

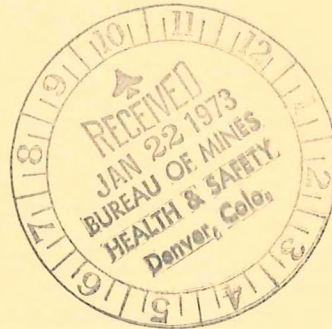
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Glass Wool From Waste Glass



UNITED STATES DEPARTMENT OF THE INTERIOR

Report of Investigations 7708

Glass Wool From Waste Glass

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Tuscaloosa Metallurgy Research Laboratory, Tuscaloosa, Ala.**

**With an Appendix on Economic Evaluation of Glass Wool Production
by Paul W. Johnson**



**UNITED STATES DEPARTMENT OF THE INTERIOR
Rogers C. B. Morton, Secretary**

**BUREAU OF MINES
Elburt F. Osborn, Director**

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CONTENTS

	<u>Page</u>
Abstract.....	1
Introduction.....	1
Raw materials.....	2
Experimental conditions.....	2
Batch composition.....	2
Orifice size.....	3
Fiber formation.....	3
Physical properties.....	5
Conclusions.....	6
References.....	8
Appendix.--Economic evaluation of glass wool production.....	9

ILLUSTRATIONS

1. Melting furnace and collection drum used for producing glass wool..	4
2. Glass wool (coarse fiber).....	5
3. Compressive characteristic of glass wool.....	6
A-1. Glass wool from waste glass.....	9
A-2. Product value as affected by interest rate of return on investment.	16

TABLES

1. Chemical analyses of College Park residue glass and clean, mixed-glass cullet.....	2
2. Batch mixtures.....	2
3. Chemical analyses of test fibers and a commercial glass wool.....	3
4. Materials balance of test fibers.....	4
A-1. Daily thermal and utility requirements.....	10
A-2. Estimated capital cost.....	11
A-3. Major items of equipment.....	12
A-4. Equipment cost summary, glass wool manufacture.....	12
A-5. Raw material and utility requirements.....	14
A-6. Direct labor requirements.....	14
A-7. Estimated annual operating cost.....	15

GLASS WOOL FROM WASTE GLASS

by

Alan H. Goode,¹ M. E. Tyrrell,² and I. L. Feld³

With an Appendix on Economic Evaluation of Glass Wool
Production by Paul W. Johnson

ABSTRACT

Glass wool meeting requirements for commercial use was made from glassy fractions of urban solid wastes by the Bureau of Mines. This research was a part of the Bureau's program to develop building products and other usable materials from reclaimed urban waste materials. Mixes of molten glass were fiberized into glass wool during laboratory studies by impingement of a jet of compressed air on a stream of the molten glass. The principal test variable studied was composition of the melt; this was varied by adding dolomite and alumina to obtain molten glass with the handling characteristics required for producing final wool products of the desired composition and physical characteristics.

When no charge is made for the waste glass and approximately \$75 per ton can be obtained for the wool product, an interest rate of return on investment after taxes of about 12 percent can be obtained. If a charge of \$5 per ton is required for the waste glass, a selling price of about \$78 per ton would be necessary to obtain a 12-percent-interest rate of return on investment after taxes.

INTRODUCTION

Glass wool manufacturing is an expanding industry, and production of glass wool for thermal and acoustic insulation and other uses is continuing to increase. During 1970, about 1,206,082,000 pounds (1)⁴ of glass fiber insulation, worth about \$45 million at an assumed value of \$75 per ton, was produced.

Glass wool is used principally for thermal insulation against heat and cold; sound absorption and isolation are probably the next most important uses. Both its thermal and acoustic values result primarily from the physical

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⁴Underlined numbers in parentheses refer to items in the list of references preceding the appendix.

structure of the heterogeneous mixture of fibers and air--the form in which the fibers are produced and handled. For this reason, differences in chemical composition within fairly wide limits are relatively unimportant; for most conventional applications, all types are competitive in properties and value (4).

The solid waste research program conducted at the Bureau of Mines Tuscaloosa Metallurgy Research Laboratory, Tuscaloosa, Ala., is concerned with the utilization of the high-glass fraction from municipal incinerator residues in the production of glass wool and various other structural products. The glass residue used for this research was obtained from the College Park Metallurgy Research Center, Edmonston, Md., Solid Waste Research Pilot Plant (5). Glass wool is an ideal use for either clean or poorly cleaned residue waste glass, because even the presence of metal in the batch mixture does not interfere with the wool fiberizing method used at the Tuscaloosa Laboratory.

