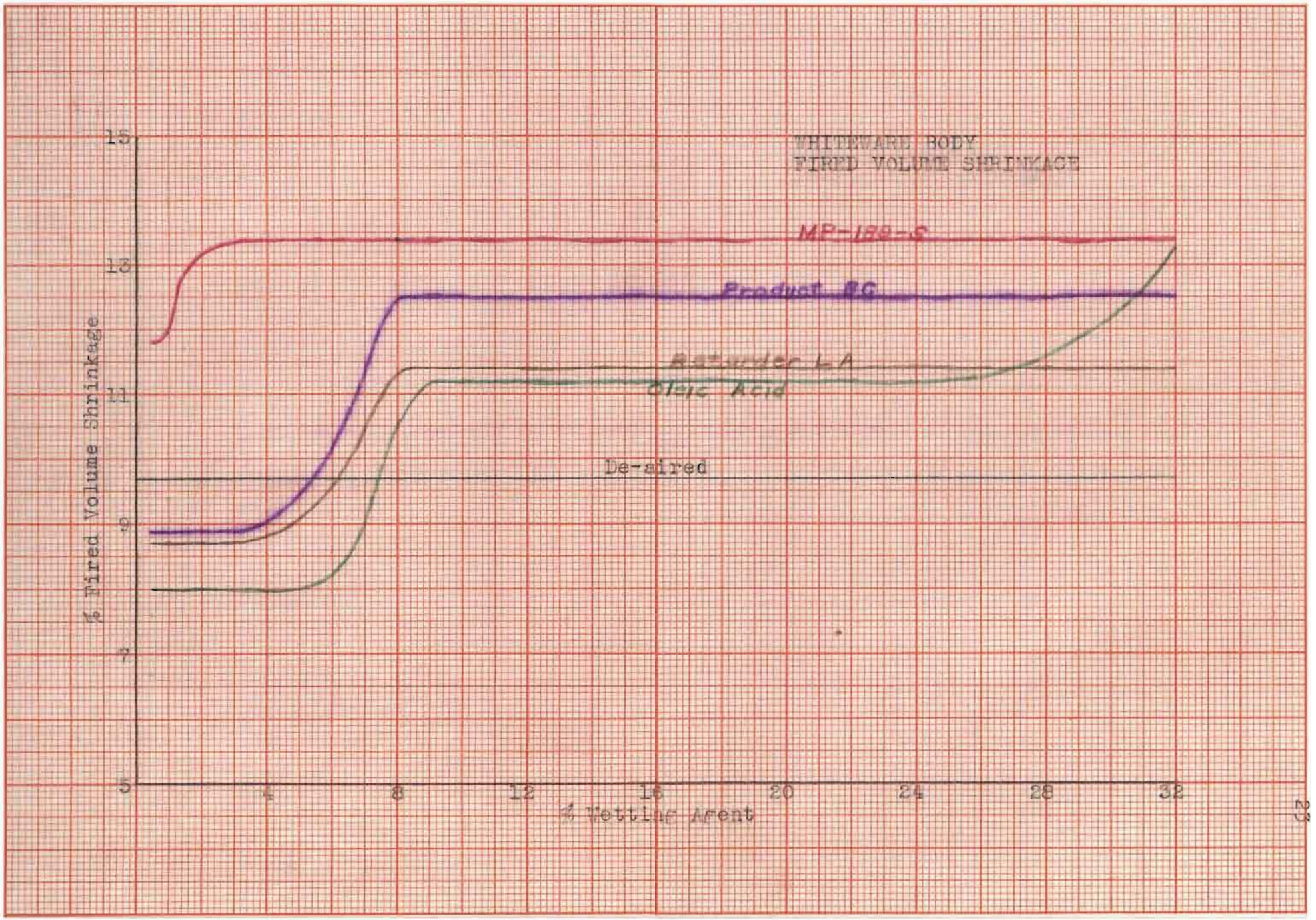
De-aired		9.7%	+1.8,-3.3
0.5%	Oleic acid	10.3	+1.9,-2.2
0.5	Du Pont Product BC	6.7	+4.2,-4.5
0.5	Du Pont MP-189-S	10.6	+3.1,-5.3
0.5	Du Pont Retarder LA	7.6	+4.1,-5.3
1.0	Oleic acid	5.7	+4.3,-4.9
1.0	Du Pont Product BC	9.4	+2.8,-1.9
1.0	Du Pont MP-189-S	14.0	+2.7,-2.3
1.0	Du Pont Retarder LA	9.4	+1.0,-2.2
2.0	Oleic acid	5.8	+2.7,-3.7
2.0	Du Pont Product BC	9.4	+4.1,-4.8
2.0	Du Pont MP-189-S	12.3	+2.3,-2.9
2.0	Du Pont Retarder LA	9.2	+1.4,-2.9
4.0	Oleic acid	7.0	+2.7,-6.0
4.0	Du Pont Product BC	3.8	+3.3,-3.6
4.0	Du Pont MP-189-S	13.5	+2.5,-2.4
4.0	Du Pont Retarder LA	7.9	+1.3,-2.4
8.0	Oleic acid	11.4	+3.3,-2.0
8.0	Du Pont Product BC	12.7	+2.4,-4.0
8.0	Du Pont MP-189-S	13.4	+1.5,-2.9
8.0	Du Pont Retarder LA	11.1	+2.2,-1.4
16.0	Oleic acid	10.9	+2.3,-3.2
16.0	Du Pont Product BC	12.9	+2.0,-2.4
16.0	Du Pont MP-189-S	14.5	+3.3,-5.5
16.0	Du Pont Retarder LA	13.7	+3.5,-3.2
32.0	Oleic acid	15.0	+9.8,-7.5
32.0	Du Pont Product BC	12.0	+2.2,-2.9
32.0	Du Pont MP-189-S	11.3	+2.5,-6.0
32.0	Du Pont Retarder LA	11.1	+1.9,-2.2

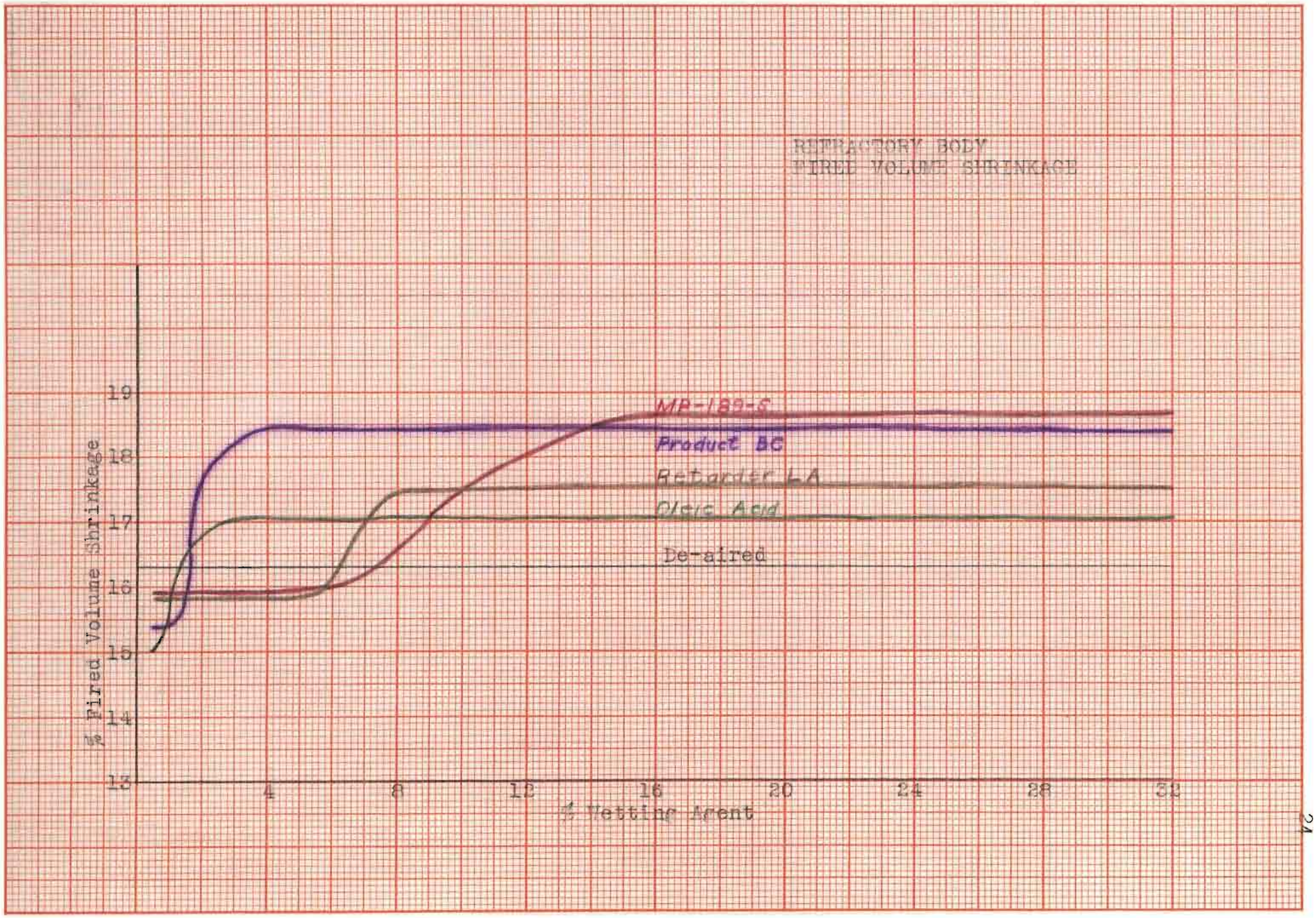
REFRACTORY BODY

VOLUME FIRING SHRINKAGE

De-aired		16.3%	+2.8,-2.0
0.5%	Oleic acid	15.0	+2.9,-5.8
0.5	Du Pont Product BC	16.4	+3.0,-3.0
0.5	Du Pont MP-189-S	18.2	+4.8,-3.2
0.5	Du Pont Retarder LA	17.1	+1.1,-2.1
1.0	Oleic acid	15.4	+1.0,-2.0
1.0	Du Pont Product BC	14.8	+6.7,-4.4
1.0	Du Pont MP-189-S	15.4	+4.0,-2.3
1.0	Du Pont Retarder LA	15.8	+3.1,-2.7
2.0	Oleic acid	20.5	+5.2,-2.7
2.0	Du Pont Product BC	20.5	+5.2,-2.7
2.0	Du Pont MP-189-S	15.9	+5.0,-3.3
2.0	Du Pont Retarder LA	13.7	+5.9,-1.6
4.0	Oleic acid	19.0	+3.2,-2.7
4.0	Du Pont Product BC	17.2	+5.1,-3.2
4.0	Du Pont MP-189-S	15.1	+1.9,-2.2
4.0	Du Pont Retarder LA	15.5	+1.3,-2.2
8.0	Oleic acid	16.2	+4.0,-1.7
8.0	Du Pont Product BC	18.3	+2.9,-2.4
8.0	Du Pont MP-189-S	16.6	+0.8,-2.3
8.0	Du Pont Retarder LA	18.3	+3.7,-1.5
16.0	Oleic acid	16.2	+1.7,-2.8
16.0	Du Pont Product BC	18.6	+1.7,-1.9
16.0	Du Pont MP-189-S	18.6	+6.3,-6.3
16.0	Du Pont Retarder LA	15.8	+1.8,-4.1
32.0	Oleic acid	17.5	+4.9,-4.5
32.0	Du Pont Product BC	21.0	+3.4,-2.4
32.0	Du Pont MP-189-S	18.8	+8.8,-6.5
32.0	Du Pont Retarder LA	17.5	+0.3,-0.7


