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Rock Island Arsenal Laboratory

TECHNICAL REPORT

SUBJECT Aging of Barrier Materials

PROJECT NO. TB4-672d **REPORT NO.** 1

LAB. REPORT NO. 52-2804

PREPARED BY R.J. Wulf

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AGING OF BARRIER MATERIALS

Project Title: Packaging Materials Problems

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Object

The object of this study is to determine the physical and chemical properties of barrier materials in conformance with specifications JAN-B-121, JAN-B-148, JAN-P-131, and AXS-1638, after exposure to various deteriorating influences with a view toward improving their aging resistance and establishing their range of usefulness.

Summary

Barrier materials meeting the requirements of Joint Army and Navy Specification JAN-B-121 have been investigated for their physical and chemical properties after exposure to the deteriorating influences of light, water, and heat in the Atlas Weatherometer.

Tests were run before and after in the Atlas Weatherometer. These results are tabulated in table form for further reference and use.

Samples were subjected to forty-eight hours or less time in the Atlas Weatherometer which involved the deteriorating influences of heat, light, and water. Test results show that this test reduced the properties of the materials about 25%. Since 50% was the goal set up for the program, further aging by this method will be attempted.

The physical and checmical properties of barrier materials meeting the requirements of Joint Army and Navy Specification JAN-B-121 have been determined both before and after exposure to the deteriorating influences of light, heat, and water in the Atlas Weatherometer. These results have been tabulated in table form for further reference and use. (See Tables 2 to 11) These results show that the properties were decreased about 25% by exposure to the Weatherometer.

The tensile strength retained an overall average of between 70 and 80% after aging in the Weatherometer for 48 hours. The burst, however, varied with the material, decreasing in value more than increasing. This was usually due to the stiffening of the material. The tear seemed to increase in almost every case, being due to the stiffening and shrinkage of the materials.

The time required for water penetration was determined by the dry indicator method and proved satisfactory. The moisture-vapor-transmission (M.V.T.) rate was determined on each material and found to be reliable and reproducible, with the exception of materials which have pin holing due to manufacture. In this case erratic results can be expected.

The acidity or alkalinity was determined with the Fisher Titrimeter. The acid content was calculated from the titration results.

Grade C wraps generally increased in acidity upon aging, while Grade A materials varied in no set pattern. Acidity is considered to decrease the stability of the barrier material, while alkalinity increases stability.

The reducible sulfur test was made in order to determine the sulfur and sulfur compounds present which may cause staining upon reaction with acids in the paper, or on the material to be protected. The results, however, are more qualitative than quantitative as the percentages were by visual comparison with standards.

Copper number was used to determine the extent of cellulose deterioration and proved satisfactory for Grade A sheets. Grade C materials, however, were difficult to test by this method and copper numbers on these samples are more susceptible to error than the Grade A sheets. This is due to the wax coatings on these barrier materials.

Conclusion

The physical and chemical tests chosen to follow the deterioration of the barrier materials are adequate and give reliable and useful results. The conditioning of the materials at 73.5°F. ± 2°F. temperature and 50% ± 4% relative humidity give reproducible and accurate results.

Recommendations

No specific recommendations can be made at this time as to improvements needed. Further tests and conditions have to be determined to follow the exact changes of the chemical characteristics as the barrier materials age.

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Introduction

1. The Field Service Depot at Rock Island Arsenal is currently engaged in an extensive program of reprocessing and repackaging of Ordnance items. The poor condition of many of these items taken from storage has indicated that there remains much to be desired from the standpoint of packaging materials, particularly with regard to their aging resistance.

2. At present many of the barrier materials are used with little or no knowledge as to their resistance to the many deteriorating influences they are exposed to during storage or weathering. The need for adequate data as to deficiencies of barrier materials for use when choosing such material for a specific problem has long been realized. Very little work up to the present has been carried out with regard to these aging properties.

3. The present study consists of compiling physical and chemical properties of the barrier materials with regard to aging. Most of the tests used are standard with a few modifications. The exact nature of change of these materials was difficult to evaluate, since no extensive work has preceded this for comparison.

4. This study endeavors to distinguish between commercially available materials conforming to the same type, class, and grade of the barrier materials of Specifications

JAN-P-121, JAN-B-131, JAN-B-148, and AXS 1638, to allow selection of the best aging material, and to select adequate aging criteria. This study is designed to further the knowledge of the aging process, thereby lending a view towards improving their aging resistance and establishing their range of usefulness. The results will be summarized and applied to packaging methods and problems in order to correct deficiencies and ultimately minimize the cost of reprocessing Ordnance parts.

5. This report is the first of a series which will determine the physical and chemical properties in conformance with selected test methods after exposure to deteriorating influences such as ultra violet light, oxygen, ozone, water, water vapor, heat, fungi, and cold, humidity, heat, and pressure cycles. The time of exposure will vary with the materials. The limiting time will be adjusted so that a deterioration of 50% will be obtained.

6. In order to make reporting more meaningful and applicable, this report contains the work completed on the first five companies' samples which involves a total of twenty-two materials. A complete list of all the barrier materials submitted by the thirteen companies may be found in Table 1.

7. The work is continuing on the remaining eight companies' materials which involves thirty-nine more

samples. Tests will be continued with the weatherometer and also other tests using oxygen, ozone, water, water-vapor, heat, fungi, and cold, humidity, heat and pressure cycles.

Procedure

8. The barrier materials were subjected to forty-eight hours in the Atlas Weatherometer. (Three samples were removed earlier because of decomposition.) The heat in the weatherometer was controlled at 145°F. and provided for 102 minutes of light followed by 18 minutes of light and water spray. (The light is filtered so as to give only wave lengths above 2750 angstrom units or those which are found in direct sunlight at sea level.) This is in conformance with Federal Specification TT-P-141B and Test Method 615.1. (See Figure 4.)

9. The materials were then subjected to the following physical and chemical tests both before and after aging.

Physical Tests	Fed.Spec.	TAPPI Method*
Tensile strength	UU-P-31A	T404 m-41
Mullen burst	UU-P-31A	T413 m-41
Elmendorf tear	UU-P-31A	--
Water permeability	--	T433 m-41
Moisture-vapor-transmission	--	T448 m-41

*TAPPI - Technical Association of the Pulp and Paper Industry.

Chemical Tests	Fed. Spec.	TAPPI Method
Copper number	-	T430 m-41
Reducible sulfur	-	T406 m-41
Acid content	JAN-B-121	
pH Value	JAN-B-121	

10. The physical properties of paper vary widely with changes in moisture content. The control of moisture by conditioning to equilibrium in an atmosphere of constant relative humidity and temperature is therefore a necessary prerequisite to accurate controlled testing. The conditions in Federal Specification No. 1 for Laboratory Atmospheric Conditions for Testing were used for all the testing in this study. These conditions are 73.5°F. ± 2°F. temperature and 50% ± 4% relative humidity.

11. The weight was determined in conformance with TAPPI Method T410 m-41. The weight is then calculated as pounds per 1000 sheets, 24 x 36 inches.

12. The thickness was determined on the Federal Thickness Tester in conformance with TAPPI Method T411 m-36.

13. The remaining properties were determined both before and after the accelerated aging.

14. The tensile strength and tear strength were determined in both machine and cross directions.

15. The water permeability was determined by the dry indicator method and in conformance with TAPPI method T433 m-41. The samples were allowed to remain in test until

failure. Hours given are approximate due to the difficulty of running the test in an eight hour day.

16. The General Foods Moisture Vapor Transmission Humidity Cabinet (See Figure 5) was used for all the moisture-vapor-transmission tests. However, in future experiments the Thwing-Albert Electric Hygrometer will be used to measure moisture-vapor-transmission rates of materials with thick films, to eliminate the possibility of measuring absorption rather than the true transmission rate. The General Foods Method is in conformance with Joint Army and Navy Specification JAN-P-117, paragraph E-5 section F-4a. Tests were run before and after aging by the Atlas Weatherometer.

17. The copper number was determined on each sample before and after aging. The copper number is defined as the number of grams of metallic copper in the cuprous oxide reduced from copper sulfate by 100 grams of the paper fibers under the conditions of the test.

18. In this test one and one-half grams of defibered paper are treated with an alkaline copper sulfate solution for three hours in a steam bath. The pulp is then washed with sodium carbonate solution and water. The precipitated copper oxide is then dissolved with molybdophosphoric acid solution and the solution titrated with potassium permanganate. The copper number is reported on the basis of

of total fiber content. Figure #6, Row #1, and Figure #7 show the apparatus and solutions used for this test.

19. The copper numbers on the Grade C materials were very difficult to determine because of the difficulty of filtering a waxy material. Therefore, not too much emphasis should be placed on the copper numbers reported for Grade C and wax coated papers. The copper numbers on the Grade A materials, however, are excellent proof of the deterioration of the cellulose. No corrections were made on any of the materials for the presence of contaminants other than for moisture content.

20. Reducible sulfur was determined on each of the materials before aging and in conformance with TAPPI Method T406 m-41. In pulp and paper, the term reducible sulfur refers to any form of sulfur or sulfur compound which is converted to hydrogen sulfide upon treatment with a metal (such as aluminum or zinc) and an acid. The value is a measure of the quantity of sulfur compounds present which may react with ferrous metals to cause staining. The apparatus used is shown in Figure 6 on the second row of the steam bath.

21. The amount of reducible sulfur present was found by comparing stained filter papers. A group of standards were used for the comparisons, therefore, the

test is more qualitative than quantitative. The standards were for 0.0002, 0.0004, 0.0006, 0.0008, 0.001 percent and any thing above 0.001 percent was designated 0.001 in Tables 2 through 11.

