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INVESTIGATION OF GLASS-METAL COMPOSITE MATERIALS

SEVENTH QUARTERLY PROGRESS REPORT

COVERING PERIOD MARCH 15, 1957 to JUNE 15, 1957

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by

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JULY 5, 1957

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OWENS-CORNING FIBERGLAS CORPORATION
Basic and Applied Research Center
Newark, Ohio

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I INTRODUCTION

The major efforts during the period covered by this report (March 15 to June 15, 1957) have been in the following directions:

- A. Improving existing and investigating new methods of forming and working composites of aluminum and aluminum coated glass fibers.
- B. Determining a complete set of physical data on a standard glass-reinforced aluminum composite in order to indicate the general characteristics of glass-reinforced metals as a class of materials.
- C. Developing a method of forming composites of aluminum and bare glass fibers and evaluating the physical properties of these composites.
- D. Production and testing of glass-reinforced aluminum tubular shapes.
- E. Developing a theory on the interaction of metals and glass fibers.
- F. Developing a glass-reinforced metal having utility at temperatures about 1000°F.

The work reported represents the combined efforts of Messrs. J. I. Aber, R. E. Evans, B. B. Garick, P. A. Lockwood, H. E. Mathews, E. S. Mattern, C. A. Riesbeck, E. W. Smart, R. S. Swain, G. E. Wince, and the author, of the Glass-Metals Research Laboratory, and Dr. H. B. Whitthurst, Department Head. Acknowledgement is also made of the valuable assistance given by many other members of the Basic and Applied Research Center.

Physical property measurements of the glass-metal test bars were performed by the Olin-Mathisson Chemical Corporation in New Haven, Connecticut, and by the

Ohio State Engineering Experiment Station of the Ohio State University in
Columbus, Ohio.

Work on fabrication of large shapes, in particular tubing, of glass-reinforced
metals has been subcontracted to the Olin-Mathieson Chemical Corporation in
New Haven, Connecticut.

II SUMMARY

An evaluation has been made of several of the major variables in the vacuum injection technique of compositing aluminum and aluminum coated glass fibers. This evaluation was made with the intention of producing better composite materials and simplifying the processes used to make these materials. The standard technique uses a vacuum of about 0.1 mm Hg absolute pressure to pull molten 14S aluminum up around about 50 grams of aluminum coated glass fibers longitudinally oriented in a pyrex tube. The use of various degrees of vacuum up to 303 mm Hg absolute pressure does not decrease the resultant composite strength, but the use of a vacuum of 550 mm Hg absolute pressure causes a significant decrease in composite strength. The use of over 80 grams of aluminum coated glass fibers in place of the standard 50 grams results in composites having lower tensile strengths. In both cases the cause of the reduction in composite tensile strength was probably due to incomplete penetration of the molten aluminum into the fiber bundle. A strong, fluid casting alloy, 122L aluminum, has been reinforced with glass fibers to give a composite some 10% stronger than the standard glass-reinforced 14S aluminum alloy. The use of a Vycor mold in place of the standard Pyrex mold also increases the composite tensile strength about 10%.

Samples of glass-reinforced aluminum were successfully hot forged at temperatures of 1100°F to 1300°F. Indications are that hot forging will be a satisfactory method of providing some end-use shapes from glass-reinforced aluminum ingots.

Additional creep data reinforces the earlier conclusions that the creep rate of glass-reinforced aluminum is less than 1% of the creep rate of unreinforced aluminum. The wear resistance of glass-reinforced aluminum is less than that of

unreinforced aluminum. A composite made by hot pressing aluminum coated glass fibers had a room temperature tensile strength of 48,000 psi as compared to a room temperature tensile strength of less than 30,000 psi for the unreinforced aluminum alloy.

A study of the wetting of several aluminum alloys on fibers of fifty different glasses has shown no glass to be appreciably better than E glass in its ability to be coated by aluminum. In general, the metal composition is more important than the glass composition with respect to indicating the extent of the glass-metal interaction and the ability of the glass to be metal coated.

Modifications to the Olin-Mathieson centrifugal casting unit have resulted in improved operation. Several large tubular shapes of glass-reinforced aluminum have been cast, but no test results are available as yet. A small glass-reinforced aluminum tube tested in internal bursting did not fail at 36,000 psi rim stress at room temperature.

Initial work has begun on a study of the interaction of metals and glass fibers and on a program to develop a glass-reinforced metal that may be used at temperatures above 1000°F.

III DISCUSSION

A. Improving existing and investigating new methods of forming and working composites of aluminum and aluminum coated glass fibers.

1. Composites made using varying amounts of aluminum coated glass fibers.

Using the standard vacuum injection technique,⁽¹⁾ glass-reinforced aluminum composites were made containing various amounts of aluminum coated glass fibers. The aluminum coated glass fibers are pulled into a graphite tube mold so that all the fibers are longitudinally oriented. Then molten aluminum is pulled up around these fibers by application of vacuum to the mold. The glass concentrations have not been determined precisely, but fall in the range of 20 to 35 volume percent. Composites containing 60, 70, 75, 80, and 85 grams of aluminum coated glass fibers were made and tested. The composites were heat treated at 940°F for 3 1/2 hours, quenched in water, and aged at 340°F for 17 hours. Table I gives the results of this study.