MISSOURI RED CLAY
FIRED VOLUME SHRINKAGE
% Fired Volume Shrinkage
21
19
17
15
13
4
8
12
16
20
24
28
32
Retarder 1A
Oleic Acid
De-aired
MR-180-S
Product BC


WHITEWARE BODY
FIRED VOLUME SHRINKAGE
MP-188-C
Product #C
Reworder L.A
Oleic Acid
De-aired
% Fired Volume Shrinkage
15
10
5
0
4
8
12
16
20
24
28
32
% Wetting Agent


REFRACTORY BODY
FIRED VOLUME SHRINKAGE
% Fired Volume Shrinkage
19
18
17
16
15
14
13
4
8
12
16
20
24
28
32
% Wetting Agent
MP-189-S
Product BC
Retarder LA
Oleic Acid
De-aired

MISSOURI RED SURFACE CLAY

DRY MODULUS OF RUPTURE

De-aired		275psi	+235,-105
0.5%	Oleic acid	600	+125,-155
0.5	Du Pont Product BC	425	+ 65,- 55
0.5	Du Pont MP-189-S	670	+150,-135
0.5	Du Pont Retarder LA	815	+165,-235
1.0	Oleic acid	540	+180,-115
1.0	Du Pont Product BC	405	+ 65,-105
1.0	Du Pont MP-189-S	405	+ 85,-175
1.0	Du Pont Retarder LA	740	+175,-250
2.0	Oleic acid	560	+110,-135
2.0	Du Pont Product BC	400	+ 67,-75
2.0	Du Pont MP-189-S	445	+ 85,-155
2.0	Du Pont Retarder LA	640	+165,-410
4.0	Oleic acid	640	+165,-205
4.0	Du Pont Product BC	510	+260,-270
4.0	Du Pont MP-189-S	720	+150,-190
4.0	Du Pont Retarder LA	620	+270,-235
8.0	Oleic acid	560	+285,-320
8.0	Du Pont Product BC	640	+145,-300
8.0	Du Pont MP-189-S	315	+ 90,-165
8.0	Du Pont Retarder LA	665	+100,-250
16.0	Oleic acid	275	+100,- 55
16.0	Du Pont Product BC	400	+155,-100
16.0	Du Pont MP-189-S	370	+120,-140
16.0	Du Pont Retarder LA	615	+155,-170
32.0	Oleic acid	215	+125,- 65
32.0	Du Pont Product BC	390	+100,-120
32.0	Du Pont MP-189-S	465	+115,-225
32.0	Du Pont Retarder LA	260	+120,-115

MISSOURI RED SURFACE CLAY

FIRED MODULUS OF RUPTURE

De-aired		1225psi	+415,-510
0.5%	Oleic acid	3400	+2870,-1520
0.5	Du Pont Product BC	2940	+1130,-1015
0.5	Du Pont MP-189-S	1690	+1400,-535
0.5	Du Pont Retarder LA	2540	+1260,-1045
1.0	Oleic acid	3850	+880,-1210
1.0	Du Pont Product BC	3230	+1220,-595
1.0	Du Pont MP-189-S	2785	+2235,-1135
1.0	Du Pont Retarder LA	2595	+2015,-1525
2.0	Oleic acid	3580	+1150,-845
2.0	Du Pont Product BC	3025	+785,-905
2.0	Du Pont MP-189-S	1865	+1105,-385
2.0	Du Pont Retarder LA	2650	+1150,-1445
4.0	Oleic acid	3355	+985,-990
4.0	Du Pont Product BC	3080	+990,-575
4.0	Du Pont MP-189-S	1705	+1485,-645
4.0	Du Pont Retarder LA	1340	+890,-360
8.0	Oleic acid	3470	+920,-1125
8.0	Du Pont Product BC	2160	+295,-225
8.0	Du Pont MP-189-S	1740	+480,-630
8.0	Du Pont Retarder LA	885	+185,-125
16.0	Oleic acid	2860	+1300,-160
16.0	Du Pont Product BC	2045	+655,-1225
16.0	Du Pont MP-189-S	1605	+1395,-545
16.0	Du Pont Retarder LA	2620	+1175,-835
32.0	Oleic acid	2340	+900,-810
32.0	Du Pont Product BC	2510	+730,-1245
32.0	Du Pont MP-189-S	2305	+1505,-2010
32.0	Du Pont Retarder LA	930	+500,-450

WHITEWARE BODY

DRY MODULUS OF RUPTURE

De-aired		110psi	+43,-70
0.5%	Oleic acid	103	+45,-33
0.5	Du Pont Product BC	130	+23,-29
0.5	Du Pont MP-189-S	119	+16,-23
0.5	Du Pont Retarder LA	130	+42,-47
1.0	Oleic acid	111	+29,-30
1.0	Du Pont Product BC	125	+19,-23
1.0	Du Pont MP-189-S	101	+14,-24
1.0	Du Pont Retarder LA	107	+20,-22
2.0	Oleic acid	118	+ 7,-15
2.0	Du Pont Product BC	112	+12,-13
2.0	Du Pont MP189-S	121	+32,-33
2.0	Du Pont Retarder LA	140	+26,-22
4.0	Oleic acid	143	+39,-52
4.0	Du Pont Product BC	107	+52,-51
4.0	Du Pont MP-189-S	111	+39,-22
4.0	Du Pont Retarder LA	160	+19,-20
8.0	Oleic acid	140	+17,-18
8.0	Du Pont Product BC	79	+17,-13
8.0	Du Pont MP-189-S	100	+18,-23
8.0	Du Pont Retarder LA	147	+33,-21
16.0	Oleic acid	93	+22,-35
16.0	Du Pont Product BC	97	+23,-15
16.0	Du Pont MP-189-S	73	+14,-15
16.0	Du Pont Retarder LA	115	+40,-24
32.0	Oleic acid	81	+12,- 9
32.0	Du Pont Product BC	88	+13,-13
32.0	Du Pont MP-189-S	127	+17,-19
32.0	Du Pont Retarder LA	124	+29,-15

WHITEWARE BODY

FIRED MODULUS OF RUPTURE

De-aired		3000psi	+1500,- 980
0.5%	Oleic acid	2405	+1295,- 667
0.5	Du Pont Product BC	2805	+1215,- 775
0.5	Du Pont MP-189-S	2235	+ 575,- 745
0.5	Du Pont Retarder LA	2585	+ 655,- 650
1.0	Oleic acid	2900	+1430,- 960
1.0	Du Pont Product BC	1995	+ 635,- 835
1.0	Du Pont MP-189-S	2245	+ 845,- 485
1.0	Du Pont Retarder LA	2615	+ 770,- 445
2.0	Oleic acid	1600	+ 440,- 355
2.0	Du Pont Product BC	2680	+ 320,- 650
2.0	Du Pont MP-189-S	2655	+ 765,- 905
2.0	Du Pont Retarder LA	1505	+ 985,- 680
4.0	Oleic acid	2610	+1520,- 965
4.0	Du Pont Product BC	2300	+ 770,-1090
4.0	Du Pont MP-189-S	2885	+1045,- 735
4.0	Du Pont Retarder LA	2720	+ 810,- 780
8.0	Oleic acid	2465	+1235,-1648
8.0	Du Pont Product BC	2120	+ 500,- 720
8.0	Du Pont MP-189-S	2805	+1435,-1265
8.0	Du Pont Retarder LA	2325	+ 745,- 875
16.0	Oleic acid	2445	+ 440,- 645
16.0	Du Pont Product BC	2020	+1120,- 660
16.0	Du Pont MP-189-S	2045	+ 675,- 445
16.0	Du Pont Retarder LA	2325	+ 595,- 585
32.0	Oleic acid	2400	+1810,-1110
32.0	Du Pont Product BC	2060	+ 480,- 700
32.0	Du Pont MP-189-S	3035	+1770,-1730
32.0	Du Pont Retarder LA	2070	+1310,-1586