Results

22. The results of all the physical and chemical tests are tabulated in table form in Tables 2 through 11. These results include 22 samples from 5 companies as listed:

H. P. Smith Paper Co., Chicago, Illinois
Thilmany Pulp and Paper Co., Kaukauna, Wisc.
Floyd A. Holes, Inc., Bedford, Ohio
Sherman Paper Corp., Newton Upper Falls, Mass.
Minerva Wax Products, Minerva, Ohio

H. P. Smith Paper Co.

Arctic Pak 1, JAN-B-121, Grade A, Type 1, Class 1, uncreped

23. This is a polyethylene coated kraft paper which meets the requirements of Joint Army and Navy Specification JAN-B-121. The visual effects of the accelerated aging were not too noticeable, however, there was some shrinkage and wrinkling. The physical and chemical properties did show greater changes than the eye observed. The tensile retained 76.3% of its strength in the machine direction and 81.8% in the cross direction. The bursting strength remained unchanged. The tearing strength increased by 22% in the machine direction and 30% in the cross direction. This was

found true in a great many cases, probably being due to the shrinkage and some stiffening. The time required for water penetration was 22 hours and no change took place after aging.

24. The moisture-vapor-transmission rate increased from .59 to 1.87 gms./100 sq.in./24 hours. This is due to shrinkage irregularities in the polyethylene caused by the ultra violet light and elevated temperature (145°F.).

25. There was no change in the pH value after aging and no acid was found present. The sulfur content was greater than 0.001%.

26. The copper number increased from .66 to 1.15 indicating deterioration of the cellulose.

Arctic Pak 1, JAN-B-121, Grade A, Type 1, Class 1, creped

27. This is a polyethylene coated creped kraft paper which meets the requirements of Joint Army and Navy Specification JAN-B-121. The visual effects of the accelerated aging were not as noticeable as the preceding material, probably being due to the crepeing. There were also less changes in the physical and chemical properties in the creped material. The tensile strength remained the same, while the burst increased by 8.5%. The tearing strength increased 31.7% in the machine direction and 24.5% in the cross direction. The time required for water penetration was 22 hours both before and after aging.

28. The moisture-vapor-transmission rate decreased from .82 to .69 gms./100 sq.in./24 hours. This could be due to the crepeing which may cause damage to the polyethylene coating.

29. The pH value was 6.5 before aging and 7.4 after aging, and an acid content of .003% was found. The reducible sulfur was found to be 0.0008%. The copper number increased from .56 to 1.38, indicating cellulose deterioration.

Arctic Pak 2, JAN-B-121, Grade A, Type 2, Class 1

30. This is a polyethylene coated kraft paper which meets the requirements of Joint Army and Navy Specification JAN-B-121. No undesirable visual effects of the accelerated aging were noticeable, except for a slight wrinkling which could be indicative of shrinkage of the polyethylene or kraft backing. The tensile retained 88.5% of its strength in the machine direction and 75.0% in the cross direction. The burst retained 97.0% of its original property. The tearing strength increased again due to shrinkage which in many cases has this effect, the increase being 8% in the machine direction and 25% in the cross direction. The time required for water penetration was 22 hours both before and after aging.

31. The moisture-vapor-transmission rate increased from .64 to .74 gms./100 sq.in./24 hours. This is indicative of the damage in aging to the polyethylene coating.

32. The pH value changed from 6.5 to 7.3 before and after aging respectively, and .005% acid was found to be present. The reducible sulfur content was 0.0004%. The copper number increased from .34 to 1.41 which again indicated deterioration of the cellulose.

Lamine 1, JAN-B-121, Grade A, Type 1, Class 1
Lamine 2, JAN-B-121, Grade A, Type 2, Class 1

33. These barrier materials consist of glassine securely laminated to kraft backing. These materials meet the requirements of Joint Army and Navy Specifications JAN-B-121, except permanence. This was very clearly illustrated in the accelerated aging to which it was subjected. The glassine was entirely delaminated from the kraft backing upon removal from the weatherometer after 26.9 hours. (See Figures 1 and 2.) There was also fading and wrinkling. Delamination made it difficult to determine the after aging physical properties, so no attempt was made to analyze them individually. The samples have no water or water vapor resistant properties.

34. No acid was found to be present. The sulfur content was 0.0006% and 0.0002% respectively.

35. The copper numbers were larger before aging than after aging. This could be due to the washing away, during aging, of the filler which was used to laminate the papers. This seems to be the most logical explanation, for the copper

number was determined in the same manner before and after aging. The copper number was 3.03 before aging and 1.94 after aging on the sample of Lamine 1. On the sample of Lamine 2 it was 4.48 before aging and 2.05 after aging.

Self-Wrap, JAN-B-121, Grade A, Type 2, Class 2

36. This is a heavily waxed creped kraft material which meets the requirements of Joint Army and Navy Specification JAN-B-121. The visual effects of accelerated aging were fading and shrinkage. There was also noticeable slippage of the waxy covering material. This removal and slipping of the wax on the paper was probably the cause of irregularities in the after aging properties. The tensile strength decreased by 9.8% in the machine direction and increased by 10.9% in the cross direction. The tearing strength retained 80.1% in the machine direction and 77.9% in the cross direction. The burst retained 80% of its strength after aging.

37. The time required for water penetration before aging was 22 hours and 2 hours after aging. This was indicative of the loss of waxy covering. The moisture-vapor-transmission rate decreased from 1.54 to .70 gms./100 sq.in. per 24 hours, which can be explained by the slippage and removal of the waxy covering material.

38. A change from alkalinity to acidity was noted after aging, which is rather representative of wax covered

materials. However, they are usually Grade C wraps. The acid content was .086% after aging. The reducible sulfur content was 0.0008%.

39. The copper number increased from .17 to 1.42, indicating cellulose deterioration.

Thilmany Pulp and Paper Company

Thilco Poly-Kraft, JAN-B-121, Grade A, Type 1, Class 1 uncreped

Thilco Poly-Kraft, JAN-B-121, Grade A, Type 1, Class 1 creped

40. These are polyethylene coated kraft paper, one being creped and the other uncreped. The samples meet the requirements of Joint Army and Navy Specification JAN-B-121. The visual effects of the accelerated aging were fading and some blistering beneath the polyethylene. The tensile on the uncreped material retained 79.2% of its strength in the machine direction and 70.4% in the cross direction. The creped material retained 92.5% in the machine direction and 87.4% in the cross direction. The tearing strength increased 38.4% in the machine direction and 14.4% in the cross direction. The creped material increased 4.2% in the machine direction and 19.7% in the cross direction. The bursting strength remained the same on the uncreped material and increased 19.9% on the creped material, again due to stiffening.

41. The time required for water penetration was 12 hours before aging and after aging on the uncreped

material and time ranging from 12 to 23 hours for the before and after aging on the creped material. The moisture-vapor-transmission rate increased from .65 to .99 gms./100 sq.in./24 hours before and after aging on the uncreped material. The rate remained the same, .77 gms./100 sq.in./24 hours on the creped material. This is due to the blistering which was more prevalent in the creped material and would allow for greater transmission of the moisture.

42. The pH was alkaline in all cases and increased in alkalinity after aging. The creped material contained greater than 0.001% sulfur while the uncreped material contained 0.0006%. The copper number increased from .19 to 1.49 on the uncreped material and from .13 to .99 on the creped material, indicating a cellulose deterioration in each.

Thilco Poly-Kraft, JAN-B-121, Grade A, Type 2, Class 1 uncreped

Thilco Poly-Kraft, JAN-B-121, Grade A, Type 2, Class 1 creped

43. These are polyethylene coated materials on kraft backing, the difference in these and the above materials being the Type 2, or medium heavy material rather than heavy duty. The visual effects of the accelerated aging were fading and some blistering under the polyethylene coating. The tensile on the uncreped material retained 65% of its strength in the machine direction and 68.5% in the cross direction. The tensile retained 99% of its

strength in the machine direction and 93.3% in the cross direction in the creped material. The tear strength retained 93.5% in the machine direction and 90% in the cross direction in the uncreped material, while it increased by 15.3% in the machine direction and 10.5% in the cross direction in the creped material. The bursting strength increased 20% on the uncreped material and increased by 7.3% in the creped material.

44. The time for water penetration varied about 50% each for 12 hours and 23 hours on the uncreped material. The time for water penetration on the creped material was 12 hours before and after aging. The moisture-vapor-transmission rate was .74 before aging and .82 after aging on the uncreped material. The moisture-vapor-transmission rate was 1.09 before aging and .89 gms./100 sq.in./24 hours after aging.

45. The creped and uncreped material was alkaline after aging. The reducible sulfur content was 0.0002% for the uncreped material and 0.0008% for the creped material. The copper number for the creped material was .42 before aging and 1.10 after aging. The copper number for the uncreped material was .15 before aging and 1.31 after aging.

Floyd A. Holes, Inc., Bedford, Ohio

Hi-Binder #50, JAN-B-121, Grade C, Type 1, Class 1

46. This is a cotton scrim with a cellophane film

and wax. The material meets the requirements of Joint Army and Navy Specification JAN-B-121. The visual effect of the accelerated aging was very noticeable after 25.3 hours. (See Figure 3.) The material was removed from the weatherometer at this time and photographed. The film was removed and a great deal of the wax had run and washed away. The tensile retained 80.5% of its strength in the machine direction and 75% in the cross direction. The tear retained 71.5% of its strength in the machine direction and 68.4% in the cross direction. The burst retained 64.5% of its strength after the 25.3 hours in the weatherometer.

47. The time required for water penetration was 24 hours before aging, and since the sample was in such poor condition after aging no attempt was made to run this test again. The moisture-vapor-transmission rate increased from .29 to 3.42 gms./100 sq.in./24 hours. This, however, is surprisingly low considering the destruction of the material.

48. The pH value changed from 7.4 to 5.5 after aging. The acid content was 0.029%. The copper number increased from .07 to .17.

Hi-Binder #50, JAN-B-121, Grade C, Type 1, Class 2

49. This is a cotton scrim with a self-adhering coating applied to both sides. The material meets the

requirements of Joint Army and Navy Specification JAN-B-121. The tensile retained 44.5% of its strength in the machine direction and 19.1% in the cross direction. The tear retained 25% of its strength in the machine direction and 19.1% in the cross direction. The burst retained 38.3% of its strength after aging.

50. The time required for water penetration was 24 hours before aging and 6 hours after aging. The moisture-vapor-transmission rate was .058 before aging and .077 gms./100 sq.in./24 hours after the accelerated aging. The two side coating was responsible for this.

51. The pH value was 7.8 before aging and 6.7 after the accelerated aging. The acid content was .003%. A reducible sulfur content was 0.0004%. The copper number was .15 before aging and .28 after the accelerated aging.