TABLE I

COMPARISON OF VARIOUS GLASS FIBER CONCENTRATIONS

<u>Sample Number</u>	<u>Grams of Aluminum Coated Glass Fibers</u>	<u>Tensile Strength at Room Temperature, psi</u>	<u>Average Tensile Strength, psi</u>
EH-XXII-166A	60	31,800	
166B	60	24,050	
166C	60	19,400	26,000
166D	60	26,800	_____
175A	70	20,800	
175B	70	19,600	21,100
175C	70	22,800	_____

(1) H.B. Whitehurst - First Annual Progress Report, Contract #Ord 15764

TABLE I (Continued)

<u>Sample Number</u>	<u>Grams of Aluminum Coated Glass Fibers</u>	<u>Tensile Strength at Room Temperature, psi</u>	<u>Average Tensile Strength, psi</u>
EH-XXII-176A	75	22,800	
176B	75	31,050	26,600
176C	75	30,100	
176D	75	22,500	
177A	80	22,700	
177C	80	17,350	
177D	80	32,900	24,100
177E	80	23,500	
177F	80	24,100	
185A	85	18,300	
185B	85	22,000	
185C	85	11,450	15,800
185D	85	15,250	
185F	85	11,750	

It would appear that the use of over 80 grams of aluminum coated glass fibers resulted in a decrease in composite strength due to incomplete penetration of the molten aluminum around the fibers.

2. Composites made by the vacuum injection technique using varying degrees of vacuum.

In the standard vacuum injection technique molten aluminum is pulled up around longitudinally oriented fibers by the application of vacuum to the mold containing the fibers. Composites have been made using various degrees of vacuum to determine the effect of this variable on composite tensile strength. The samples are made by pulling lbs aluminum around aluminum coated glass fibers. The composites were not

heat treated. Table II gives a summary of the data taken in this study.

TABLE II
COMPARISON OF DIFFERENT DEGREES OF VACUUM

<u>Absolute Pressure In Mold, mm Hg.</u>	<u>Number of Samples Tested</u>	<u>Average Tensile Strength at Room Temperature, psi</u>
0.1	2	19,700
13	4	19,600
27	1	7,700
56	1	24,600
87	1	20,300
303	5	19,000
550	6	10,700

Apparently, an absolute pressure of 303 mm Hg, i.e. a vacuum of 457 mm Hg, is as satisfactory as a full vacuum of 0.1 mm Hg absolute pressure. However, at 550 mm Hg absolute pressure a definite decrease in composite strength is evident. This decrease in composite strength may be due to incomplete penetration of the molten aluminum around the fibers thus forming a composite containing considerable voids.

3. Forging of glass-reinforced aluminum

Preliminary experiments have been conducted into forming end-use shapes by hot forging glass-reinforced aluminum. A forging die was constructed to fit a press in the Olin-Mathieson forge shops in New Haven, Connecticut. The hot forging experiments were then conducted at New Haven. Samples of glass-reinforced aluminum made by the vacuum injection technique and the hot pressing of aluminum coated glass fibers technique were successfully hot forged at temperatures of 1100°F to 1300°F. These

samples ranged approximately from 20 to 50 volume percent glass fibers.

It would appear that a narrow temperature range is desirable for the hot forging of glass-reinforced aluminum. Any temperature much above the optimum results in metal being expressed from the composite due to the high metal plasticity. Any temperature much below the optimum results in cracking of the composite due to the large local forces set up in the material. The optimum temperature for hot forging glass-reinforced aluminum samples containing 20-30 volume percent longitudinally oriented glass fibers is in the range of 1100-1200°F. It appears that composites containing increased amounts of glass fibers will require a slightly higher forging temperature. It is to be expected that fiber orientation will also have some effect on the required hot forging conditions.

4. Improved fiber predrying techniques.

A previous report (1) has shown that predrying aluminum coated glass fibers at 600°F for 24 hours before combining them with molten aluminum by the vacuum injection process results in improved composite tensile strengths. Recent experiments have shown that predrying aluminum coated fibers for several hours at 300°F followed by additional drying for at least 20 minutes at 600°F results in composites having tensile strengths equal to those of composites made from fibers dried for 24 hours at 600°F. Neither predrying fibers for one week at 220°F nor for 15 minutes at 1200°F resulted in satisfactory composite tensile strengths.

(1) H. B. Ailes - Second Annual Progress Report; Contract NOrd 15764.

5. Composites made in a Vycor mold.

Composites made by the standard vacuum injection technique using a Vycor (96% fused silica) mold have room temperature tensile strengths higher than similar composites made using a Pyrex mold. Table III shows the tensile strengths of composites made using a Vycor mold. Similar composites made with a Pyrex mold have an average room temperature tensile strength of 26,130 psi.