REFRACTORY BODY

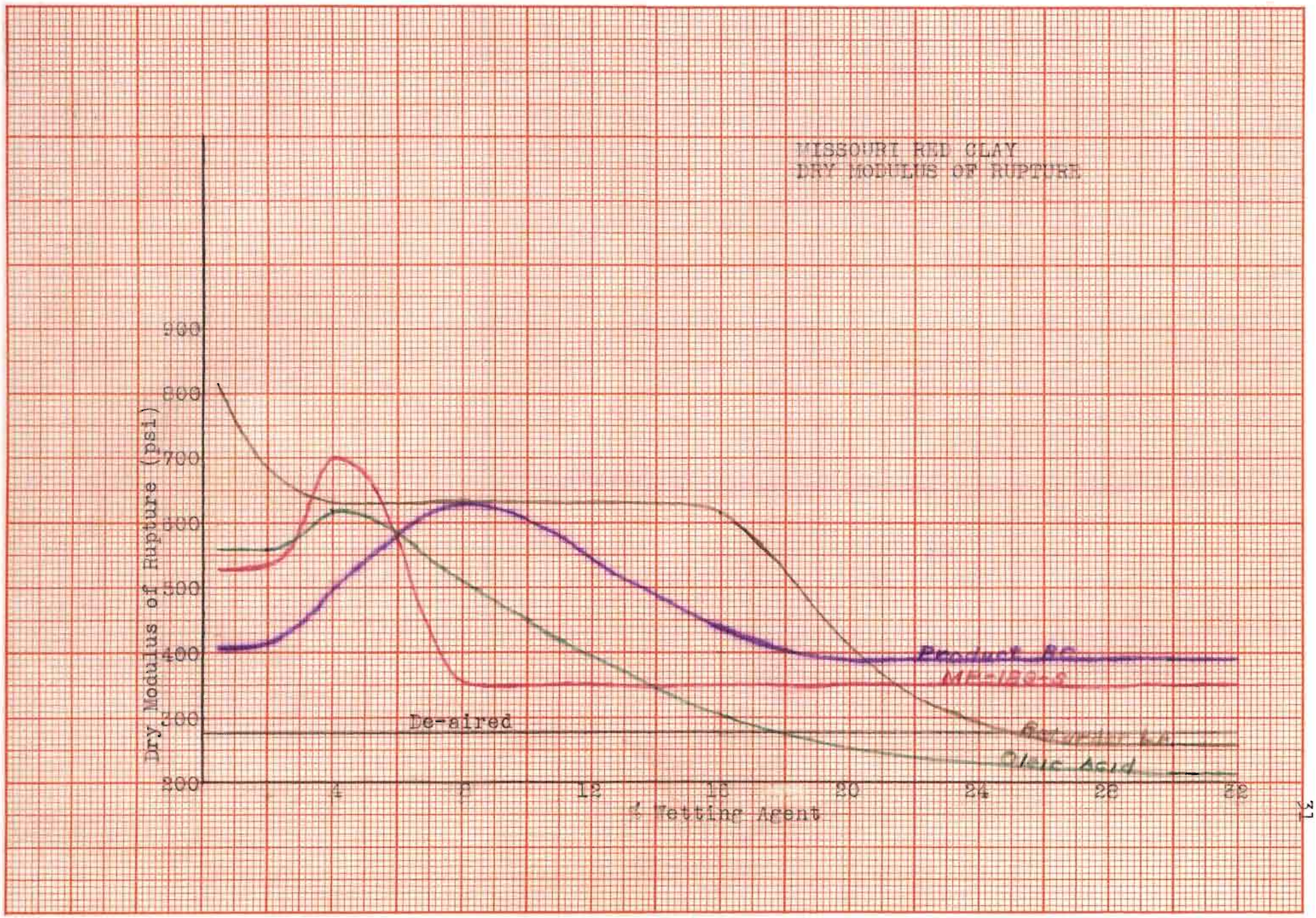
DRY MODULUS OF RUPTURE

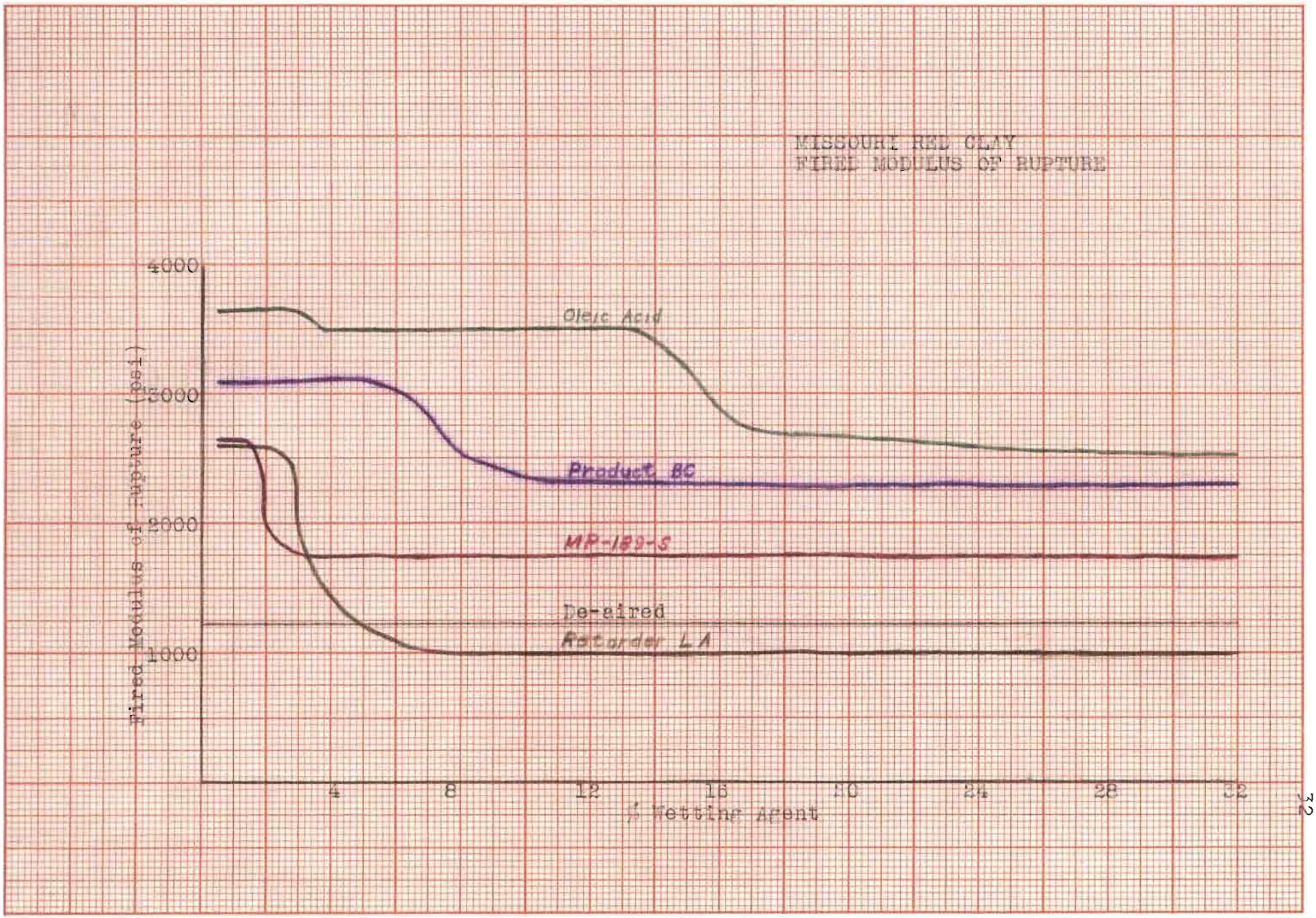
De-aired		70psi	+19,-19
0.5%	Oleic acid	66	+13,-11
0.5	Du Pont Product BC	40	+16,-10
0.5	Du Pont MP-189-S	61	+ 9,- 8
0.5	Du Pont Retarder LA	98	+ 9,-15
1.0	Oleic acid	92	+10,-16
1.0	Du Pont Product BC	43	+ 5,- 7
1.0	Du Pont MP-189-S	71	+17,- 4
1.0	Du Pont Retarder LA	71	+ 6,-11
2.0	Oleic acid	94	+17,- 5
2.0	Du Pont Product BC	72	+10,-18
2.0	Du Pont MP-189-S	78	+ 7,-15
2.0	Du Pont Retarder LA	60	+10,- 9
4.0	Oleic acid	55	+15,-11
4.0	Du Pont Product BC	65	+22,-17
4.0	Du Pont MP-189-S	38	+ 3,- 2
4.0	Du Pont Retarder LA	74	+20,- 8
8.0	Oleic acid	58	+19,-15
8.0	Du Pont Product BC	62	+10,- 9
8.0	Du Pont MP-189-S	69	+11,-13
8.0	Du Pont Retarder LA	54	+10,- 6
16.0	Oleic acid	44	+ 5,- 9
16.0	Du Pont Product BC	56	+ 6,-12
16.0	Du Pont MP-189-S	102	+16,-20
16.0	Du Pont Retarder LA	51	+19,-15
32.0	Oleic acid	48	+27,-10
32.0	Du Pont Product BC	82	+ 8,- 9
32.0	Du Pont MP-189-S	89	+12,-17
32.0	Du Pont Retarder LA	41	+ 5,- 5