An economic evaluation of this experimental process for making glass wool from waste glass was made by the Economic Evaluation Section at the College Park Metallurgy Research Center. This report is presented in the appendix.

RAW MATERIALS

Incinerator residue glass, uncalcined dolomite, and alumina were the raw materials used in making glass wool during this investigation. Table 1 shows a comparison in chemical analyses of College Park residue glass and clean, mixed-glass cullet.

TABLE 1. - Chemical analyses of College Park residue glass and clean, mixed-glass cullet

Material	Analysis, percent							
	SiO ₂	Al ₂ O ₃	Na ₂ O	CaO	MgO	Fe ₂ O ₃	K ₂ O	Cr ₂ O ₃
Residue glass.....	64.8	2.50	14.20	7.60	2.00	5.70	0.50	0.05
Mixed cullet.....	69.30	1.74	13.91	10.02	.43	.86	.55	.03

EXPERIMENTAL CONDITIONS

Batch Composition

Raw materials were weighed individually to make a batch that was blended mechanically and placed in the melting furnace. Table 2 shows the weight-percent of each rawmaterial used in the batch mixtures.

TABLE 2. - Batch mixtures

Wool fiber	Weight-percent			
	Residue glass	Dolomite	Alumina	Total
Fine.....	46	52	2	100.0
Coarse.....	78	20	2	100.0

Table 3 shows chemical analyses of glass wool made from the two batch mixtures. For comparison, a commercial slag wool is also shown. It should be noted that the principal difference between the slag wool and the fibers made from waste glass is in the distribution of fluxes. In the slag wool, calcia is the major flux; in the fibers made from waste glass, part of calcia is replaced by soda.

TABLE 3. - Chemical analyses of test fibers
and a commercial glass wool

Wool fiber	Analysis, percent						
	SiO ₂	Al ₂ O ₃	Na ₂ O	CaO	MgO	Fe ₂ O ₃	K ₂ O
Fine.....	42.4	4.4	8.35	28.0	15.0	0.25	0.29
Coarse.....	60.3	4.2	12.50	14.3	3.9	.16	.29
Commercial...	41.0	4.5	.17	35.3	14.1	1.6	.82

Orifice Size

Each batch was melted in a natural-gas-fired furnace at 2,600° F. The batch was placed in a silicon carbide crucible with an orifice of 3/16 inch in diameter in the crucible bottom for producing fine fiber wool and a 1/4-inch-diameter orifice for making coarse fiber wool. The increase in orifice size for coarse fiber wool was made to facilitate flow of the melt because of its viscosity increase due to the greater amount of silica present in the batch.

Fiber Formation

After approximately 3-1/2 hours (when the batch was sufficiently fluid), a plug in the orifice was removed, and the molten glass flowed through the bottom of the crucible and out of the furnace. About 10 inches below the bottom of the furnace the molten glass was fiberized by impingement of a jet of compressed air (100 psig) at a right angle to the vertically flowing glass stream. Fifty cubic feet per minute of air was required to fiberize the batch in 15 minutes, or a total of approximately 750 cubic feet of air was used per batch test. Figure 1 shows the equipment used for producing glass wool. The compressed air has a shearing and fiberizing action upon the molten glass, breaking it into individual drops and fibers while they are blown into a collection area. As the drops of molten glass are propelled through the air, friction causes them to develop long "tails." These tails are the insulating fibers and any remnants of the original drops are called "shot" (2). The shot content, which was generally less than 25 percent, was not considered excessive for wool made in laboratory-scale equipment. Figure 2 shows coarse-fiber glass wool made in this manner.

The materials balance for the test fibers are shown in table 4. It should be noted that the lower recovery for the coarse fiber is due to the increase in viscosity of the melt; therefore, a portion of the batch remained inside the crucible.