Hi-Binder #81, JAN-B-121, Grade A, Type 1, Class 1

52. This is a polyethylene coated kraft paper. The visual effects of the aging were a great deal of bleaching and wrinkling with blistering of the polyethylene coating. The tensile retained 45.5% of its strength in the machine direction and 74% in the cross direction. The tearing strength however increased 55% in the machine direction and 6.2% in the cross direction. The bursting strength also increased by 9.3%. These increases are due primarily to the stiffening and shrinkage of the material.

53. The time required for water penetration before aging was 6 hours and 9 hours after the accelerated aging. This is probably due to the non-continuous coating in the film when the material shrinks. The moisture-vapor-transmission rate increased from 1.14 to 2.64 gms./100 sq.in. per 24 hours.

54. The pH value before aging was found to be 6.6 and 7.6 after aging. The acid content was .003%. A low sulfur content of 0.0002% was also found. The copper number increased from .54 to 1.33.

Hi-Binder #82, JAN-B-121, Grade A, Type 2, Class 1, uncreped

55. This is a polyethylene coated material of medium heavy duty (Type 2). The visual effects of the accelerated aging were fading, wrinkling and blistering of the polyethylene coating. The tensile retained 80.3% of its strength in the machine direction and 69.8% in the cross direction. The tearing strength increased by 6.3% in the machine direction and by 3.8% in the cross direction. The bursting strength remained the same before and after aging.

56. The time required for water penetration was 6 hours before aging and 9 hours after aging. The moisture-vapor-transmission rate was 1.44 before and 2.77 gms./100 sq.in./24 hours after aging. This is due to the blister which makes the material more susceptible to the transmission

of water vapor. The pH value was 7.1 before aging and 7.7 after aging. The reducible sulfur content was 0.0004%. The copper number, indicative of a cellulose deterioration, increased from .60 to 1.46.

Hi-Binder #83, JAN-B-121, Grade A, Type 2, Class 1, creped

57. This is the same type of a barrier material as the one previously reported, except for being creped. The visual effects of aging were bleaching and blistering. The creped materials show less shrinkage and stiffening during aging then the uncreped materials. The tensile retained 77.7% of its strength in the machine direction and 85.7% in the cross direction. The tearing strength increased 7.0% in the machine direction and 26.3% in the cross direction. The burst also increased by 13.9%.

58. The time required for water penetration was 6 hours before aging and 12 hours after aging. The moisture-vapor-transmission rate was 1.30 before and 4.60 gms./100 sq.in./24 hours after aging. This increase is due to the non-continuous film.

59. The pH value was 7.0 before aging and 7.8 after the accelerated aging. A reducible sulfur content of 0.0004% was found. The copper number increased from .54 to 1.60 which again indicated deterioration of the cellulose.

Sherman Paper Corporation, Newton Upper Falls, Mass.

V-18 Corroflex, JAN-B-121, Grade A

60. This material consists of a strong kraft outer lamination with creped kraft backing sheet coated with polyethylene. This is a corrugating medium and can be used for products which require a protective cushion and a strong covering. The material meets the requirements of Joint Army and Navy Specification JAN-B-121. The visual effects of aging were curling of the edges and wrinkling. The tensile retained 69.3% of its strength in the machine direction and 85.3% in the cross direction. The tear retained 88.2% of its strength in the machine direction and 82.4% in the cross direction. The bursting strength increased 4.3%.

61. The time required for water penetration was 12 hours before and after the accelerated aging. The moisture-vapor-transmission rate was 1.64 before and 1.77 gms./100 sq.in./24 hours after aging.

62. The pH value was 6.6 before aging, giving an acid content of .005%. The pH after aging was 7.6. The reducible sulfur content was 0.006%. The copper number increased from .74 to 1.22 after aging.

V-27 V-Line, JAN-B-121, Grade C, Types 2 and 3

63. This material is a wax coated paper having wax on both sides. The material meets the requirements of Joint

Army and Navy Specification JAN-B-121. The visual effects of accelerated aging were fading and slight shrinkage of the cotton scrim. There was very little slipping of the wax. The tensile retained 74.3% of its strength in the machine direction and 50% in the cross direction. The tear retained 75.7% of its strength in the machine direction and 81.5% in the cross direction. The bursting strength retained 92.5% of its original property.

64. The time required for water penetration was two hours both before and after aging. The moisture-vapor-transmission rate decreased from 1.36 to .92 gms./100 sq. in./24 hours. This is probably due to the reorientation of the wax on the surface of the material.

65. The before aging pH value was 6.6 and after aging was 4.7. This gave an acid content of 0.005 and 0.051 respectively. The reducible sulfur content was 0.0002%. The copper number increased from .17 to .54 after aging.

V-28 V-Line, JAN-B-121, Grade A, Type 2, uncreped

66. This is a two-ply laminated wrap combining a neutral kraft impregnated with a rust-inhibitor oil and a mold-inhibitor plus a transparent plastic film laminated to the kraft paper with a greaseproof rosin. The material meets the requirements of Joint Army and Navy Specification JAN-B-121. The visual effects of the aging were fading and part delamination. The tensile retained 51%

of its strength in the machine direction and 78.8% in the cross direction. The tear retained 87% of its strength in the machine direction and 80.3% in the cross direction. The bursting strength increased 15.6% after aging. This usually indicates stiffening of the material.

67. The time required for water penetration was 1/2 hour before aging and immediately after aging. The moisture-vapor-transmission rate was approximately 61.8 grams/100 sq.in./24 hours before aging and 101.2 gms./100 sq.in./24 hours after accelerated aging.

68. The pH value was 6.4 before aging and an acid content of .007%. The pH value after aging was also 6.4 with an acid content of .006%. The reducible sulfur content was 0.0002%. The copper number increased from .81 to 1.46 after aging indicating a cellulose deterioration.

V-29 V-Line, JAN-B-121, Grade A, Type 2, creped

69. This material consists of a transparent plastic film laminated to creped kraft with a greaseproof resin. The material meets the requirements of Joint Army and Navy Specification JAN-B-121. The visual effects of the accelerated aging were fading and part delamination of the plastic film. The tensile strength remained the same before and after aging. The tear retained 85.5% of its strength in the machine direction and 83.7% in the cross direction. The bursting strength increased 20.2% after aging.

70. The time required for water penetration was 1/2 hour before aging and immediately after aging. The moisture-vapor-transmission rate was 71.4 grams/100 sq.in. per 24 hours before aging and 115.3 grams/100 sq.in./24 hours after accelerated aging.

71. The pH value was 6.4 before aging with an acid content of .009. The after aging pH was 7.4. The reducible sulfur content was 0.0006%. The copper number increased from .09 to 1.69 indicating a deterioration of the cullulose.

Minerva Wax Products, Minerva, Ohio

Ord. Wrap. #101-B, JAN-B-121, Grade A, Type 1, Class 1

72. This is a sample of glassine and kraft papers with an asphalt filler. The material meets the requirements of Joint Army and Navy Specification JAN-B-121. The visual effects of the accelerated aging were part delamination and channeling causing damage to both paper coverings. The delamination was not uniform and this in part is the reason for the irratic results. The tensile retained 60.6% of its strength in the machine direction and 45.6% in the cross direction. The tearing strength increased slightly, 2.8% in the machine direction and 15.8% in the cross direction. The burst retained 80.0% of its strength after aging.

73. The time required for water penetration was 18 hours before aging and 6 hours after aging. This was

due to the delamination which removed some of the asphalt and allowed water penetration. The moisture-vapor-transmission rate was 2.67 before and 2.60 gms./100 sq.in./24 hours after aging.

74. The pH value was 7.5 before aging and 7.0 after the accelerated aging. The reducible sulfur content was 0.0008%. The copper number was .55 before aging and 1.24 after aging.

Ord. Wrap #101-C, JAN-B-121, Grade A, Type 2, Class 1

75. This is a material of the same composition as the previously reported material, except for being of medium heavy duty rather than heavy duty. The delamination was not, however, as prevalent on this sample. The tensile retained 74.5% of its strength in the machine direction and 78% in the cross direction. The tearing strength increased 4.5% in the machine direction and 13.6% in the cross direction. The bursting strength remained unchanged after aging.

76. The time required for water penetration was 45 hours before aging and an average of 14 hours after aging. The moisture-vapor-transmission rate was 1.48 before aging and 1.32 gms./100 sq.in./24 hours after aging.

77. The pH value remained the same before and after aging 6.6 with an acid content of .003%. The reducible sulfur content was 0.0004%. The copper number was 1.10 before aging and 1.05 after aging.

Ord.Wrap #201, JAN-B-121, Grade C, Type 2, Class 2 creped

78. This is a waxed creped paper of the pressure seal type. The material meets the requirements of Joint Army and Navy Specification JAN-B-121. The visual effects of the accelerated aging were some fading and a little distortion of shape or reorientation of the wax. The tensile strength increased 1.8% in the machine direction and 10.3% in the cross direction. The tear retained 76.2% in the machine direction and 72.5% in the cross direction. The burst retained 84.0% of its strength after aging.

79. The time required for water penetration was one hour before and after aging. The moisture-vapor-transmission rate was 1.25 before and .91 gms./100 sq.in./24 hours after aging. This was due either to the redistribution of the wax or pin holing during manufacture.

80. The material had a pH value of 7.1 before aging and 4.5 after aging. This gave an acid content of .058%. The reducible sulfur content was 0.0008%. The copper number increased from .27 to .61 after aging.

Discussion

81. The effects of the accelerated aging in the Atlas Weatherometer appears to give excellent proof of the theories concerning the chemistry of paper. The physical strength properties were greatly affected by the aging, however, they were not consistent in increasing, decreasing, or retaining of strength properties. The

Atlas Weatherometer gives a method by which it is possible to control the deteriorating influences of heat, water and light. The heat was controlled at 145°F. and the water was in the form of a fine spray. The water and light cycle was controlled for 102 minutes of light and 18 minutes of water spray and light. The light is filtered to give only light of the wave lengths above 2750 angstrom units or those found in strong sunlight. The samples were subjected to test for 48 hours or less as specified.