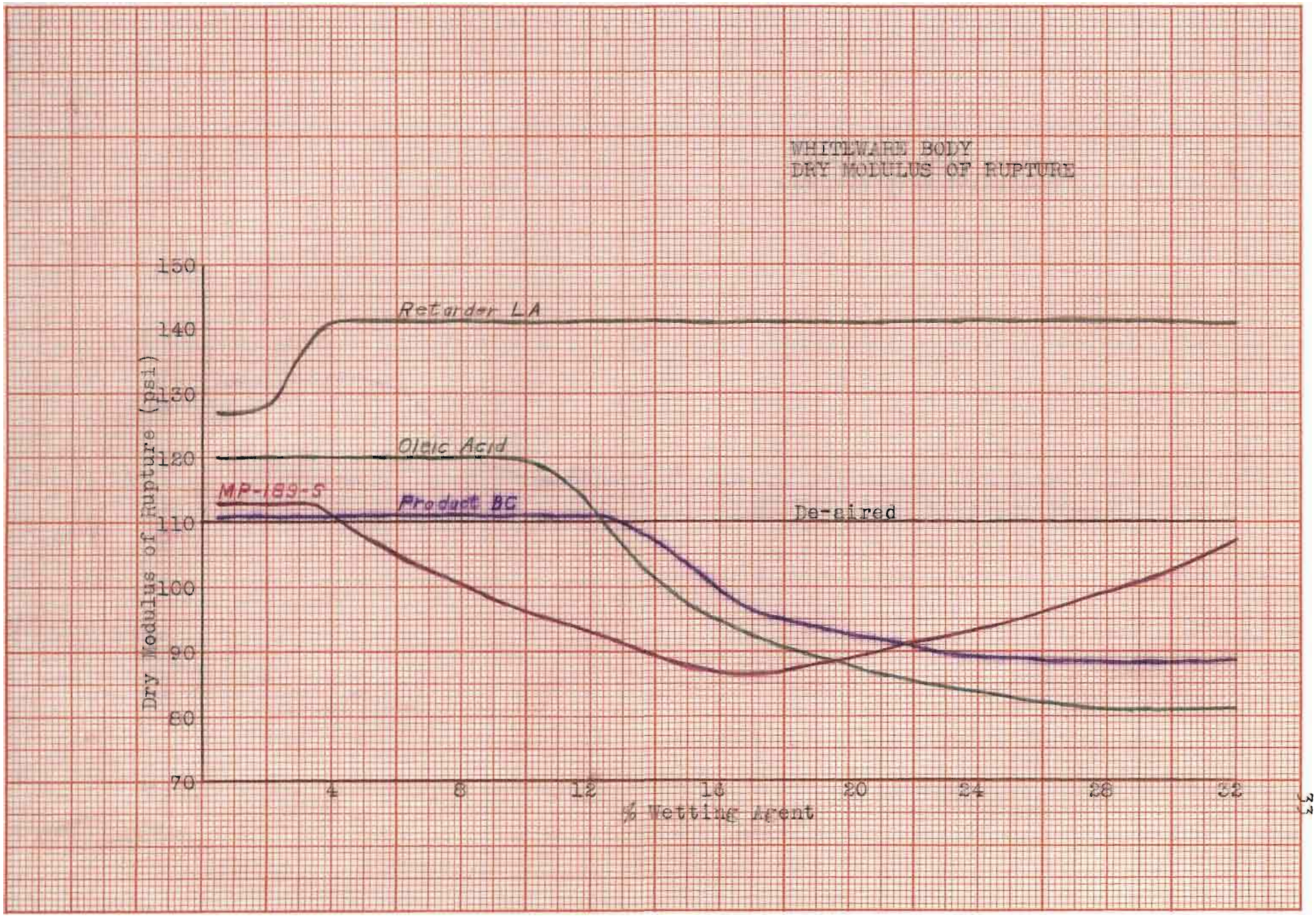
REFRACTORY BODY

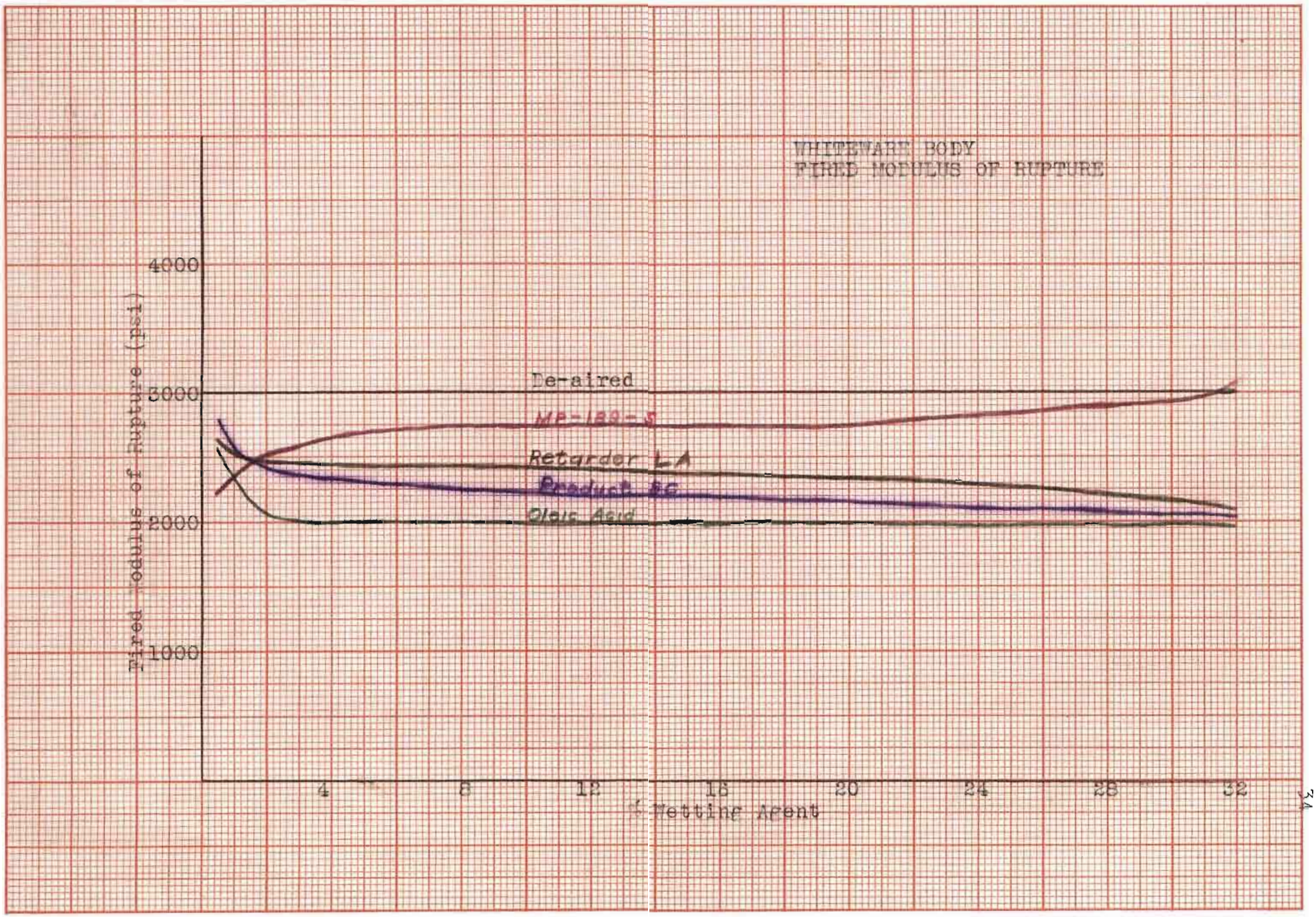
FIRED MODULUS OF RUPTURE

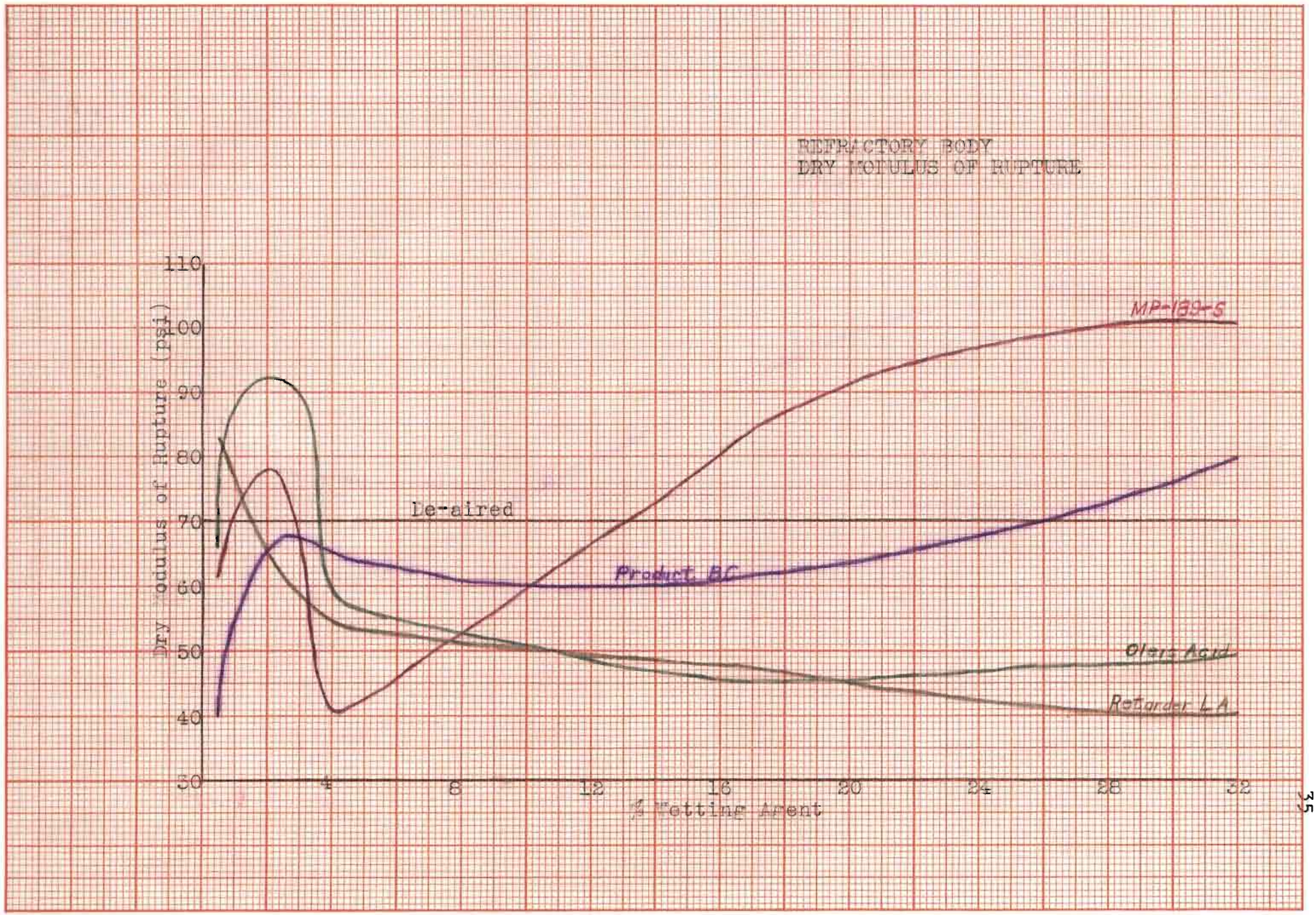
De-aired		505psi	+235,-163
0.5%	Oleic acid	825	+ 75,-230
0.5	Du Pont Product BC	565	+255,-255
0.5	Du Pont MP-189-S	695	+130,-160
0.5	Du Pont Retarder LA	805	+160,-205
1.0	Oleic acid	1160	+110,-140
1.0	Du Pont Product BC	560	+125,-115
1.0	Du Pont MP-189-S	580	+ 95,- 95
1.0	Du Pont Retarder LA	665	+125,-105
2.0	Oleic acid	1545	+100,-165
2.0	Du Pont Product BC	895	+365,-410
2.0	Du Pont MP-189-S	465	+ 95,-115
2.0	Du Pont Retarder LA	565	+115,-130
4.0	Oleic acid	795	+ 95,-120
4.0	Du Pont Product BC	600	+155,-210
4.0	Du Pont MP-189-S	485	+ 95,- 95
4.0	Du Pont Retarder LA	430	+ 15,- 75
8.0	Oleic acid	525	+200,-225
8.0	Du Pont Product BC	845	+215,-135
8.0	Du Pont MP-189-S	655	+160,-185
8.0	Du Pont Retarder LA	655	+ 20,- 75
16.0	Oleic acid	505	+120,-120
16.0	Du Pont Product BC	1300	+165,-190
16.0	Du Pont MP-189-S	865	+250,-285
16.0	Du Pont Retarder LA	470	+160,-180
32.0	Oleic acid	650	+125,-140
32.0	Du Pont Product BC	1520	+250,-115
32.0	Du Pont MP-189-S	635	+255,- 75
32.0	Du Pont Retarder LA	735	+225,-200