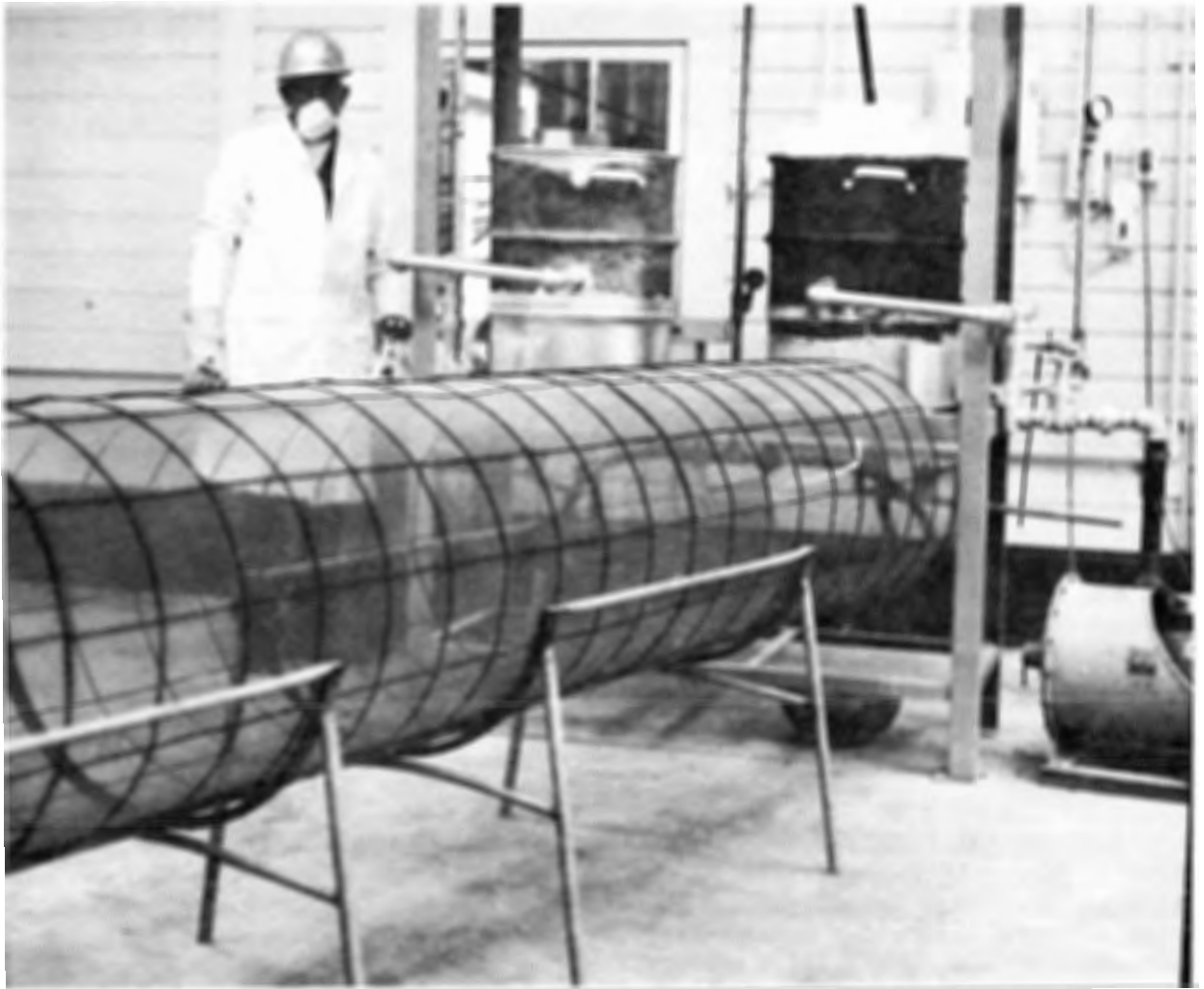


FIGURE 1. - Melting Furnace and Collection Drum Used for Producing Glass Wool.

TABLE 4. - Materials balance of test fibers

Wool fiber	Batch weight, grams	CO ₂ loss, grams ¹	Recovery	
			Weight, grams	Weight- percent
Fine.....	6,000	1,494	3,905	86.7
Coarse.....	5,275	505	3,338	70.0

¹CO₂ loss, grams = batch weight x dolomite, percent
x 0.479.