82. Since the physical properties of paper change with variations in its moisture content, it is necessary to condition at constant temperature and humidity if standard test data is to be obtained. Therefore, the materials were all conditioned in conformance with the requirements of Federal Specification No. 1 which are 73.5°F. ± 2°F. temperature and 50% ± 4% relative humidity.

83. The physical tests choosen were those to best follow the deterioration of the barrier materials during aging. The test results are averages of 10 or more tests for tensile strength, Elmendorf tear, Mullen burst and water permeability. Three tests were run for moisture-vapor-transmission rates on each sample. The results are tabulated in Tables 2 through 11.

84. The acidity was determined when present with the Fisher Titrimeter and calculated as the percentage of

sulfuric anhydride. The action of acids on cellulose results in a weakening of the material and yields at the same time a whole range of degradation products. In general, the rate of hydrolysis is associated with the strength of the acid. If the acid is in the form of sulfuric, it forms a material designated "hydrocellulose", exhibiting reduced strength properties and increased copper number. This was found true in several cases. Acid content and the reducible sulfur present indicate that several of the barrier materials would disintegrate more rapidly for this reason.

85. In the presence of air, strong alkali also leads to marked disintegration of the of the cellulose. This again depends on the strength of the alkali present. Alkalinity is considered to increase the stability of the materials in minute proportions and often fillers of $CaCO_3$ are added for this purpose.

86. The number of grams of metallic copper in the cuprous oxide reduced from cupric hydroxide by 100 grams of paper treated under specific conditions with an excess of cupric hydroxide solution is defined as the copper number. The copper number indicates the relative number of reducing groups in the pulp or paper and is used as a measure of its chemical quality and stability. Excellent and reproducible results were determined on the Grade A sheets. Corrections

were made for moisture only, since the sample retained the same contaminants before and after aging. The results on the Grade C sheets were difficult to determine, and therefore not too much emphasis should be placed on these copper numbers. Because of the waxy material, the difficulty of filtering allows the possibility of a great many errors. However, even with the possibility of errors, these copper numbers do show some deterioration of cellulose.

87. Tests are continuing to determine the exact physical and chemical changes which take place when a barrier material ages. Table 1 contains a listing of the barrier materials received thus far for test. These materials include samples conforming to the specifications of JAN-B-121, JAN-B-148, JAN-P-131 and AXS-1638.

Report by: R. J. Wulf

Supervised by: A. C. Saunders

Approved by: A. C. HANSON

List of Figures and Tables

TABLE 1

Name of Material	Specification
H. P. SMITH PAPER CO., Chicago, Illinois	
Arctic Pak 1	JAN-B-121-Grade A Type 1 Class 1
Arctic Pak 1	JAN-B-121 Grade A Type 1 Class 1
Arctic Pak 2	JAN-B-121
Lamine 1	JAN-B-121 Grade A Type 1 Class 1
Lamine 2	JAN-B-121 Grade A Type 2 Class 1
Self-Wrap	JAN-B-121 Grade A Type 2 Class 2
THILMANY PULP AND PAPER CO., Kaukauna, Wisconsin	
Thilco Poly-Kraft(uncreped)	JAN-B-121 Grade A Type 1 Class 1
Thilco Poly-Kraft(uncreped)	JAN-B-121 Grade A Type 2 Class 1
Thilco Poly-Kraft(creped)	JAN-B-121 Grade A Type 1 Class 1
Thilco Poly-Kraft(creped)	JAN-B-121 Grade A Type 2 Class 1
FLOYD A. HOLES, INC., Bedford, Ohio	
Hi-Binder #50	JAN-B-121 Grade C Type 1 Class 1
Hi-Binder #50	JAN-B-121 Grade C Type 1 Class 2
Hi-Binder #81	JAN-B-121 Grade A Type 1 Class 1
Hi-Binder #82	JAN-B-121 Grade A Type 2 Class 1
Hi-Binder #83	JAN-B-121 Grade A Type 2 Class 1
SHERMAN PAPER CORPORATION, Newton Upper Falls, Mass.	
V-18 Corroflex	JAN-B-121 Grade A
V-27 V-Line	JAN-B-121 Grade C Types 2 and 3
V-28 V-Line	JAN-B-121 Grade A Type 2
V-29 V-Line	JAN-B-121 Grade A Type 2
MINERVA WAX PRODUCTS, Minerva, Ohio	
Minerva Ord. Wrap #101-B	JAN-B-121 Grade A Type 1 Class 1
Minerva Ord. Wrap #101-C	JAN-B-121 Grade A Type 2 Class 1
Minerva Ord. Wrap #201	JAN-B-121 Grade C Type 2 Class 2

TABLE 1
(Cont'd.)

Name of Material	Specification
DOBECKMAN CO., Cleveland, Ohio	
"Benbar" Barrier #1001	JAN-B-121 Grade A Type 1 Class 1
"Benbar" Barrier #1002	JAN-B-121 Grade A Type 2 Class 1
"Benbar" Barrier #1003	JAN-B-121 Grade A Type 2 Class 1
"Benbar" Barrier #1004	JAN-B-121 Grade A Type 1 Class 1
GUMOND PRODUCTS	
G 30	JAN-B-121 Grade A Type 2 Class 1
MID WEST WAX & PAPER CO., Fort Madison, Iowa	
Seal-Tite	JAN-B-121 Grade C Type 1 Class 1
Seal-Tite	JAN-B-121 Grade C Type 1 Class 2
Seal-Tite	JAN-B-121 Grade C Type 2 Class 1
Seal-Tite	JAN-B-121 Grade C Type 2 Class 2
Seal-Tite	JAN-B-121 Grade C Type 1 Class 2
Seal-Tite	JAN-B-121 Grade C Type 3
Seal-Tite	JAN-B-121 Grade A Type 2 Class 2
FABRICON PRODUCTS, River Rouge, Mich.	
Export-O-Pak #10	JAN-B-121 Grade C
Export-O-Pak #15	JAN-B-121 Grade C
Export-O-Pak #20	JAN-B-121 Grade C
MARVELLUM CO., Holyoke, Mass.	
Barrier Material	JAN-B-121 Grade A Type 1 Class 1
	JAN-B-121 Grade A Type 1 Class 1
	JAN-B-121 Grade A Type 2 Class 1
	JAN-B-121 Grade A Type 2 Class 1
	JAN-B-121 Grade A Type 2 Class 2
	JAN-B-121 Grade C Type 1 Class 1
	JAN-B-121 Grade C Type 1 Class 1
	JAN-B-121 Grade C Type 1 Class 2
	JAN-B-121 Grade C Type 1 Class 2
	JAN-B-121 Grade C Type 2 Class 2
	JAN-B-121 Grade C Type 3 Class 2
	JAN-B-121 Grade C Type 3 Class 2

TABLE 1
(Cont'd.)

Name of Material	Specification
ANGIER CORPORATION, Fraingham, Mass.	
Induwrap, creped	JAN-B-121 Grade A Type 1 Class 1
Induwrap, creped	JAN-B-121 Grade A Type 2 Class 1
Induwrap, flat	JAN-B-121 Grade A Type 1 Class 1
Induwrap, flat	JAN-B-121 Grade A Type 2 Class 1
Indufoil	JAN-B-121 Type 2, Class 1
AVERY CORPORATION, Chicago and New York	
R-V4C Wrap	JAN-B-121 Grade C Type 1 Class 1
R-V4C Wrap	JAN-B-121 Grade C Type 1 Class 2
R-V #440 M.V. Barrier	MIL-B-131A Type 1 Class A
MID-STATES	
Green Core Cloth Rap	
Green Core Rap	
Green Core Kraft Rap (Heavy Wt.)	
Green Core Kraft Rap (Light Wt.)	
The Visking Corporation, Terre Haute, Ind.	
8 - different thicknesses of polyethylene of the following thicknesses: 0.01, 0.008, 0.006, 0.005, 0.004, 0.003, 0.002, 0.0015	AXS-1638
REYNOLDS METALS CORPORATION, Louisville, Kentucky	
Plain Aluminum Foil 0.001" - "O"; 0.0015"- "O"; 0.002" - "O"; 0.003" - "O"	JAN-P-148
RM-102 Barrier Material	

TABLE 2

Original Properties

H.P. Smith Paper Co., Chicago, Illinois

	Arctic Pak 1 JAN-B-121 Grade A Type 1 Class 1 (uncreped)	Arctic Pak 1 JAN-B-121 Grade A Type 1 Class 1 (creped)	Arctic Pak 2 JAN-B-121 Grade A Type 2 Class 1 (uncreped)	Lamine 1 JAN-B-121 Grade A Type 1 Class 1	Lamine 2 JAN-B-121 Grade A Type 2 Class 1	Self Wrap JAN-B-121 Grade A Type 2 Class 2 (creped)
Weight 24 x 36 1000 sheets	181.5	174.0	151.0	166.3	139.7	194.5
Thickness	.007	-	.006	.0065	.0045	-
Tensile M.D.	44.8	18.8	39.0	50.9	30.9	16.2
Strength C.D.	34.7	13.7	23.6	26.8	22.5	12.9
Elmendorf M.D.	200	186	138	122	72	116
Tear C.D.	226	208	152	144	90	154
Mullen Burst	69.6	30.4	46.0	62.3	57.8	29.0
Water Permeability	22 hours	22 hours	22 hours	2 hours	2 hours	2 hours
M.V.T.	.59	.82	.64	152.0	131.2	1.54
pH value	7.3	6.5	6.5	7.4	7.1	7.1
Acid content	0	.003	.005	0	0	0
Reducible Sulfur	>0.001	0.0008	0.0004	0.0006	0.0002	0.0008
Copper No.	.66	.56	.34	3.03	4.48	.17