TABLE III

GLASS-REINFORCED ALUMINUM MADE IN VYCOR MOLD

<u>Sample Number</u>	<u>Tensile Strength at Room Temperature, psi</u>	<u>Average Tensile Strength, psi</u>
EH-XXII-172I	35,700	
819-51A	27,400	
819-51B	25,400	30,620
819-51C	24,100	
819-51D	40,500	

6. Bi-metallic combinations.

Unsuccessful attempts have been made to reinforce aluminum with metal coated glass fibers having higher tensile strengths than aluminum coated glass fibers. Using the vacuum injection technique attempts were made to pull molten aluminum around glass fibers coated with lead, copper, and silver. In all cases insufficient penetration was realized to make a composite suitable for testing.

7. 122L aluminum alloy.

A relatively strong aluminum casting alloy, 122L, has been reinforced by aluminum coated glass fibers. It was hoped that this alloy, having some-

what better fluidity, might offer an improvement over the standard 14S aluminum alloy as a matrix for glass fibers. Table IV presents the tensile strengths of composites made by the standard vacuum injection technique using 122L aluminum alloy as the matrix alloy. The resultant composites were heat treated at 940°F for 5 hours, quenched in water, and aged at 340°F for 18 hours.

TABLE IV

GLASS-REINFORCED 122L ALUMINUM ALLOY

<u>Sample Number</u>	<u>Tensile Strength at Room Temperature, psi</u>	<u>Modulus of Elasticity at Room Temperature, psi</u>
819-15C	31,300	10.9 x 10 ⁶
819-15D	33,300	10.8 x 10 ⁶
819-15F	29,700	10.2 x 10 ⁶
819-15G	22,900	10.3 x 10 ⁶

These samples are about 10% stronger than those using the 14S aluminum matrix. This might be due to sounder castings due to the use of the more fluid 122L aluminum alloy.

B. Determining a complete set of physical data on a standard glass-reinforced aluminum composite in order to indicate the general characteristics of glass-reinforced metals as a class of materials.

1. Composites made by the vacuum injection method.

It was deemed advisable to get a relatively complete evaluation of the physical properties of a material which is essentially 14S-F6 aluminum reinforced with 20-30 volume percent continuous longitudinally oriented glass fibers. This material is made by pulling, under vacuum, molten

14S aluminum into a mold containing aluminum coated glass fibers. This material was chosen as the best available one year ago, when the evaluation began. However, since that time, developments have been made which affect the physical properties of glass-metal composites. It has been decided to continue the evaluation of physical properties based on the original composite type so that a related set of physical property data will exist. This set of data can then be used to indicate the properties of materials which incorporate any future developments. The information collected during this reporting period follows:

a. Creep rate and stress rupture time.

Data on the creep rate and stress rupture time of the standard glass-reinforced aluminum samples is shown in Table V and plotted in Figure I. The sensitivity of the apparatus used allows the measurement of .001 mm deformation over a 3 inch gage length or .0013% deformation.

TABLE V
CREEP AND STRESS RUPTURE

<u>Sample Number EH-XXII-94F (1)</u> <u>Tensile Stress, 15,000 psi @ 500°F.</u>		<u>Sample Number EH-XXII-94I</u> <u>Tensile Stress, 13,500 psi @ 500°F.</u>			
<u>Time, Hours</u>	<u>Total Deformation, %</u>	<u>Time, Hours</u>	<u>Total Deformation, %</u>	<u>Time, Hours</u>	<u>Total Deformation, %</u>
0	.224	0	.217	78.5	.250
14	.282	2	.222	79.5	.252
15	.290	2.5	.231	167	.253
16	.290	4.5	.247	167.5	.255
17	.290	5	.242	198.5	.259
21	.305	5.5	.243	215	.260
23	.326	6	.242	223	.256

(1) In last report (H. B. Ailes - Second Annual Progress Report, Contract WOrd 15764) this data was erroneously presented as being taken at a stress of 12,500 psi. Actually the sample was stressed for 9 hours at 12,500 psi with no elongation and hence, the stress was raised to 15,000 psi at which time the above data was initiated.

TABLE V (continued)

Sample Number EH-XXII-94F
Tensile Stress, 15,000 psi @ 500°F.

Sample Number EH-XXII-94I
Tensile Stress, 13,500 psi @ 500°F.