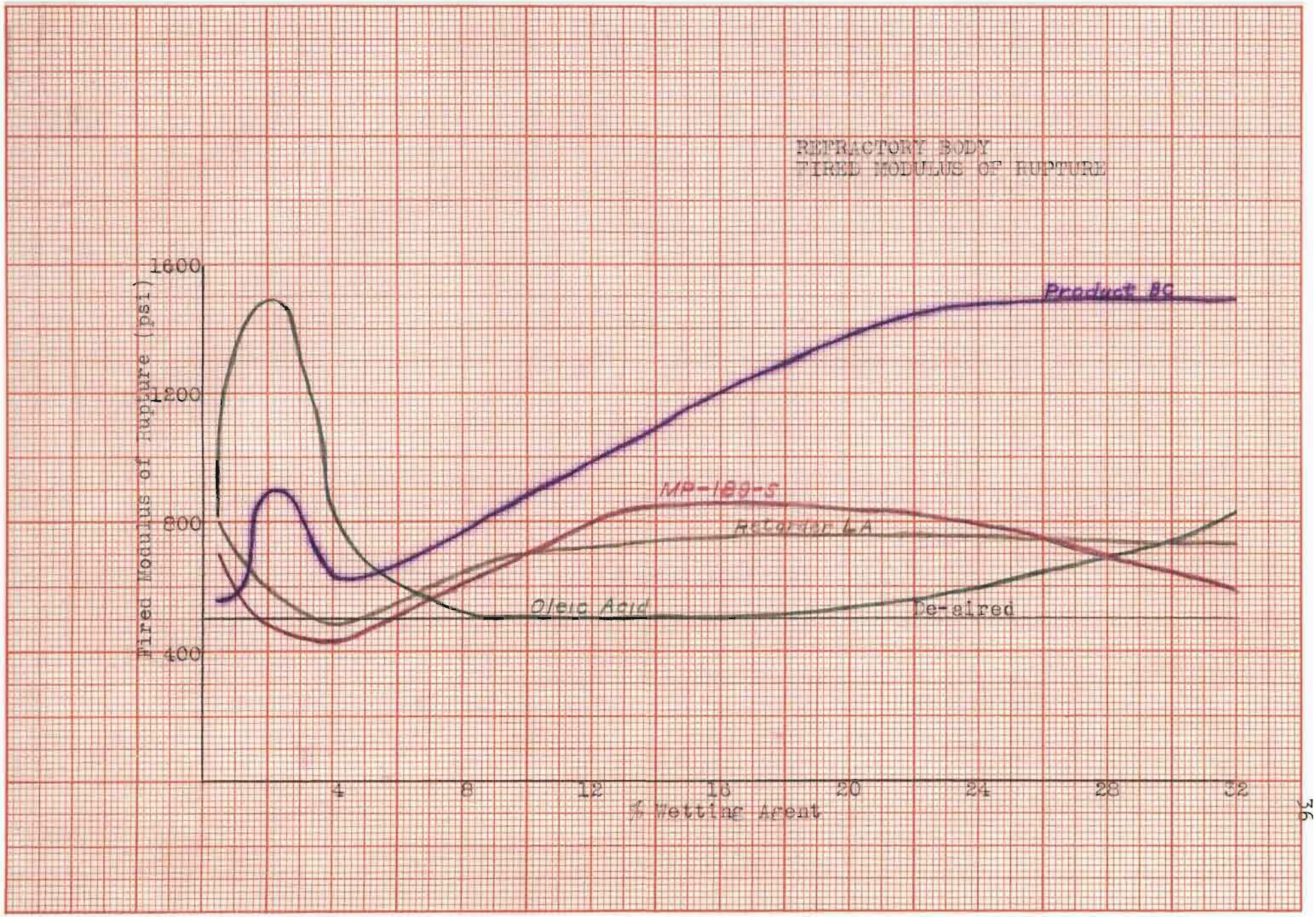

MISSOURI RED CLAY
DRY MODULUS OF RUPTURE
Dry Modulus of Rupture (psi)
900
800
700
600
500
400
300
200
4
8
12
16
20
24
28
32
% Wetting Agent
De-aired
Product EC
MP-1EC-2
Oleic Acid


MISSOURI RED CLAY
FIRED MODULUS OF RUPTURE
4000
3000
2000
1000
Fired Modulus of Rupture (psi)
Oleic Acid
Product BC
MP-189-S
De-aired
Retorder LA
4
8
12
16
20
24
28
32
% Wetting Agent


WHITEWARE BODY
DRY MODULUS OF RUPTURE
Dry Modulus of Rupture (psi)
150
140
130
120
110
100
90
80
70
Retarder LA
Oleic Acid
MP-189-S
Product BC
Desired
4
8
12
16
20
24
28
32
% Wetting Agent


WHITEWARE BODY
FIRED MODULUS OF RUPTURE
Fired Modulus of Rupture (psi)
4000
3000
2000
1000
De-aired
MP-189-S
Retarder LA
Product EC
Oleic Acid
4
8
12
16
20
24
28
32
% Wetting Agent


REFRACTORY BODY
DRY MODULUS OF RUPTURE
Dry Modulus of Rupture (psi)
110
100
90
80
70
60
50
40
30
4
8
12
16
20
24
28
32
% Wetting Agent
De-aired
MP-189-S
Product BC
Olero Acid
Retarder L A


REFRACTORY BODY
FIRED MODULUS OF RUPTURE
Fired Modulus of Rupture (psi)
1600
1200
800
400
Product BC
MP-189-S
Regular LA
Oleic Acid
De-aired
4
8
12
16
20
24
28
32
% Wetting Agent

MISSOURI RED SURFACE CLAY

ABSORPTION

De-aired		1.5%	+0.7,-0.8
0.5%	Oleic acid	4.1	+2.8,-2.7
0.5	Du Pont Product BC	7.6	+1.4,-2.3
0.5	Du Pont MP-189-S	5.2	+2.7,-4.4
0.5	Du Pont Retarder LA	4.9	+2.6,-1.9
1.0	Oleic acid	4.3	+2.0,-2.5
1.0	Du Pont Product BC	7.0	+1.5,-2.9
1.0	Du Pont MP-189-S	3.7	+1.9,-2.7
1.0	Du Pont Retarder LA	3.7	+1.8,-2.7
2.0	Oleic acid	5.0	+2.2,-3.0
2.0	Du Pont Product BC	6.7	+1.8,-2.5
2.0	Du Pont MP-189-S	3.1	+2.9,-2.1
2.0	Du Pont Retarder LA	4.6	+2.1,-3.3
4.0	Oleic acid	4.5	+1.1,-2.6
4.0	Du Pont Product BC	6.9	+1.0,-2.5
4.0	Du Pont MP-189-S	2.0	+1.3,-1.2
4.0	Du Pont Retarder LA	2.0	+1.3,-1.2
8.0	Oleic acid	3.7	+3.0,-1.5
8.0	Du Pont Product BC	8.0	+2.4,-3.0
8.0	Du Pont MP-189-S	2.1	+2.0,-1.3
8.0	Du Pont Retarder LA	4.4	+3.5,-3.4
16.0	Oleic acid	2.9	+2.0,-2.3
16.0	Du Pont Product BC	7.1	+1.5,-1.8
16.0	Du Pont MP-189-S	3.0	+2.8,-2.1
16.0	Du Pont Retarder LA	3.6	+1.2,-1.5
32.0	Oleic acid	7.4	+1.7,-2.2
32.0	Du Pont Product BC	6.9	+1.9,-3.8
32.0	Du Pont MP-189-S	2.9	+0.9,-1.1
32.0	Du Pont Retarder LA	4.0	+3.7,-2.3