TABLE 3

Original Properties

<u>Thilmany Pulp and Paper Company, Kaukauna, Wisconsin</u>

		Thilco Poly-Kraft JAN-B-121 Grade A Type 1, Class 1 (uncreped)	Thilco Poly-Kraft JAN-B-121 Grade A Type 2, Class 1 (uncreped)	Thilco Poly-Kraft JAN-B-121 Grade A Type 1, Class 1 (creped)	Thilco Poly-Kraft JAN-B-121 Grade A Type 2, Class 1 (creped)
Weight 24x36 1000 sheets		191.5	157.0	201.5	147.0
Thickness		.008	.0065	-	-
Tensile Strength	M.D.	59.2	49.9	33.2	24.6
	C.D.	32.0	23.1	29.3	17.6
Elmendorf Tear	M.D.	193	118	193	118
	C.D.	236	189	208	146
Mullen Burst		71.5	50.0	58.8	45.4
Water Permeability		12 hours	4 samples 12 hours 6 samples 23 hours	4 samples 12 hours 6 samples 23 hours	12 hours
M.V.T.		.65	.74	.77	1.09
pH Value		7.4	7.2	7.2	6.7
Acid Content		0	0	0	.001
Reducible Sulfur		0.0006	0.0002	>0.001	0.0008
Copper No.		.19	.15	.13	.42

TABLE 4

Original Properties

Floyd A. Holes, Inc., Bedford Ohio

		Hi-Binder 50 JAN-B-121 Grade C Type 1 Class 1	Hi-Binder 50 JAN-B-121 Grade C Type 1 Class 2	Hi-Binder 81 JAN-B-121 Grade A Type 1 Class1	Hi-Binder 82 JAN-B-121 Grade A Type 2 Class 1 (uncreped)	Hi-Binder 83 JAN-B-121 Grade A Type 2 Class 1 (creped)
Weight 24x36 1000 sheets		392	420	153	121	131
Thickness		.015	.018	.0065	.005	-
Tensile Strength	M.D.	34.5	34.2	51.3	40.5	27.9
	C.D.	20.8	32.5	31.1	25.2	19.5
Elmendorf tear	M.D.	465	400	120	116	114
	C.D.	550	576	179	125	138
Mullen burst		62.3	57.5	55.0	48.2	43.1
Water Permeability		24 hours	24 hours	6 hours	6 hours	6 hours
M.V.T.		.29	.058	1.14	1.44	1.30
pH value		7.4	7.8	6.6	7.1	7.0
Acid Content		0	0	.003	0	0
Reducible Sulfur		>0.001	>0.001	0.0002	0.0004	0.0004
Copper No.		.07	.15	.54	.60	.54

TABLE 5
Original Properties
Sherman Paper Corp., Newton Upper Falls, Mass.

	V-18 Corroflex JAN-B-121 Grade A	V-27 V-Line JAN-B-121 Grade C Types 2 and 3	V-28 V-Line JAN-B-121 Grade A Type 2	V-29 V-Line JAN-B-121 Grade A Type 2
Weight 24x36 1000 sheets	237	326	113	122.5
Thickness	-	-	-	-
Tensile Strength M.D.	57.2	23.3	41.4	24.2
Tensile Strength C.D.	45.0	22.0	25.4	19.8
Elmendorf tear M.D.	304	172	77	82
Elmendorf tear C.D.	416	252	91	105
Mullen burst	88.6	46.5	43.6	42.9
Water Permeability	12 hours	2 hours	1/2 hour	1/2 hour
M.V.T.	1.64	1.36	61.8	71.4
pH value	6.6	6.6	6.4	6.4
Acid Content	.005	.005	.007	.009
Reducible Sulfur	0.0006	0.0002	0.0002	0.0006
Copper No.	.74	.17	.81	.09

TABLE 6

Original Properties

Minerva Wax Products, Minerva, Ohio

		Ord. Wrap #101-B JAN-B-121 Grade A Type 1 Class 1	Ord.Wrap. #101-C JAN-B-121 Grade A Type 2 Class 1	Ord.Wrap #201 JAN-B-121 Grade C Type 2 Class 2
Weight 24x36, 1000 sheets		194	205	302
Thickness		.007	.0075	-
Tensile Strength	M.D.	56.5	42.5	16.1
	C.D.	31.6	19.3	12.7
Elmendorf tear	M.D.	110	108	184
	C.D.	133	125	221
Mullenburst		59.9	35.5	26.8
Water Permeability		18 hours	45 hours	1 hour
M.V.T.		2.67	1.48	1.25
pH value		7.5	6.6	7.1
Acid Content		0	.003	0
Reducible Sulfur		0.0008	0.0004	0.0008
Copper No.		.55	1.10	.27

TABLE 7
After Aging
H. P. Smith Paper Co., Chicago, Illinois

		Arctic Pak 1 JAN-B-121 Grade A Type 1 Class 1 (uncreped)	Arctic Pak 1 JAN-B-121 Grade A Type 1 Class 1 (uncreped)	Arctic Pak 2 JAN-B-121	Lamine 1 JAN-B-121 Grade A Type 1 Class 1	Lamine 2 JAN-B-121 Grade A Type 2 Class 1	Self-Wrap JAN-B-121 Grade A Type 2 Class 2 (creped)
Tensile Strength	M.D.	34.2	21.2	34.5	53.9	45.1	14.6
	C.D.	28.4	12.8	17.7	21.2	19.2	14.3
Elmendorf tear	M.D.	244	245	149	118	193	93
	C.D.	258	259	190	158	121	120
Mullen burst		69.7	33.2	44.9	70.2	57.1	23.3
Water Permeability		22 hours	22 hours	22 hours	immed.	immed.	2 hours
M.V.T.		1.87	.69	.77	108.5	111.4	.70
pH value		7.4	7.4	7.3	8.0	7.3	5.0
Acid Content		0	0	0	0	0	.086
Copper No.		1.15	1.38	1.41	1.94	2.05	1.42

TABLE 8
After Aging
Thilmany Pulp and Paper Co., Kaukauna, Wisconsin

		Thilco Poly-Kraft JAN-B-121 Grade A Type 1, Class 1 (uncreped)	Thilco Poly-Kraft JAN-B-121 Grade A Type 2, Class 1 (uncreped)	Thilco Poly-Kraft JAN-B-121 Grade A Type 1, Class 1 (creped)	Thilco Poly-Kraft JAN-B-121 Grade A Type 2, Class 1 (creped)
Tensile Strength	M.D.	46.8	32.4	30.7	24.4
	C.D.	22.5	15.8	24.6	16.4
Elmendorf tear	M.D.	267	110.4	201	136
	C.D.	270	170.4	249	161
Mullen burst		70.9	60.0	70.3	48.7
Water Permeability		12 hours	4 samples 12 hours 6 samples 23 hours	9 samples 12 hours 6 samples 23 hours	12 hours
M.V.T.		.99	.82	.77	.89
pH value		7.7	7.6	7.5	7.5
Acid Content		0	0	0	0
Copper No.		1.49	1.31	.99	1.10

TABLE 9
After Aging
Floyd A. Holes, Inc., Bedford, Ohio

		Hi-Binder 50 JAN-B-121 Grade C Type 1 Class 1	Hi-Binder 50 JAN-B-121 Grade C Type 1 Class 2	Hi-Binder 81 JAN-B-121 Grade A Type 1 class 1	Hi-Binder 82 JAN-B-121 Grade A Type 2 Class 1 (uncreped)	Hi-Binder 83 JAN-B-121 Grade A Type 2 Class 1 (creped)
Tensile Strength	M.D.	30.5	15.5	23.4	32.6	21.7
	C.D.	15.6	6.2	23.0	17.6	16.7
Elmendorf tear	M.D.	332	100	186	126	122
	C.D.	376	110	190	130	174
Mullen burst		40.2	22.0	60.1	48.5	49.2
Water Permeability		24 hours	6 hours	9 hours	9 hours	12 hours
M.V.T.		3.42	.077	2.64	2.77	4.60
pH Value		5.5	6.7	7.6	7.7	7.8
Acid content		.029	.003	0	0	0
Copper No.		.17	.28	1.33	1.46	1.60

TABLE 11
After Aging
Minerva Wax Products, Minerva, Ohio

	Ord. Wrap #101-B JAN-B-121 Grade A Type 1 Class 1	Ord. Wrap #101-C JAN-B-121 Grade A Type 2 Class 1	Ord. Wrap #201 JAN-B-121 Grade C Type 2 Class 2
Tensile Strength	M.D. 34.2 C.D. 14.4	31.6 15.0	16.5 14.0
Elmendorf tear	M.D.114 C.D.154	113 142	140 160
Mullen burst	47.8	35.6	22.5
Water Permeability	6 hours	14 hours average	1 hour
M.V.T.	2.60	1.32	.91
pH Value	7.0	6.6	4.5
Acid content	0	.003	.058
Copper No.	1.24	1.05	.61