<u>Time,</u> <u>Hours</u>	<u>Total</u> <u>Deformation, %</u>	<u>Time,</u> <u>Hours</u>	<u>Total</u> <u>Deformation, %</u>	<u>Time,</u> <u>Hours</u>	<u>Total</u> <u>Deformation, %</u>
63	.326	6.5	.227	239	.255
87	.326	7	.234	263	.261
111	.326	7.5	.236	271	.265
135	.326	8	.248	316	.271
159	.326	23	.240	383	.257
183	.326	23.5	.244	407	.257
207	.326	47	.236	431	.263
236	rupture	53	.236	455	.244
		53.5	.230	551	.237
		56	.229	575	.270
		71	.226	599	.243

test discontinued

It will be noted from Table V and Figure I that no secondary creep was observed at stresses as high as 15,000 psi at 500°F. Some creep data on unreinforced 14S-T6 aluminum indicates a secondary creep rate of .000375 percent per hour at 9,000 psi and 400°F and .008000 percent per hour at 4,000 psi and 600°F. At the very most the secondary creep rate of glass-reinforced aluminum would be .000002 percent per hour at 13,500 psi and 500°F and .000006 percent per hour at 15,000 psi and 500°F. It is also of interest to note that a stress rupture point was obtained for sample EH-XXII-94F at 236 hours under stress of 15,000 psi at 500°F. Although this sample was stressed at a stress large enough to cause failure in 236 hours, no secondary creep was evidenced!

b. Wear resistance.

Measurements of wear resistance of the standard glass-reinforced aluminum composites were made in a Falox Wear Tester. The test samples are two notched blocks and a dowel as shown in Figure II. The dowel is rotated in the notch as load is applied to the blocks. The results of these tests are shown in Table VI (next page).

The test samples of glass-reinforced aluminum were constructed so as to have the glass fibers oriented in three perpendicular directions. The first, fourth, seventh, and eighth (as itemised in Table VI) samples had the fibers coming up out of the notch in the blocks. The second and fifth samples had the fibers oriented perpendicular to the length of the notch and the third and sixth samples had the fibers oriented parallel to the length of the notch.

It is evident that these glass-reinforced aluminum specimens evidenced considerably less wear resistance than either the unreinforced aluminum or the standard steel specimens.

c. Water absorption

A study of the water absorption of the standard glass-reinforced aluminum composites has been initiated. Samples containing various amounts of glass fibers are submerged in water and weighed at certain intervals. The average of the data taken indicate a steadily decreasing rate of weight gain reaching a maximum weight gain of .2 to .3 weight percent after about 2 weeks immersion. Tensile tests will be conducted on these samples after immersion for two months.

TABLE VI

WEAR RESISTANCE (Table reads wear in number of teeth, a relative value indicated by the Falax Tester)

TYPE OF SAMPLE	GLASS-REINFORCED ALUMINUM						14S-T6 ALUMINUM						STEEL							
	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Jaw Load:																				
Run In (50 lbs.)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
50 lbs.	104	114	73	89	101	*	*	*	*	129	*	*	17	14	20	-	-	-	-	-
100 lbs.	225	255	180	204	220		*			*			30	28	39					
150 lbs.	359	417	323	354	368								49	46	53					
200 lbs.	541	*	*	515	533								*	64	55					
250 lbs.	740			709	688									81	69					
300 lbs.	*			*	*									93	83					
350 lbs.													117	99					**	
400 lbs.													134	116						
450 lbs.													*	131						
500 lbs.															153					
550 lbs.															175					
600 lbs.															*					*

* Pin Broke

** Pin Seized

(1) Lubricant A - A Standard mineral oil (MIL - 0 - 5606 hydraulic fluid).

Lubricant B - A 1% solution of Stearic Acid in Penola Volvostic Oil.

d. Stress-strain curves.

Stress-strain curves taken during tensile testing of the standard glass-reinforced aluminum composites have indicated a change in slope, i.e. a change in modulus of elasticity. As an overall average it might be said that the modulus is about 16×10^6 psi up to 5,000 to 10,000 psi tensile stress and then decreases to $3-5 \times 10^6$ psi. A complete translation of this information has not been made, but indications are that of a phase failure at some stress considerably lower than the ultimate tensile stress.

2. Composites made by hot pressing method.

Tensile tests have been made on composites made by hot pressing aluminum coated glass fibers in the new hot pressing die. The new die forms a composite having a rectangular shape. This die was constructed to replace the old die which produced a composite having the shape of a tensile test specimen. It was thought that the old die produced composites having decreased tensile strengths due to the excessive stresses created at the necked-down section of the die. The aluminum coated glass fibers were pressed at 600°F and $3/4$ tons per square inch pressure. These specimens consist of 50-60% glass fibers in a relatively weak aluminum matrix. Table VII gives a summary of the tensile strength data taken on these composites.

TABLE VII

TENSILE STRENGTHS OF HOT PRESSED ALUMINUM COATED GLASS FIBERS

<u>Sample Number</u>	<u>Testing Temperature</u>	<u>Tensile Strength, psi</u>
101	R.T.	18,750
102	R.T.	9,210*
103	R.T.	23,409
105	R.T.	29,280
107	R.T.	47,920
109	R.T.	5,900*
104	500°F	17,280
106	500°F	21,740
108	500°F	41,840

* Visual examination of these broken tensile test specimens showed relatively little consolidation of the aluminum coated fibers at the point of failure indicating that insufficient pressure and/or temperature had been used to form this set of composites.