WHITEWARE BODY

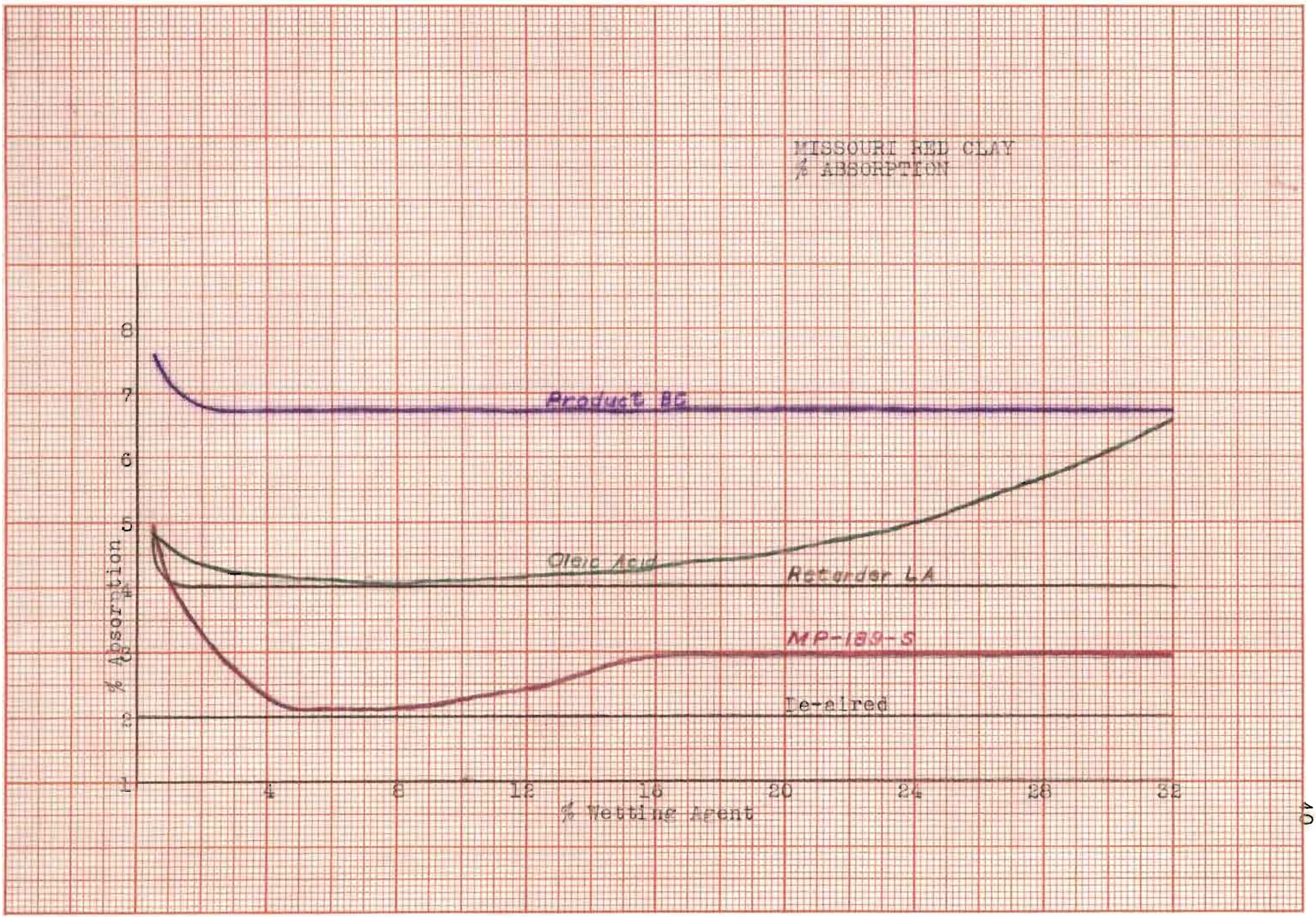
ABSORPTION

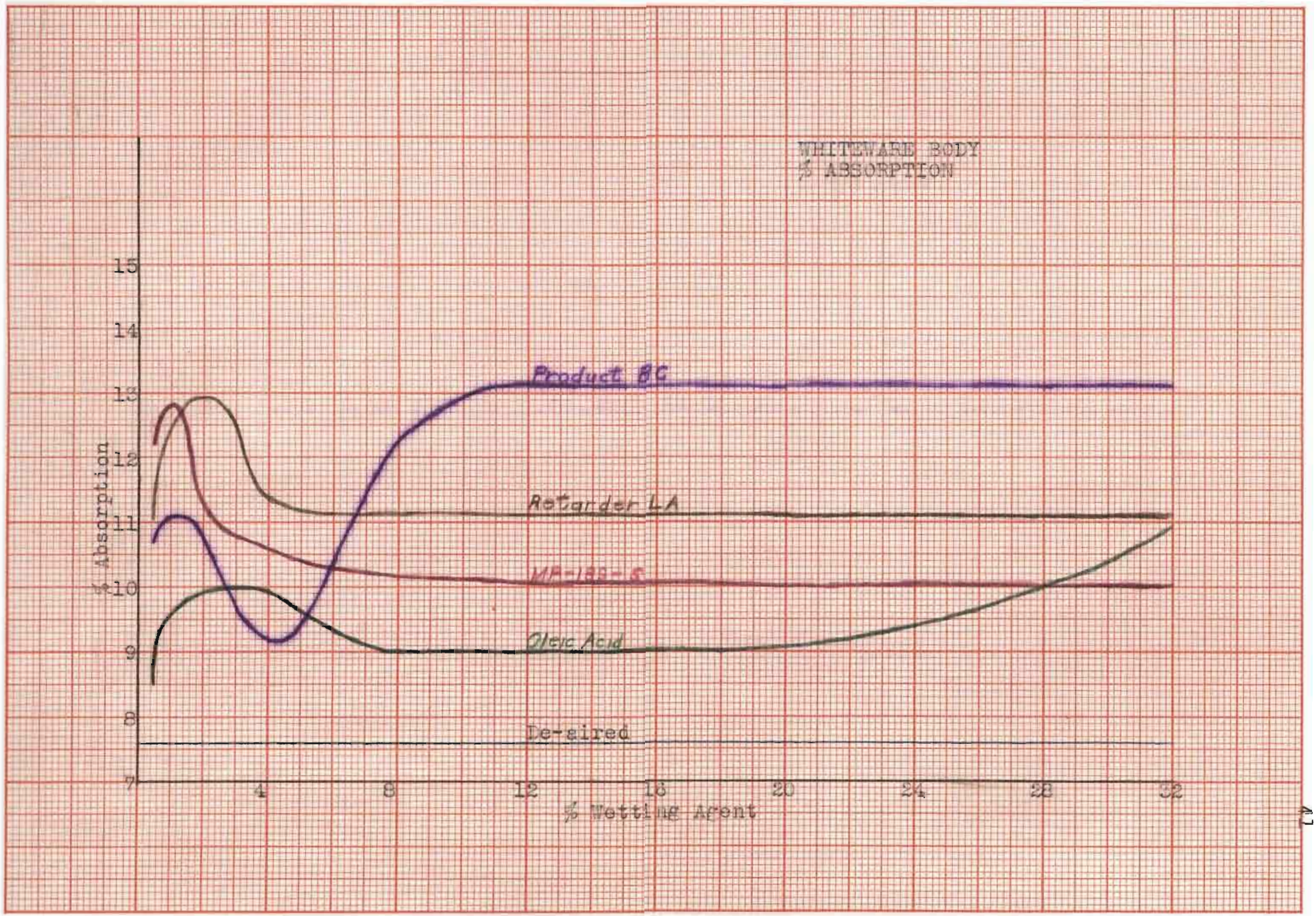
De-aired		7.6%	+1.8,-2.4
0.5%	Oleic acid	8.2	+1.7,-3.7
0.5	Du Pont Product BC	10.7	+2.6,-3.1
0.5	Du Pont MP-189-S	12.2	+2.3,-2.1
0.5	Du Pont Retarder LA	11.1	+1.9,-2.3
1.0	Oleic acid	8.3	+3.2,-1.5
1.0	Du Pont Product BC	11.2	+3.6,-1.3
1.0	Du Pont MP-189-S	12.8	+2.4,-1.0
1.0	Du Pont Retarder LA	9.4	+3.5,-2.5
2.0	Oleic acid	10.2	+2.8,-1.5
2.0	Du Pont Product BC	11.1	+2.5,-0.9
2.0	Du Pont MP-189-S	10.7	+3.9,-2.1
2.0	Du Pont Retarder LA	13.6	+1.9,-2.2
4.0	Oleic acid	10.1	+1.8,-1.4
4.0	Du Pont Product BC	8.9	+0.7,-0.8
4.0	Du Pont MP-189-S	11.2	+3.9,-4.5
4.0	Du Pont Retarder LA	11.2	+6.6,-2.2
8.0	Oleic acid	8.8	+0.6,-1.0
8.0	Du Pont Product BC	12.6	-3.9,-0.3
8.0	Du Pont MP-189-S	10.4	-2.0,-2.1
8.0	Du Pont Retarder LA	10.9	-1.6,-1.1
16.0	Oleic acid	8.6	-0.7,-1.8
16.0	Du Pont Product BC	14.6	-2.4,-3.9
16.0	Du Pont MP-189-S	12.2	-1.2,-3.4
16.0	Du Pont Retarder LA	11.4	-2.1,-3.4
32.0	Oleic acid	11.7	-5.5,-4.3
32.0	Du Pont Product BC	12.8	-3.2,-2.0
32.0	Du Pont MP-189-S	8.2	-1.8,-2.7
32.0	Du Pont Retarder LA	12.7	-1.3,-1.8

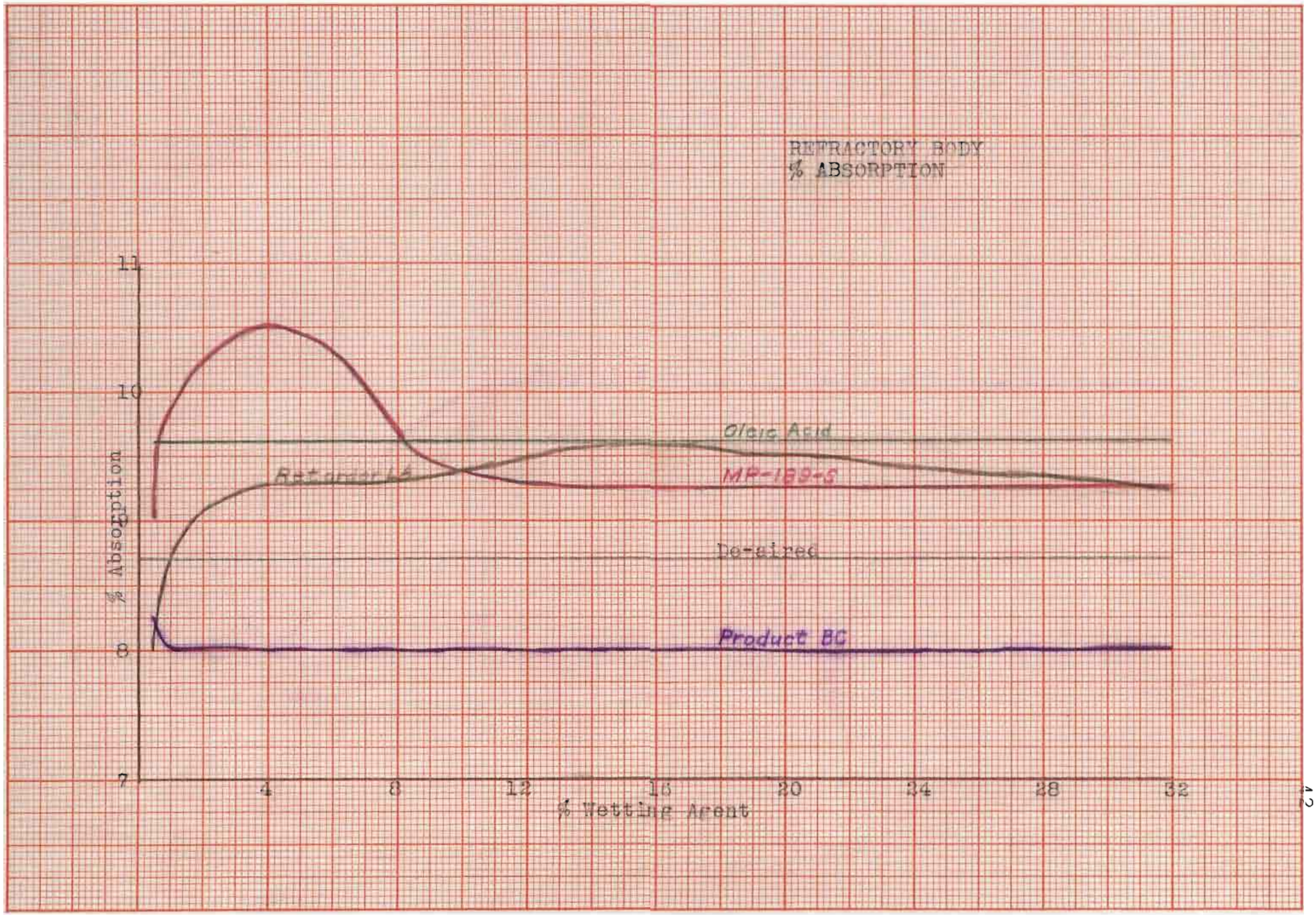
REFRACTORY BODY

ABSORPTION

De-aired		8.7%	+1.5,-1.1
0.5%	Oleic acid	9.6	+1.9,-2.4
0.5	Du Pont Product BC	9.4	+1.0,-1.1
0.5	Du Pont MP-189-S	8.6	+0.4,-0.5
0.5	Du Pont Retarder LA	7.9	+0.4,-0.4
1.0	Oleic acid	9.6	+0.0,-0.0
1.0	Du Pont Product BC	9.7	+0.9,-1.4
1.0	Du Pont MP-189-S	10.3	+0.7,-0.7
1.0	Du Pont Retarder LA	9.1	+1.4,-5.0
2.0	Oleic acid	9.6	+1.1,-1.1
2.0	Du Pont Product BC	7.4	+0.6,-0.3
2.0	Du Pont MP-189-S	10.1	+0.5,-0.4
2.0	Du Pont Retarder LA	9.2	+1.5,-1.6
4.0	Oleic acid	9.6	+1.0,-1.1
4.0	Du Pont Product BC	9.6	+1.2,-4.5
4.0	Du Pont MP-189-S	10.7	+0.6,-0.8
4.0	Du Pont Retarder LA	9.2	+0.8,-0.7
8.0	Oleic acid	9.6	+0.9,-1.8
8.0	Du Pont Product BC	8.9	+2.2,-0.8
8.0	Du Pont MP-189-S	9.6	+0.5,-0.6
8.0	Du Pont Retarder LA	8.8	+0.5,-1.3
16.0	Oleic acid	9.3	+1.5,-1.6
16.0	Du Pont Product BC	9.6	+0.7,-1.6
16.0	Du Pont MP-189-S	8.5	+1.0,-0.9
16.0	Du Pont Retarder LA	10.2	+0.6,-0.6
32.0	Oleic acid	9.7	+0.7,-0.9
32.0	Du Pont Product BC	8.6	+0.6,-1.0
32.0	Du Pont MP-189-S	9.9	+0.9,-0.5
32.0	Du Pont Retarder LA	9.2	+1.1,-1.2


MISSOURI RED CLAY
% ABSORPTION
Product BG
Oleic Acid
Retarder LA
MP-189-S
Re-aired
% Absorption
% Wetting Agent
8
7
6
5
4
3
2
1
4
8
12
16
20
24
28
32


WHITEWARE BODY
% ABSORPTION
15
14
13
12
11
10
9
8
7
% Absorption
Product BC
Retarder LA
MP-185-S
Oleic Acid
De-aired
4
8
12
16
20
24
28
32
% Wetting Agent


RETRACTORY BODY
% ABSORPTION
11
10
9
8
7
% Absorption
Oleic Acid
MP-189-S
Re-refined
Product BC
4
8
12
16
20
24
28
32
% Wetting Agent