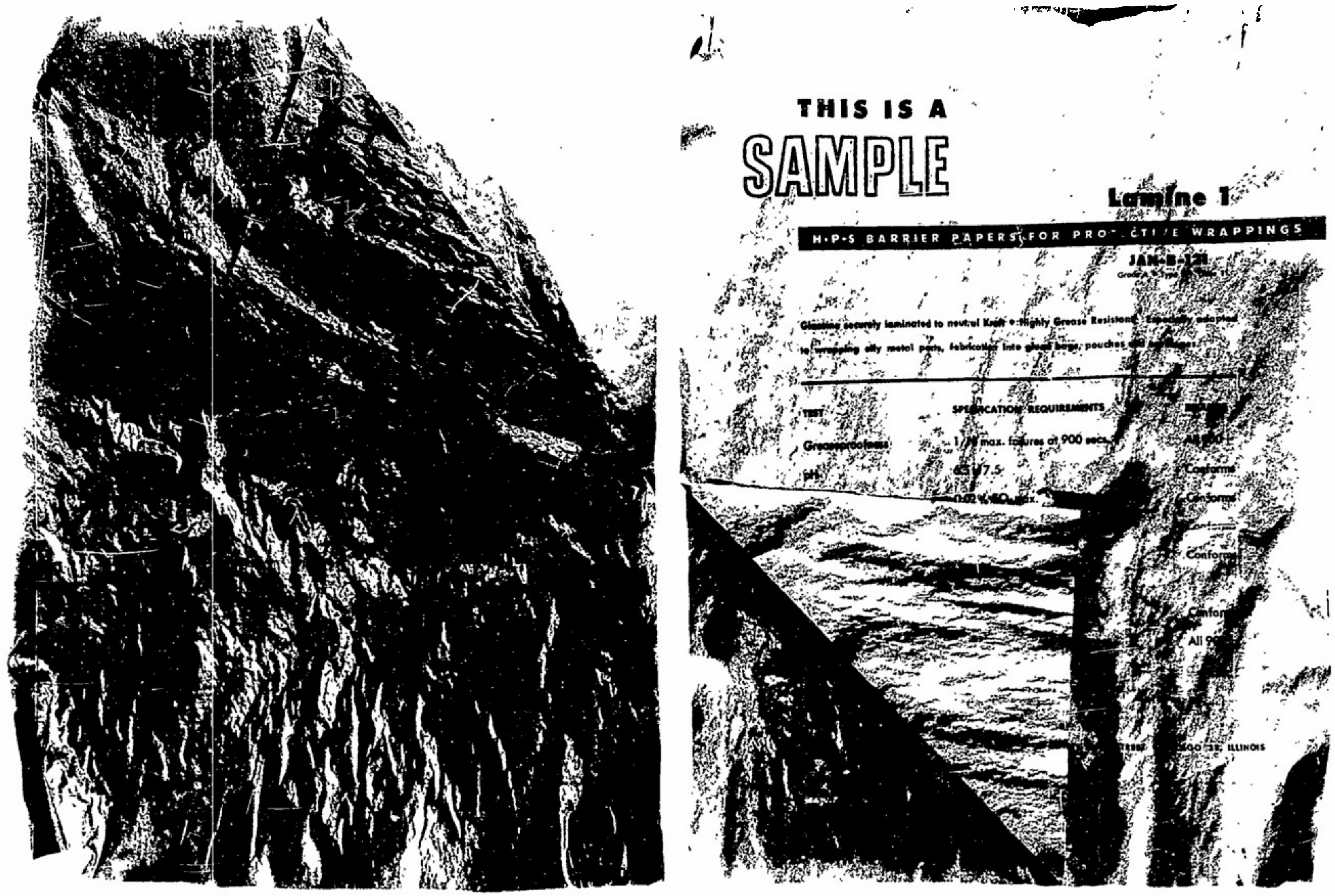

FIG. 1

H. P. SMITH PAPER CO., CHICAGO, ILLINOIS.
LAMINE #1, JAN B-121, GRADE A, TYPE 1, CLASS 1, AFTER TESTING IN WEATHEROMETER FOR 26.9 HOURS. DELAMINATED WITHIN 9.1 HOURS.
14 April 1952 RIA Lab. Neg. 4788

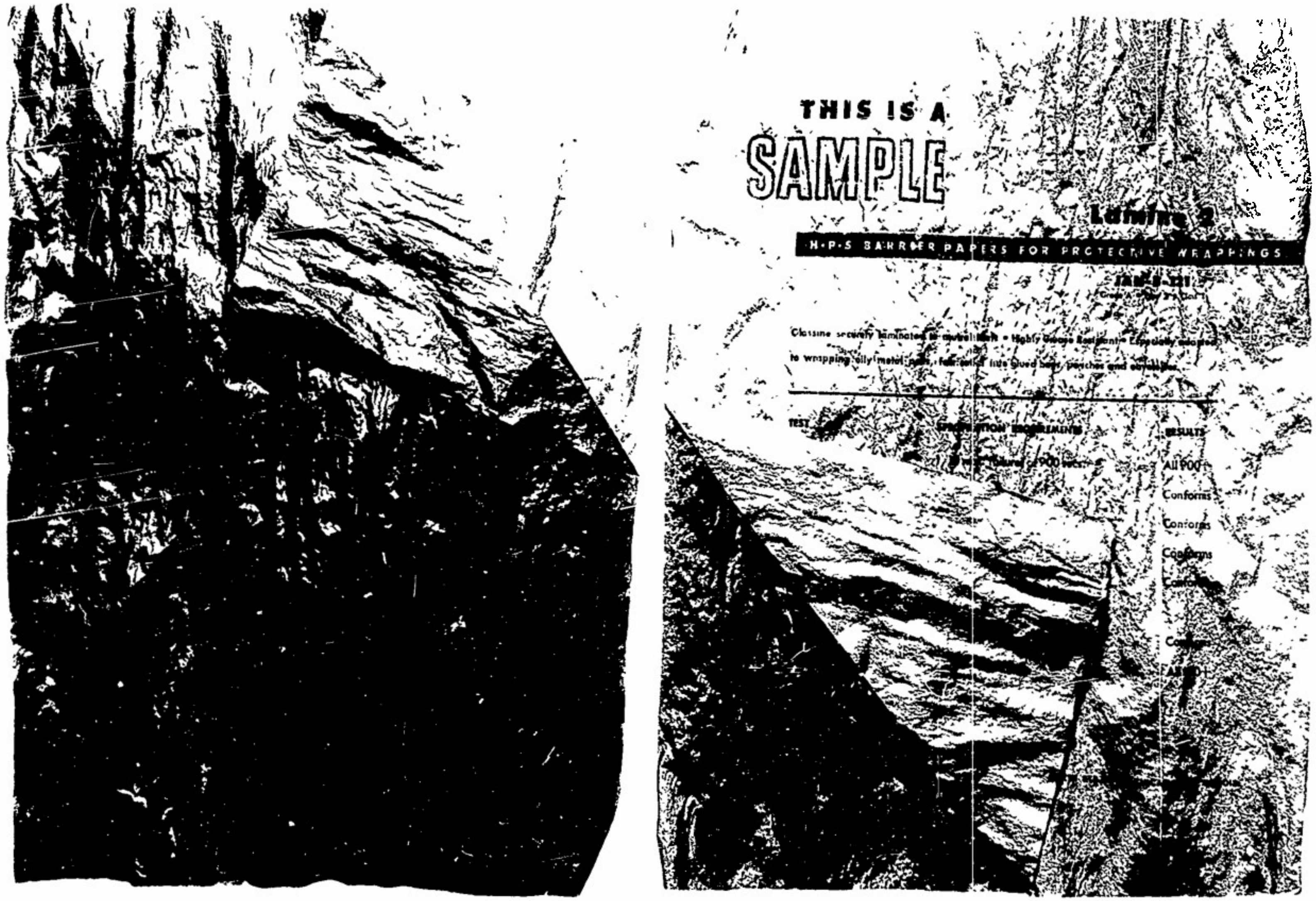

FIG. 2

H. P. SMITH PAPER CO., CHICAGO, ILLINOIS.
LAMINE #2, JAN B-121, GRADE A, TYPE 2, CLASS 1, AFTER TESTING IN WEATHEROMETER FOR 26.9 HOURS. DELAMINATED WITHIN 9.1 HOURS.

14 April 1952 RIA Lab. Neg. 4789

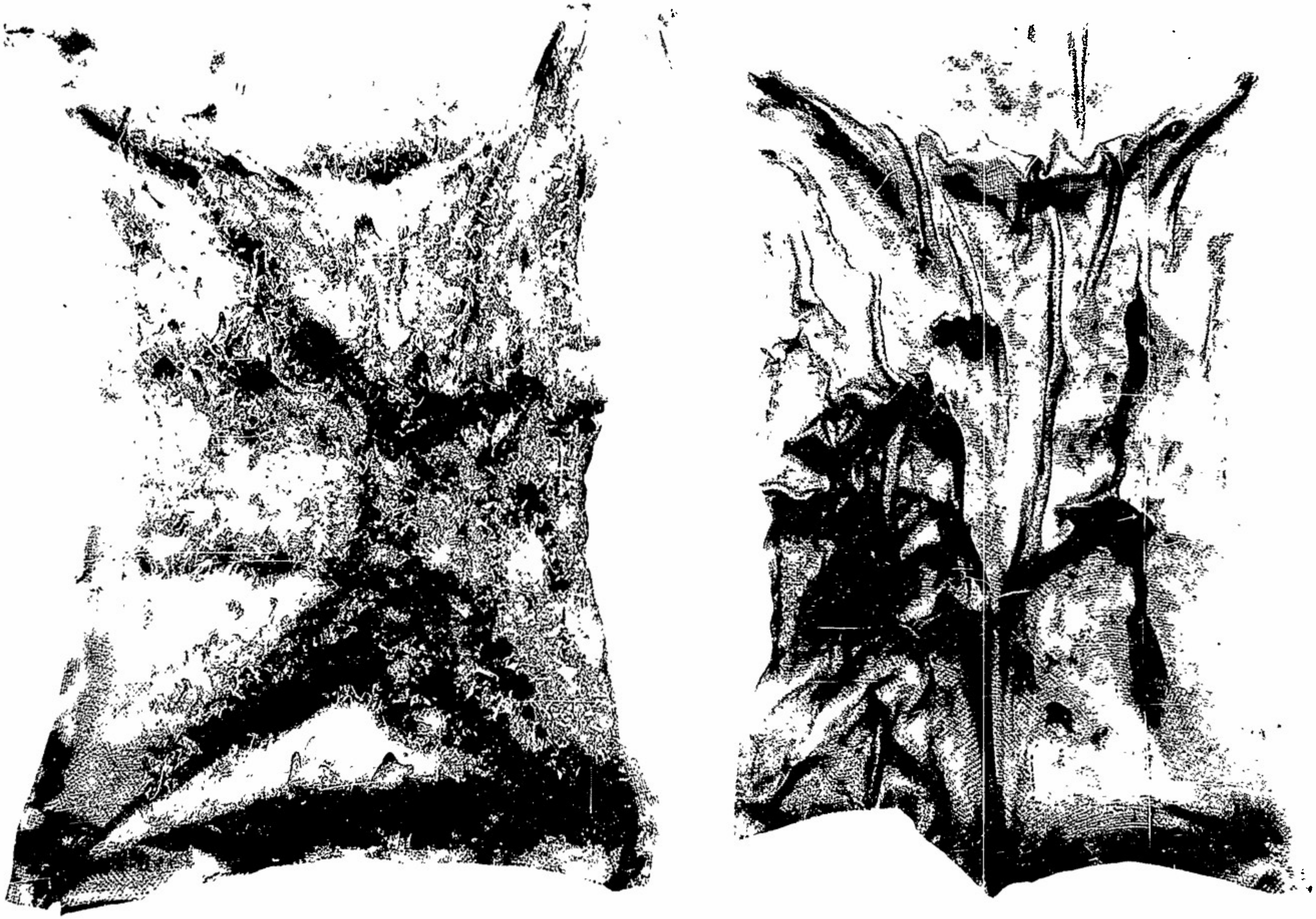

FIG. 3

FLOYD A. HOLES INC., BEDFORD, OHIO
HI-BINDER #50, JAN B-121, GRADE C, TYPE 1, CLASS 1,
AFTER TESTING IN WEATHEROMETER FOR 25.3 HOURS.
19 April 1952 RIA Lab. Neg. 4805