C. Developing a method of forming composites of aluminum and bare glass fibers and evaluating the physical properties of these composites.

1. Wetting studies.

An extensive program to evaluate the wetting of 50 different glasses by various aluminum alloys has been completed. The glasses were selected to be representative of a wide range of known glass compositions. All the glasses contained SiO₂. Twenty-four of the glasses were modifications of the standard E glass and twenty-five were of widely variant composition. The wetting of all the glasses by 2S; 14S; and 5% Zn, 1% Cd, balance

aluminum alloys was evaluated. In addition, the wetting of E glass by 56S; 3.4% Bi, balance aluminum; 9% Sn, 1% Ag, balance aluminum; and 2% Sb, balance aluminum alloys was evaluated.

These tests were conducted by forming fibers of each glass, dipping three or four fibers of each glass in each metal to be evaluated, and then visually examining the dipped fiber under a microscope. The visual examinations did not indicate any glasses which were coated appreciably better than E glass.

Although the visual examination indicated which combinations of glasses and metal gave good coatings little was indicated of the interaction or bonding of the metal and glass. Hence, selective samples were acid etched in 3 normal hydrochloric acid to remove the metal coating allowing examination of the fiber surface. Figures III, IV, V, and VI illustrate the results of this study. Figure III shows a bare glass fiber which has been etched in hydrochloric acid. Figure IV shows a glass fiber which was dip coated with the 5% Zn, 1% Cd, balance aluminum alloy and subsequently etched in hydrochloric acid. Figure V shows a glass fiber which was dip coated with 2S aluminum and etched and Figure VI shows a glass fiber which was dip coated with 14S aluminum and etched. The interaction between metal and glass is much more evident with the 14S aluminum than with the 2S aluminum which is, in turn, somewhat more evident than the interaction between glass and the 5% Zn, 1% Cd, balance aluminum alloy. It should be mentioned that these figures illustrate severe cases of interaction and are not typical of the degree of interaction which takes place between these alloys and E glass. However, this

relative order of interaction is still evident with E glass and other similar glasses having coatings which are visually superior to the ones etched away in these figures.

As stated previously, none of the fifty glasses were superior to E glass which is in present use. However, some general statements can be made based on indications from this study. In general, the presence of oxides of barium, zinc, lead, and iron (ferrous) in the glasses seemed to adversely affect the ability of the glass to be metal coated. Glasses containing 8 to 14% borates and possibly those containing 2-4% fluorine had improved ability to be metal coated. A high total content of the oxides of sodium, potassium, and lithium in a glass improves its ability to be coated by 14S aluminum, but hampers its ability to be coated by 2S aluminum and the 5% Zn, 1% Cd, balance aluminum alloy.

The results of this study indicate that the composition of the metal is, in general, more important than the composition of the glass with respect to the extent of the glass-metal interaction and the ability of the glass to be metal coated.

D. Production and testing of glass-reinforced aluminum tubular shapes.

It has been found desirable in the best interest of this project to subcontract to the Olin-Mathieson Chemical Corporation work on fabricating large glass-reinforced aluminum tubes. Initially, Olin-Mathieson will make these tubes by centrifugally casting aluminum around preforms of aluminum coated and bare glass fibers supplied by our laboratory.

1. Operation of Olin-Mathieson centrifugal casting unit.

This unit was put into operation in February, 1957. Initial shake-down runs and modifications were made. About thirty centrifugal casting shots were then made. Some promising tubular samples of glass-reinforced aluminum were formed, but it was thought that many improvements in technique and equipment could be made. Hence, a new casting mold was designed and fabricated. A new, higher speed, drive was installed and other mechanical improvements were made to the unit. The modified unit has recently been put into operation. Initial runs indicate that the additional pressure on the molten metal during casting by virtue of the higher centrifugal speed will aid considerably in producing satisfactory tubular shapes. As yet no samples have been tested for internal bursting strength.

2. Tubes 1" in diameter.

Glass-reinforced aluminum tubes 1" in diameter have been made by a previously described⁽¹⁾ modification of the vacuum injection method. These tubes have been tested in internal bursting. All tubes have been made using strands of aluminum coated glass fibers as reinforcement and 14S aluminum as a matrix alloy. The tubes were heat treated at 940°F for 3 hours, quenched in water, and aged at 340°F for 18 hours. Table VIII gives the tubular bursting strength data taken during this reporting period.

(1) H. B. Whitehurst and H. B. Ailes - Fifth Quarterly Progress Report
(Contract NOrd 15764)

TABLE VIII

GLASS-REINFORCED ALUMINUM TUBES

<u>Sample Number</u>	<u>Testing Temperature, °F.</u>	<u>Internal Bursting Pressure, psi</u>	<u>Equivalent Rim Stress, psi</u>
EH-XXII-149C	R.T.	5000+ (1)	35,600
125E	500	350	2,400
125B	1000	750	5,300
125C	1000	1150	8,500
149B	1000	250	1,900

It should be noted that the bursting strength of sample number EH-XXII-125E was unusually low. The average of previously reported values of equivalent rim stress at 500°F was about 17,000 psi.