MISSOURI RED SURFACE CLAY

APPARENT POROSITY

De-aired		3.9%	+3.7,-2.3
0.5%	Oleic acid	8.9	+5.5,-5.6
0.5	Du Pont Product BC	15.9	+3.0,-4.3
0.5	Du Pont MP-189-S	11.1	+5.4,-9.4
0.5	Du Pont Retarder LA	10.5	+4.7,-3.8
1.0	Oleic acid	9.6	+4.2,-5.6
1.0	Du Pont Product BC	14.9	+2.0,-5.6
1.0	Du Pont MP-189-S	6.4	+5.7,-5.0
1.0	Du Pont Retarder LA	7.8	+6.6,-7.0
2.0	Oleic acid	11.0	+4.4,-6.6
2.0	Du Pont Product BC	13.8	+3.7,-4.5
2.0	Du Pont MP-189-S	6.9	+6.5,-4.6
2.0	Du Pont Retarder LA	9.8	+4.6,-7.2
4.0	Oleic acid	9.9	+2.8,-5.8
4.0	Du Pont Product BC	14.7	+2.1,-5.3
4.0	Du Pont MP-189-S	4.4	+3.1,-2.6
4.0	Du Pont Retarder LA	6.5	+2.7,-3.9
8.0	Oleic acid	8.6	+7.2,-3.7
8.0	Du Pont Product BC	16.6	+4.1,-5.8
8.0	Du Pont MP-189-S	4.8	+4.4,-3.2
8.0	Du Pont Retarder LA	9.4	+4.8,-7.4
16.0	Oleic acid	6.0	+4.8,-4.7
16.0	Du Pont Product BC	14.7	+2.8,-3.4
16.0	Du Pont MP-189-S	6.3	+4.7,-4.3
16.0	Du Pont Retarder LA	8.1	+2.5,-3.5
32.0	Oleic acid	15.9	+2.8,-4.4
32.0	Du Pont Product BC	14.8	+3.8,-7.6
32.0	Du Pont MP-189-S	6.0	+3.8,-5.2
32.0	Du Pont Retarder LA	8.4	+7.4,-4.7

WHITEWARE BODY

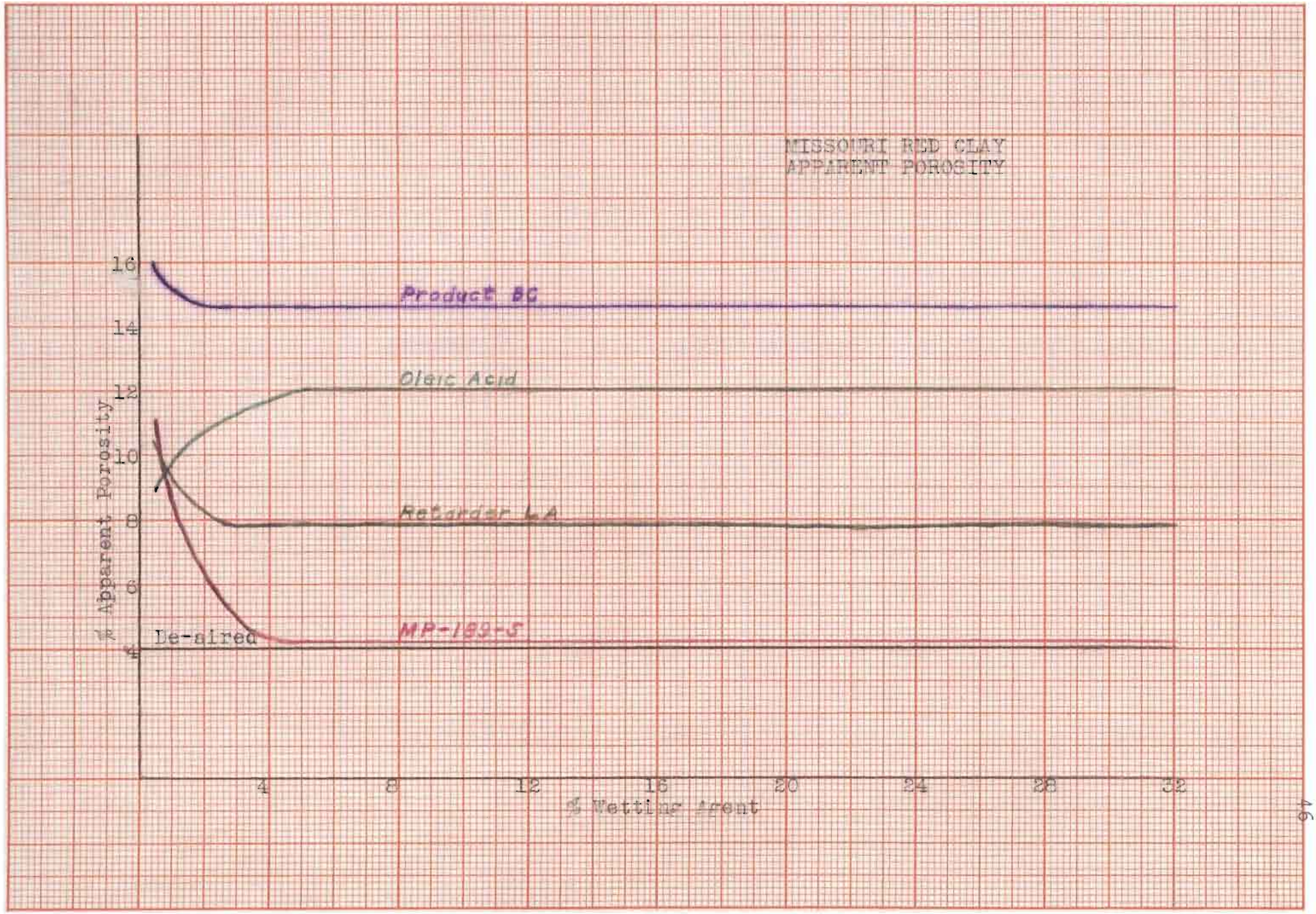
APPARENT POROSITY

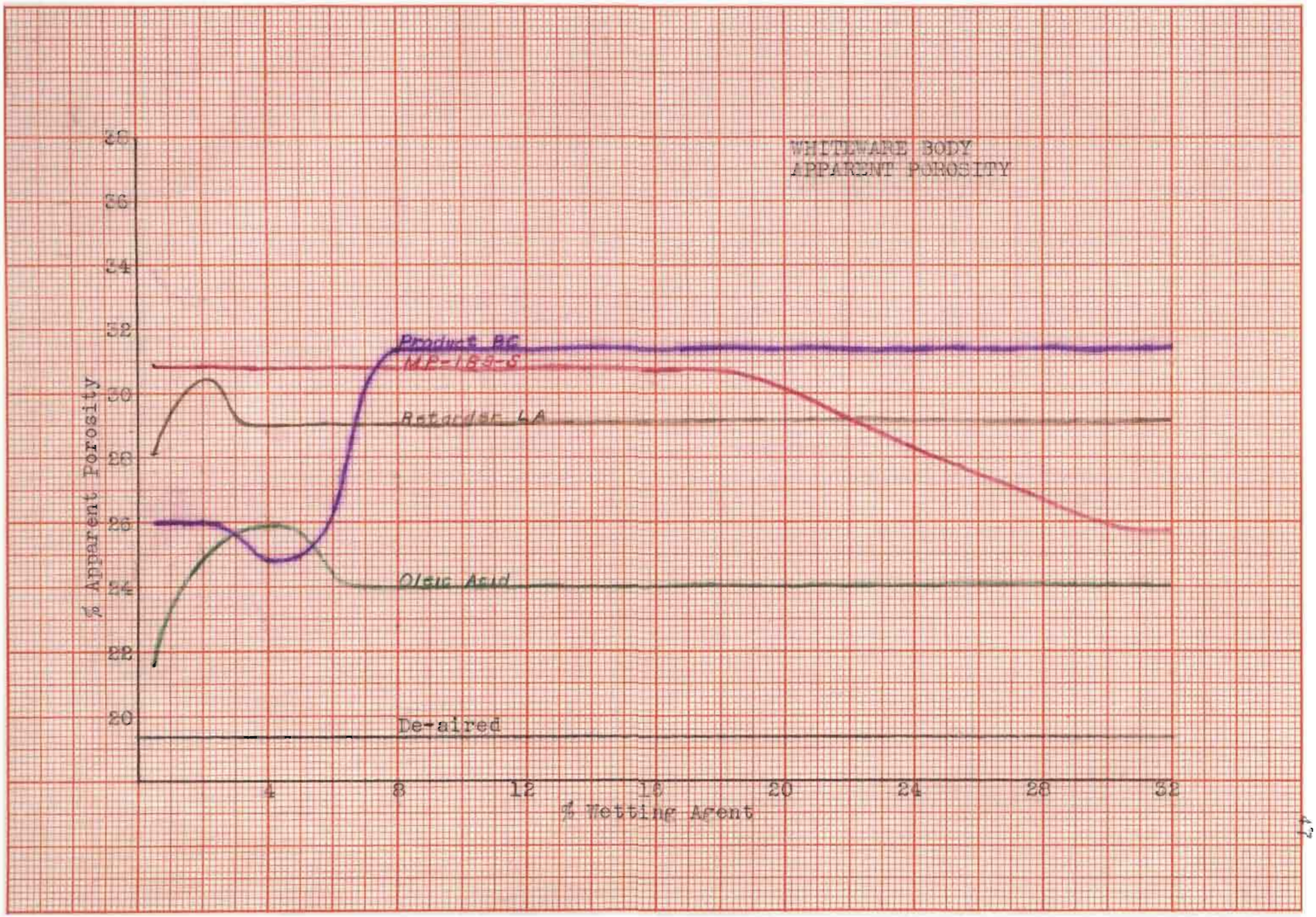
De-aired	19.3%	+ 4.9,- 5.2
0.5% Oleic acid	21.6	+ 3.3,-10.1
0.5 Du Pont Product BC	27.6	+ 6.8,- 4.8
0.5 Du Pont MP-189-S	30.9	+ 6.3,- 5.6
0.5 Du Pont Retarder LA	28.1	+ 5.1,- 6.1
1.0 Oleic acid	21.0	+ 8.4,- 5.8
1.0 Du Pont Product BC	28.3	+ 8.9,- 6.3
1.0 Du Pont MP-189-S	33.0	+ 6.0,- 2.8
1.0 Du Pont Retarder LA	24.7	+ 9.2,- 6.7
2.0 Oleic acid	25.1	+ 5.5,- 3.2
2.0 Du Pont Product BC	28.6	+ 6.6,- 2.3
2.0 Du Pont MP-189-S	27.6	+10.7,- 5.7
2.0 Du Pont Retarder LA	32.9	+ 5.2,- 1.7
4.0 Oleic acid	26.1	+ 4.9,- 3.9
4.0 Du Pont Product BC	22.7	+ 2.1,- 2.0
4.0 Du Pont MP-189-S	28.8	+10.6,-11.8
4.0 Du Pont Retarder LA	26.2	+ 3.6,- 3.0
8;0 Oleic acid	22.8	+ 2.9,- 2.4
8.0 Du Pont Product BC	36.0	+ 4.7,-4.6
8.0 Du Pont MP-189-S	27.1	+ 5.7,- 5.7
8.0 Du Pont Retarder LA	27.4	+ 5.5,- 4.3
16.0 Oleic acid	22.6	+ 2.0,- 4.8
16.0 Du Pont Product BC	38.1	+ 6.2,-11.1
16.0 Du Pont MP-189-S	31.5	+ 3.7,- 9.3
16.0 Du Pont Retarder LA	30.3	+ 5.5,- 9.4
32.0 Oleic acid	30.9	+ 5.0,-12.0
32.0 Du Pont Product BC	34.3	+ 7.5,- 6.5
32.0 Du Pont MP-189-S	21.3	+ 4.5,- 7.3
32.0 Du Pont Retarder LA	33.5	+ 3.5,- 5.3