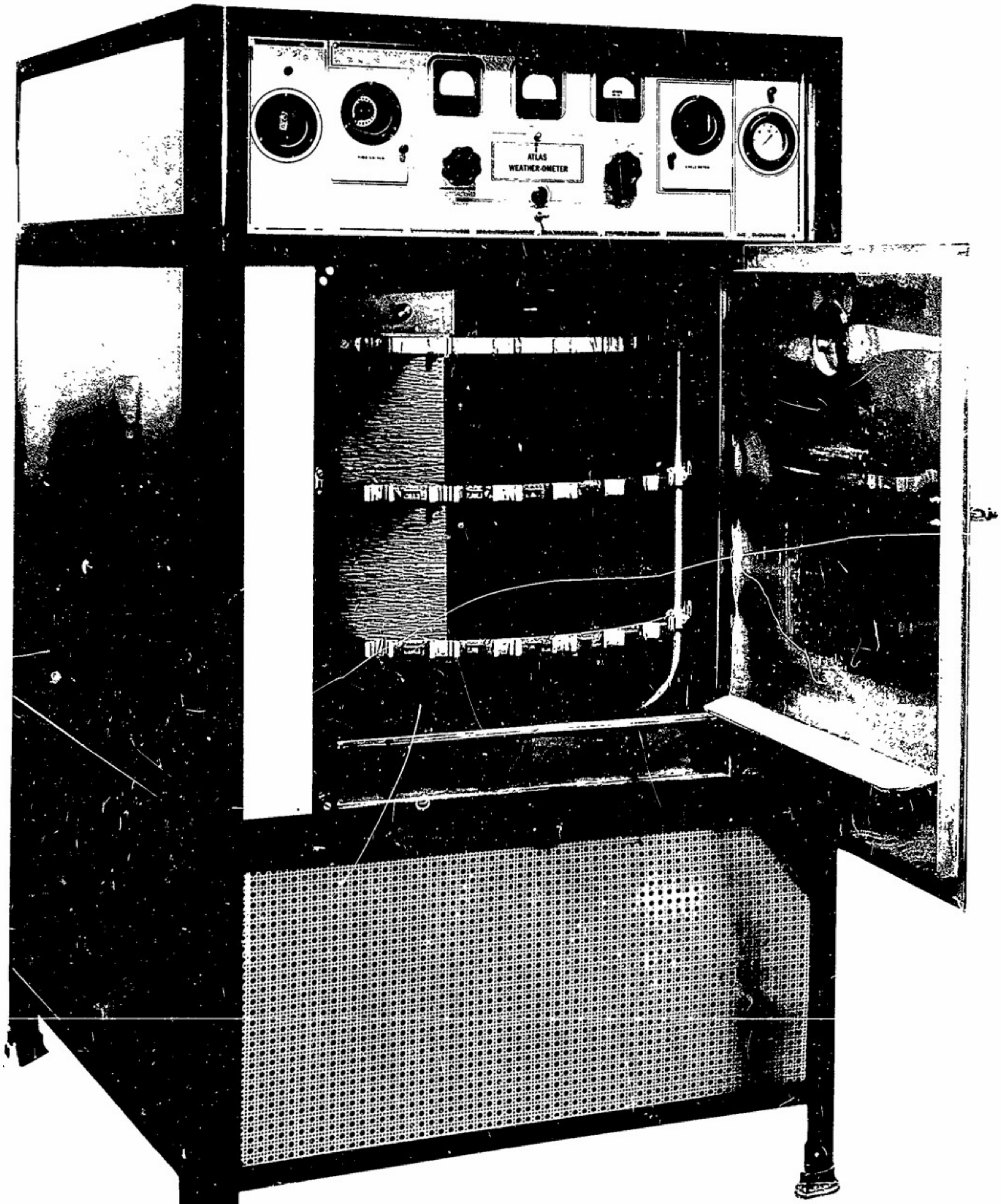

FIG. 4

ATLAS WEATHEROMETER
28 May 1952 RIA Lab. Neg. 4920

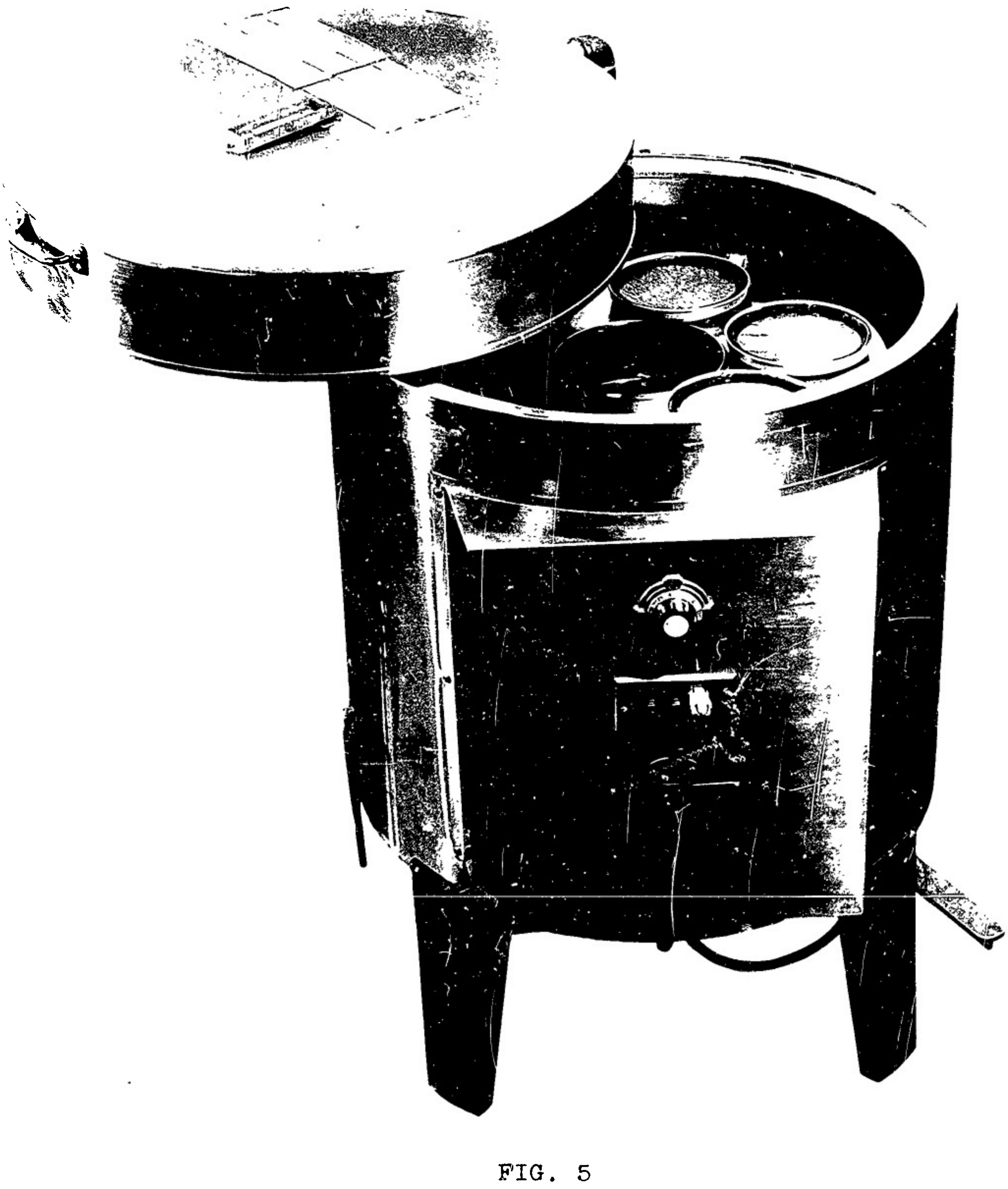

FIG. 5

GENERAL FOODS MOISTURE VAPOR TRANSMISSION HUMIDITY CABINET
28 May 1952 RIA Lab. Neg. 4917

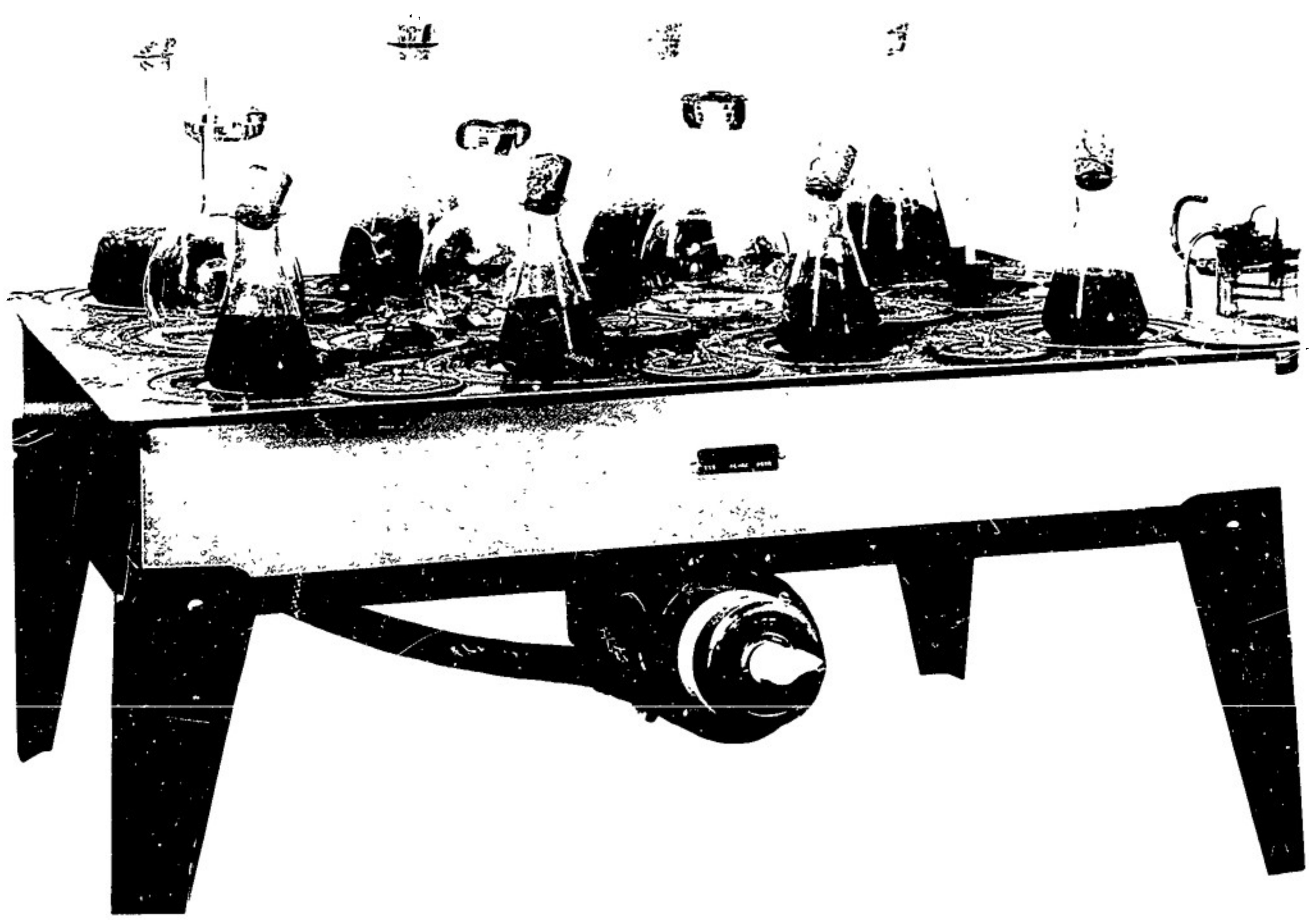

FIG. 6

STEAM BATH
ROW #1 - COPPER NUMBER DETERMINATION