E. Developing a theory on the interaction of metals and glass fibers.

The combination of most metals and glass fibers results in some degradation in the strength of the glass fibers. It is of paramount importance to understand the interaction which takes place between the metal and the glass fibers. Once the interaction is more clearly defined it will in all likelihood be possible to control this interaction and produce composite materials of glass and metals having the most desirable properties.

A single fiber tensile tester has been assembled from existing equipment and is shown in Figure VII. This tester will be used to measure the tensile strengths of glass fibers which have been contacted with metals having various melting points and chemical reactivities. The tensile tester has been placed in operation and its relative accuracy and reliability have been determined.

(1) Test had to be stopped short of failure for fear of damaging testing equipment.

F. Developing a glass-reinforced metal having utility at temperatures above 1000°F.

Preliminary considerations indicate that copper alloys may be the most satisfactory metals for initial experiments on developing a glass-reinforced metal having utility at temperatures above 1000°F. In particular, consideration will be given to reinforcing the beryllium coppers, the aluminum bronzes, the manganese bronzes, the silicon bronzes, and 70-30 brass.

Considerable work has been done on chemically coating E glass fibers with copper. This has been done by dipping fibers in the coating solutions and by applying the solutions to the fibers as the fibers are being formed. In general, the coatings which have been obtained by this method are visible on only a small percentage of the fibers which have been exposed to the coating solutions. In addition, it appears that this method will not be satisfactory since one of the coating solutions is quite unstable after initial contact with the glass fibers.

IV FUTURE WORK

Work will continue on developing improved glass-reinforced aluminum materials. The optimum conditions will be determined for forming composites by hot pressing aluminum coated glass fibers. Various fiber dimensions and orientations will then be investigated using the hot pressing technique. Preliminary experiments will be conducted on the extrusion of glass-reinforced aluminum.

Additional results will be available on physical properties of glass-reinforced aluminum composites. Modulus of elasticity in shear, compressive strength, creep rate, stress rupture characteristics, and fatigue strengths will be measured at temperatures up to 1000°F. The water absorption capacity and wet strength of glass-reinforced aluminum will be measured.

Olin-Mathieson will produce and test large tubular shapes of glass-reinforced aluminum. A static casting unit will be built to cast other large shapes of glass-reinforced aluminum.

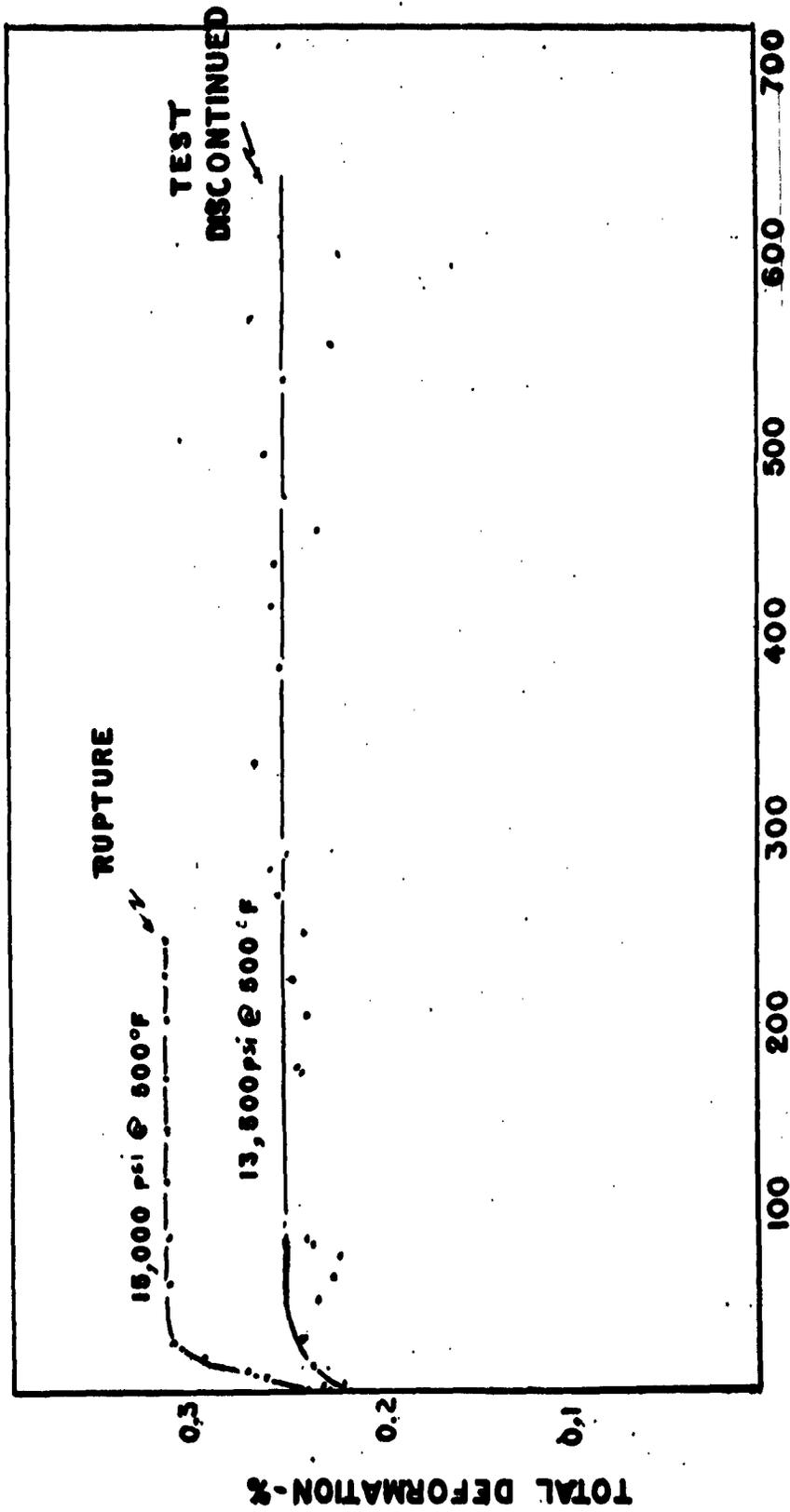
Efforts will be directed toward development of a theory explaining the formation and behavior of glass and metal combinations. Investigations of the aluminum-glass interaction will be made.