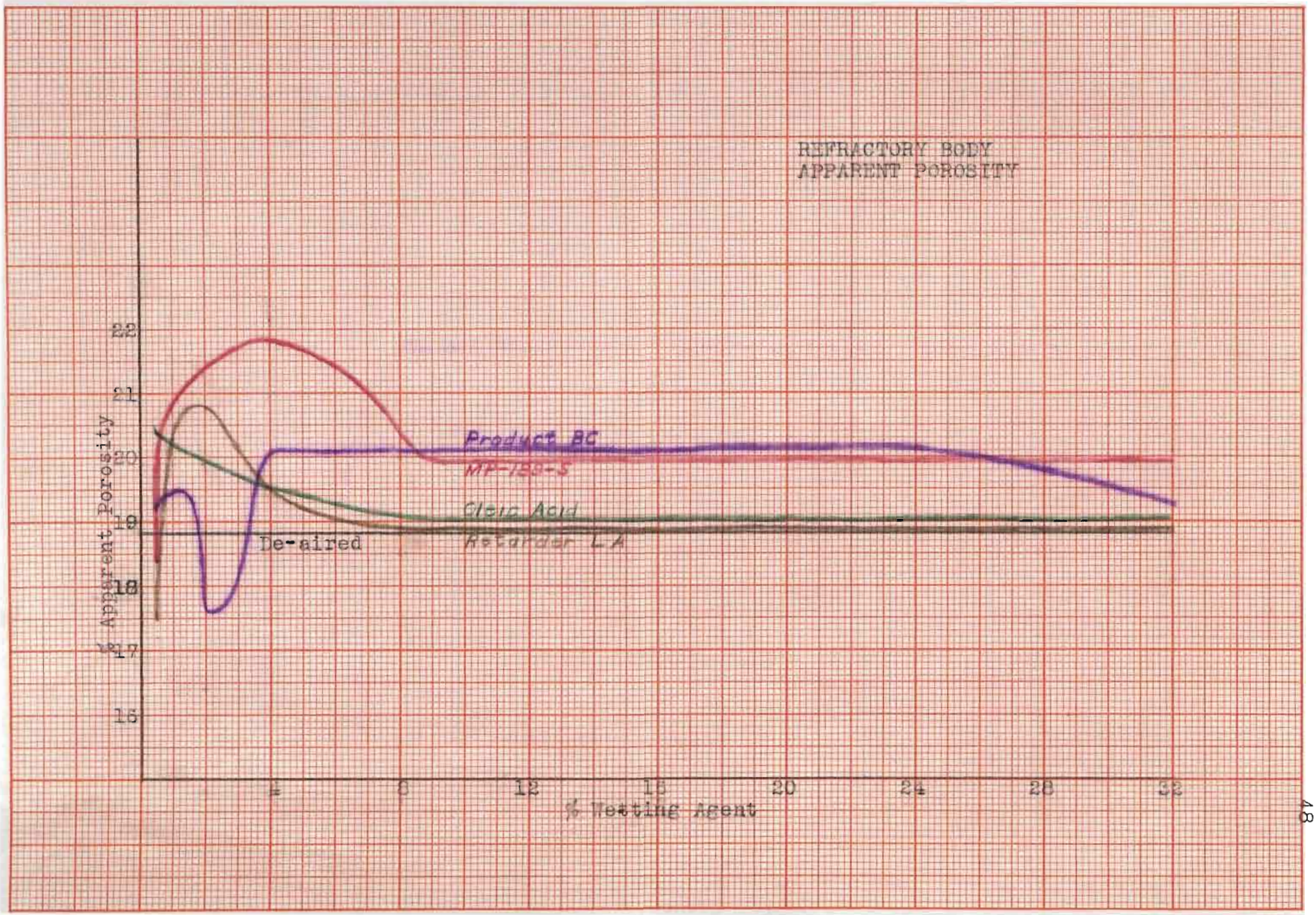
REFRACTORY BODY

APPARENT POROSITY

De-aired		18.8%	+2.3,-2.1
0.5%	Oleic acid	20.4	+2.2,-3.4
0.5	Du Pont Product BC	19.7	+2.3,-2.4
0.5	Du Pont MP-189-S	18.4	+0.7,-1.7
0.5	Du Pont Retarder LA	17.2	+0.8,-1.0
1.0	Oleic acid	20.3	+3.1,-1.4
1.0	Du Pont Product BC	19.9	+1.2,-2.8
1.0	Du Pont MP-189-S	21.3	+2.1,-1.1
1.0	Du Pont Retarder LA	21.6,	+0.6,-3.0
2.0	Oleic acid	20.0	+0.9,-1.0
2.0	Du Pont Product BC	16.4	+1.2,-0.8
2.0	Du Pont MP-189-S	21.3	+2.1,-0.8
2.0	Du Pont Retarder LA	19.9	+2.5,-3.7
4.0	Oleic acid	19.5	+1.3,-1.3
4.0	Du Pont Product BC	21.0	+0.5,-0.9
4.0	Du Pont MP-189-S	22.2	+1.5,-2.0
4.0	Du Pont Retarder LA	19.5	+1.5,-1.2
8.0	Oleic acid	18.5	+3.5,-1.7
8.0	Du Pont Product BC	18.5	+1.1,-1.4
8.0	Du Pont MP-189-S	20.0	+0.6,-2.4
8.0	Du Pont Retarder LA	18.8	+0.9,-1.4
16.0	Oleic acid	19.6	+3.4,-3.3
16.0	Du Pont Product BC	20.2	+1.2,-2.2
16.0	Du Pont MP-189-S	18.3	+1.4,-1.9
16.0	Du Pont Retarder LA	21.3	+0.9,-1.1
32.0	Oleic acid	20.1	+1.1,-1.9
32.0	Du Pont Product BC	18.5	+1.0,-1.9
32.0	Du Pont MP-189-S	21.5	+1.6,-1.1
32.0	Du Pont Retarder LA	18.1	+3.6,-0.9


MISSOURI RED CLAY
APPARENT POROSITY
% Apparent Porosity
16
14
12
10
8
6
4
Product BC
Oleic Acid
Retarder kA
MP-193-S
De-aired
4
8
12
16
20
24
28
32
% Wetting Agent


WHITEWARE BODY
APPARENT POROSITY
% Apparent Porosity
% Wetting Agent
Product PC
MP-1855-S
Retarder 4A
Oleic Acid
De-aired
28
26
24
22
20
4
8
12
16
20
24
28
32


REFRACTORY BODY
APPARENT POROSITY
% Apparent Porosity
22
21
20
19
18
17
16
De-aired
Product BC
MP-193-S
Oleic Acid
Retarder L A
4
8
12
16
20
24
28
32
% Testing Agent

CONCLUSIONS

1. It is possible, in most clay bodies, to improve the drying shrinkage, the firing shrinkage, the dry and fired strengths, and the absorption and porosity, by substituting certain additions of various wetting agents for the de-airing process. However, the apparent porosity and the per cent absorption of the Missouri red surface clay and the semi-vitreous whiteware body were not lowered by additions of wetting agents. With glazed whiteware and certain types of red clay products this might be an advantage rather than a disadvantage.

2. With the cone 8-9 semi-vitreous whiteware body, Du Pont Product BC and Du Pont Retarder LA effected the most improvements, considering all the properties collectively.

3. With the Missouri red surface clay, Du Pont Product BC effected the most improvements, considering all the properties collectively.

4. With the cone 14 fireclay refractory body, Du Pont Product BC effected the most improvements, considering all the properties collectively.

5. Considering the properties individually and the clays collectively, Du Pont Retarder LA effected the most improvements in drying and firing shrinkage, as well as dry modulus of rupture. Fired modulus of rupture and porosity were most improved by Du Pont Product BC. Absorption was improved to an equal extent by each of the four wetting agents used.

6. It is interesting to note that where improvements were effected, the wetting agent was usually present in amounts of 8% or less, based on the amount of water in the body. In amounts this small, it is probable that their use would be economically feasible.

SUMMARY

An attempt was made to determine the effect of wetting agents on clay bodies as commercially prepared, and to find if improvements could be effected by their use. Three representative types of clay bodies were chosen; a Missouri red surface clay, a cone 8-9 semi-vitreous whiteware body, and a cone 14 fireclay refractory body. To each of these three bodies four wetting agents were added: Oleic acid, Du Pont Product BC, Du Pont MP-189-S, and Du Pont Retarder LA. They were added in the following amounts, based on the amount of water used in the body: 0.5%, 1.0%, 2.0 %, 4.0%, 8.0%, 16.0%, and 32.0%.

The test bodies were made up into test pieces and dried, fired, and tested according to American Society for Testing Materials specifications. At the same time a body of each clay was made up and de-aired in the ordinary manner. This was used for purposes of comparison.

From the results here presented, it appears that wetting agents will give good workable bodies with improvement in the important dried and fired properties, even in amounts as low as 0.5% of the water content of the clay-water mass.

It should be remembered that the figures arrived at cannot be compared with figures on other clays, due to variations in grain size, adsorbed ions, mineralogical composition, and organic content. For the same reasons, and also because of differences in processing methods, the numerical results should not be taken as applicable to all manufacturing methods for the types of clays used.

It is probable that the reason for improvements with addition of wetting agents is a more thorough and even distribution of liquid throughout the clay-water mass, although in the case of Oleic acid, the dry strength is doubtless improved because of the high adhesive strength.

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VITA

Nathan Russell Sewell Jr. was born in Fulton County, Georgia on September 17, 1922, the son of Nathan R. and Frances Middlebrooks Sewell. The family later moved to East Point, Georgia, where he was graduated from Russell High School in 1939.

Upon graduation he attended University of Georgia Evening School, and later Georgia School of Technology, in Atlanta, where he received a Bachelor of Science degree in Ceramic Engineering in 1943.

He then entered the Naval Reserve, where he served as engineering officer on several ships and shore stations until 1946.

In 1946 he entered the School of Mines and Metallurgy of the University of Missouri, to do work leading to the degree of Master of Science in Ceramic Engineering.