ROW #2 - REDUCIBLE SULFUR DETERMINATION
ROW #3 - pH AND ACID DETERMINATION
28 May 1952 RIA Lab. Neg. 4918

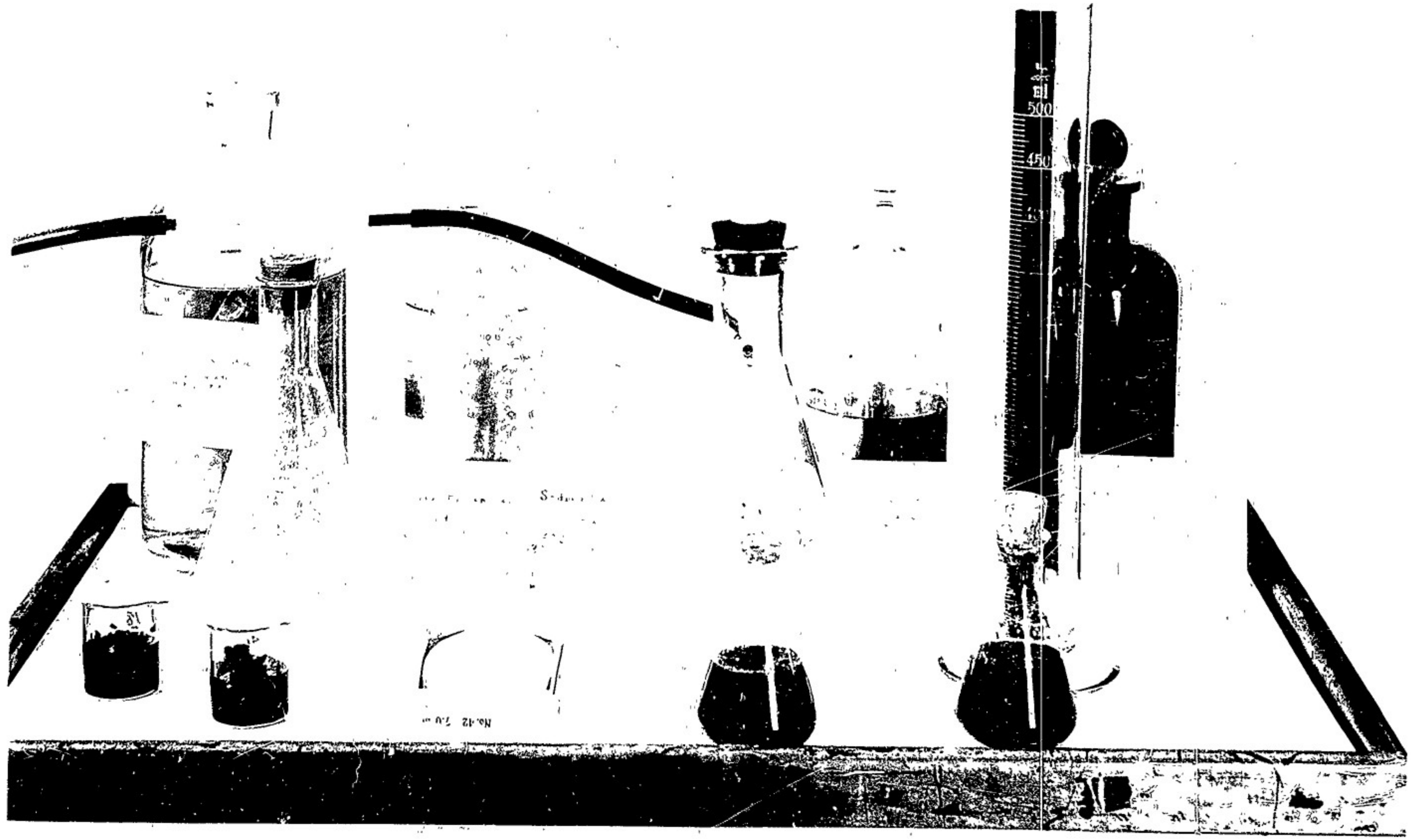

FIG. 7

APPARATUS FOR COPPER NUMBER DETERMINATION
28 May 1952 RIA Lab. Neg. 4921

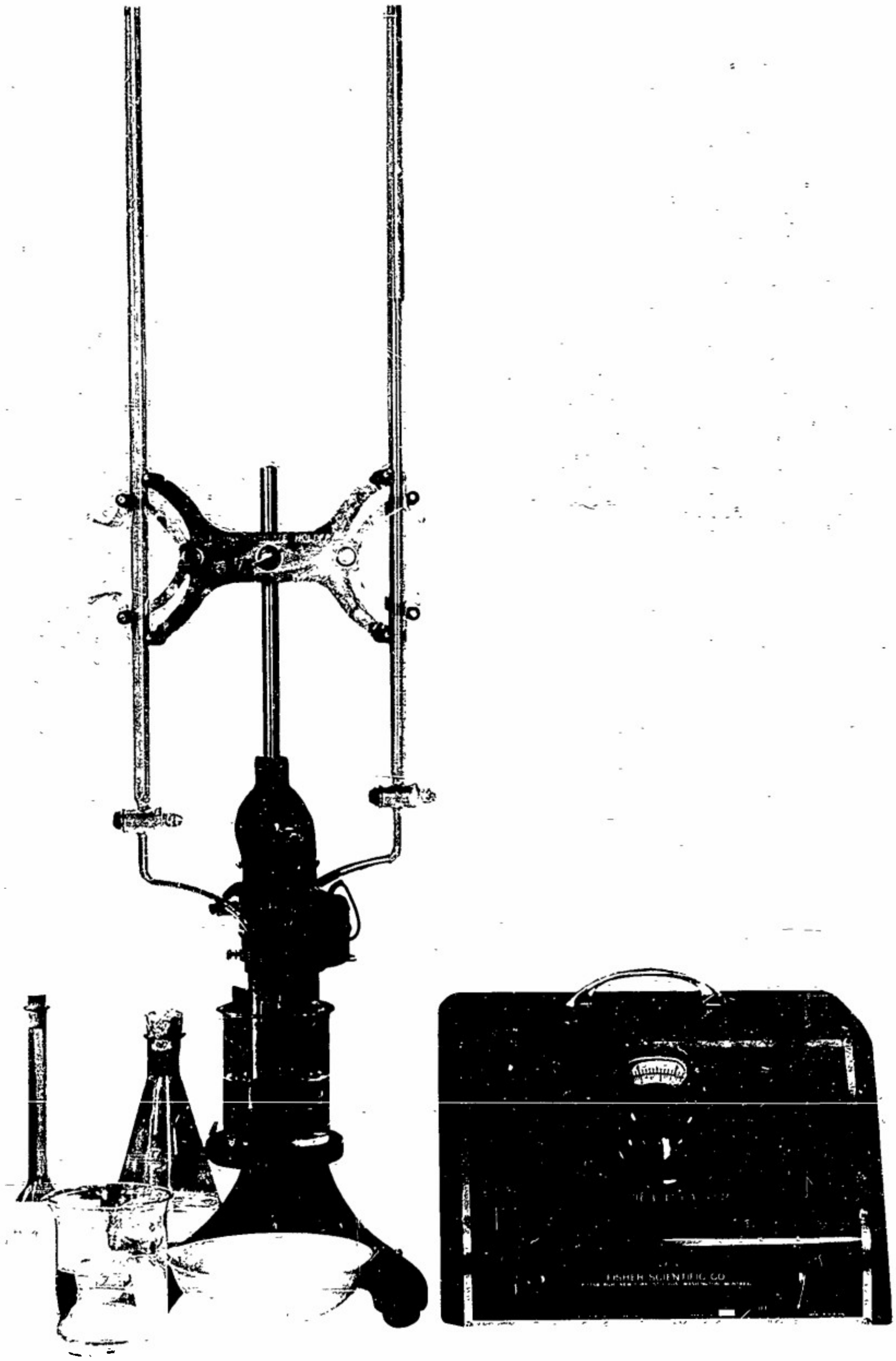

FIG. 8

FISHER TITRIMETER APPARATUS
28 May 1952 RIA Lab. Neg. 4919