Work will be done on the development of a light weight structural material which will have utility at temperatures as high as 1500°F. Attempts to form composites of glass fibers and copper alloys will be the initial efforts in this direction.

HBA/jf

Herbert B. Ailes
Glass-Metals Research Laboratory

V APPENDIX



CREEP OF GLASS-REINFORCED ALUMINUM
FIGURE 1

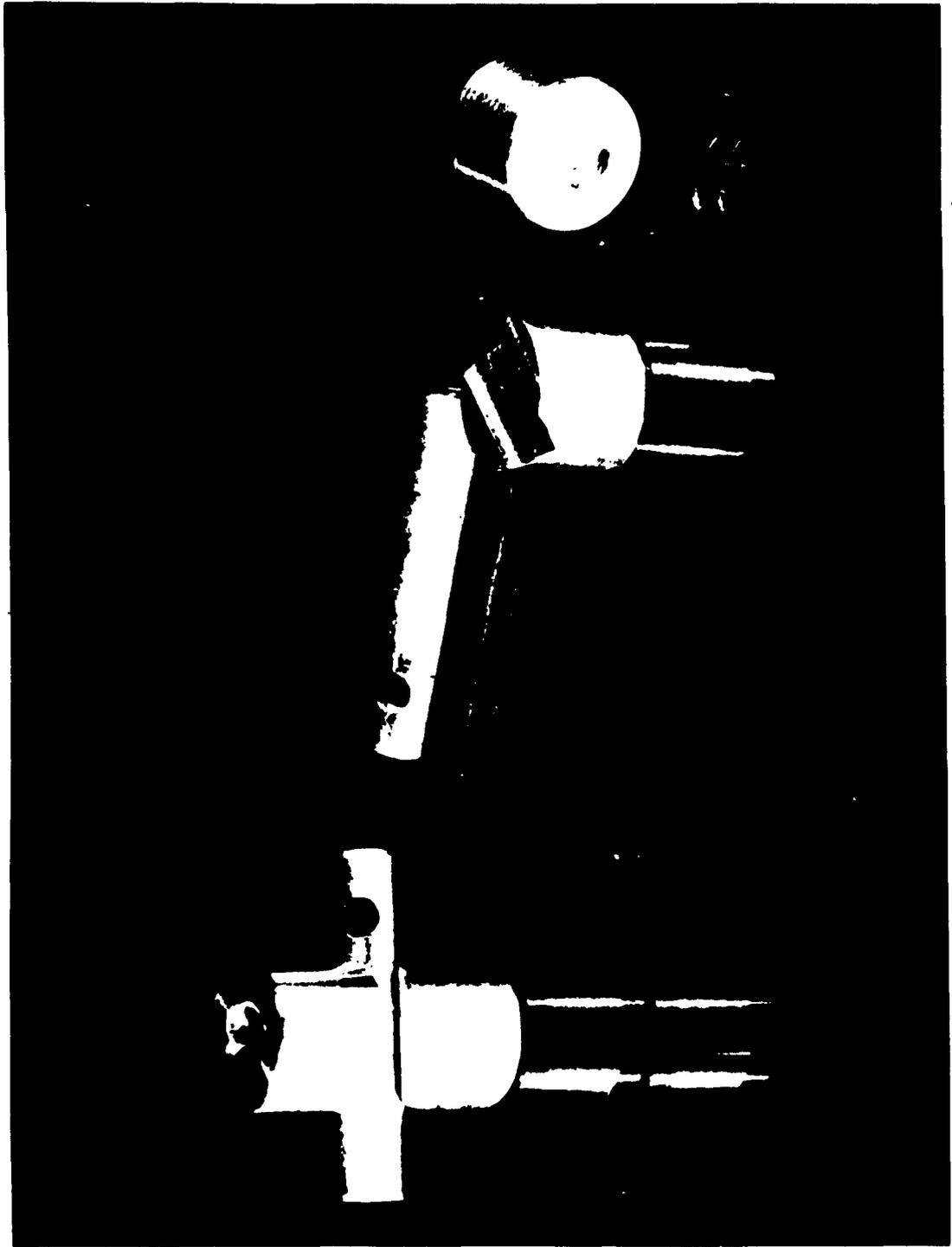


Figure II
34545 Wear Resistance Test Samples



Figure III
Bare Glass Fiber, Acid Etched



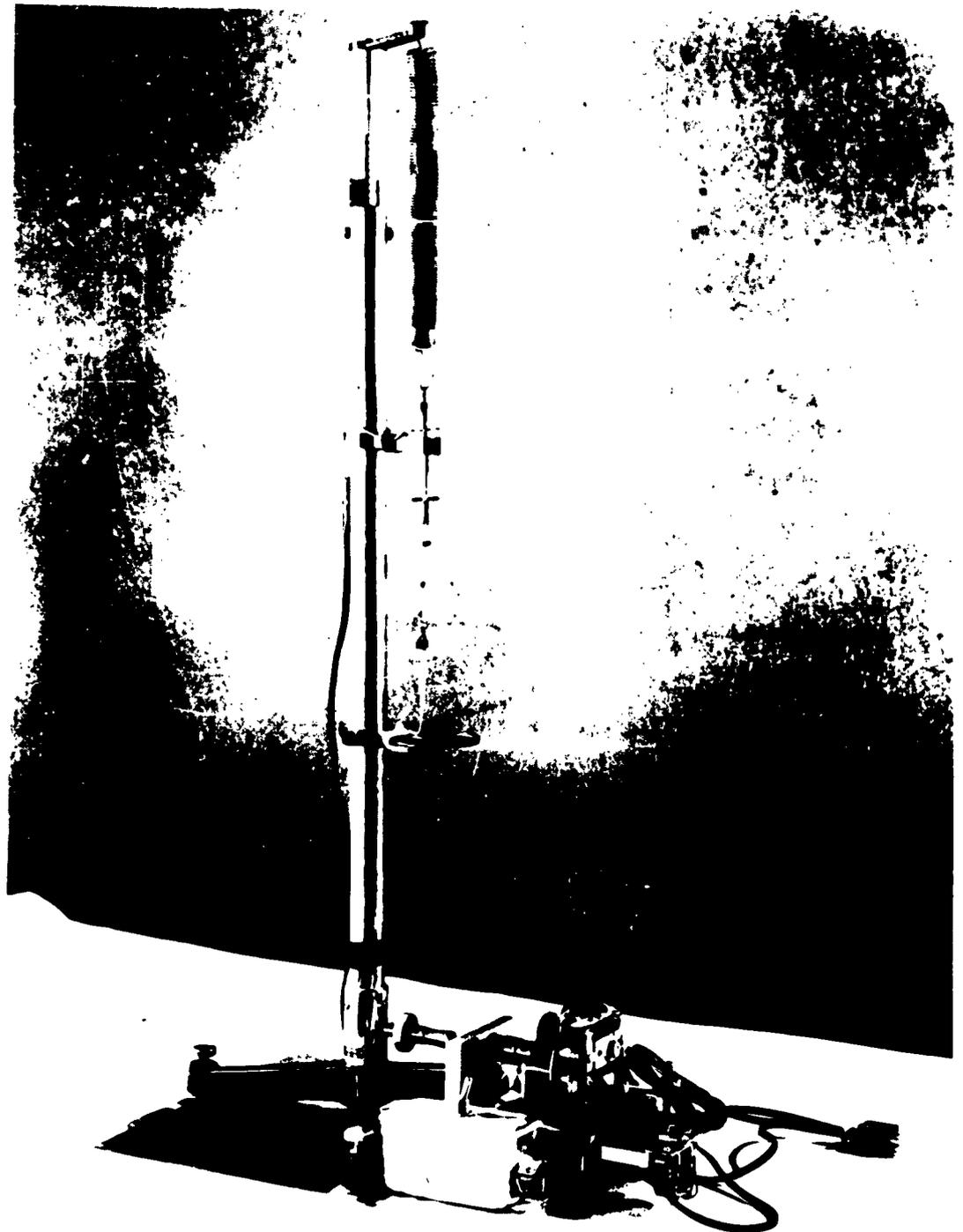
Figure IV
Glass Fiber with 5% Zn, 1% Cd, Balance
Aluminum Coating Removed by Acid Etch



Figure V
Glass Fiber with 2S Aluminum Coating
Removed by Acid Etch



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34544 *Figure VII*
Single Fiber Tensile Testing Apparatus