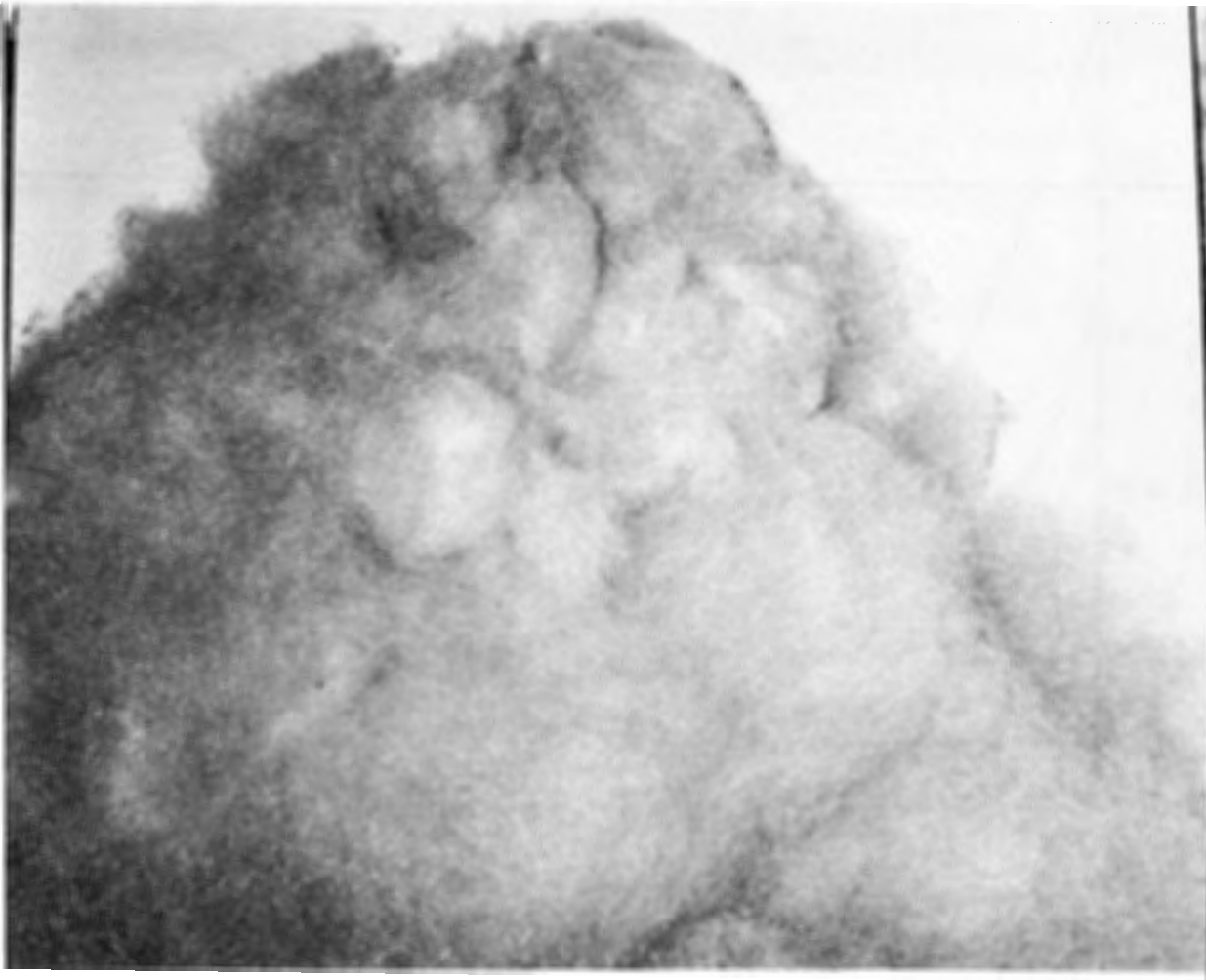


FIGURE 2. - Glass Wool (Coarse Fiber).

PHYSICAL PROPERTIES

Glass wool samples were tested according to methods described in Commercial Standards CS-131-46 issued by the U.S. Department of Commerce.

Petrographic examination of the glass wool fibers showed an average fiber diameter of 4.3 microns for fine fiber wool and 21 microns for coarse fiber wool. The increase in fiber diameter for coarse fiber wool was due to the greater amount of silica in the batch, which made the melt more viscous.

Figure 3 shows the compressive characteristic strength of fine fiber, coarse fiber, and a commercial wool as load is applied and then removed. Compressive characteristic is important for evaluating the resiliency of the wool (the ability of wool to be compressed for shipping and then to spring back to near-original volume for installation). The coarse fiber wool was quite resilient and was superior in this respect to the fine fiber wool.

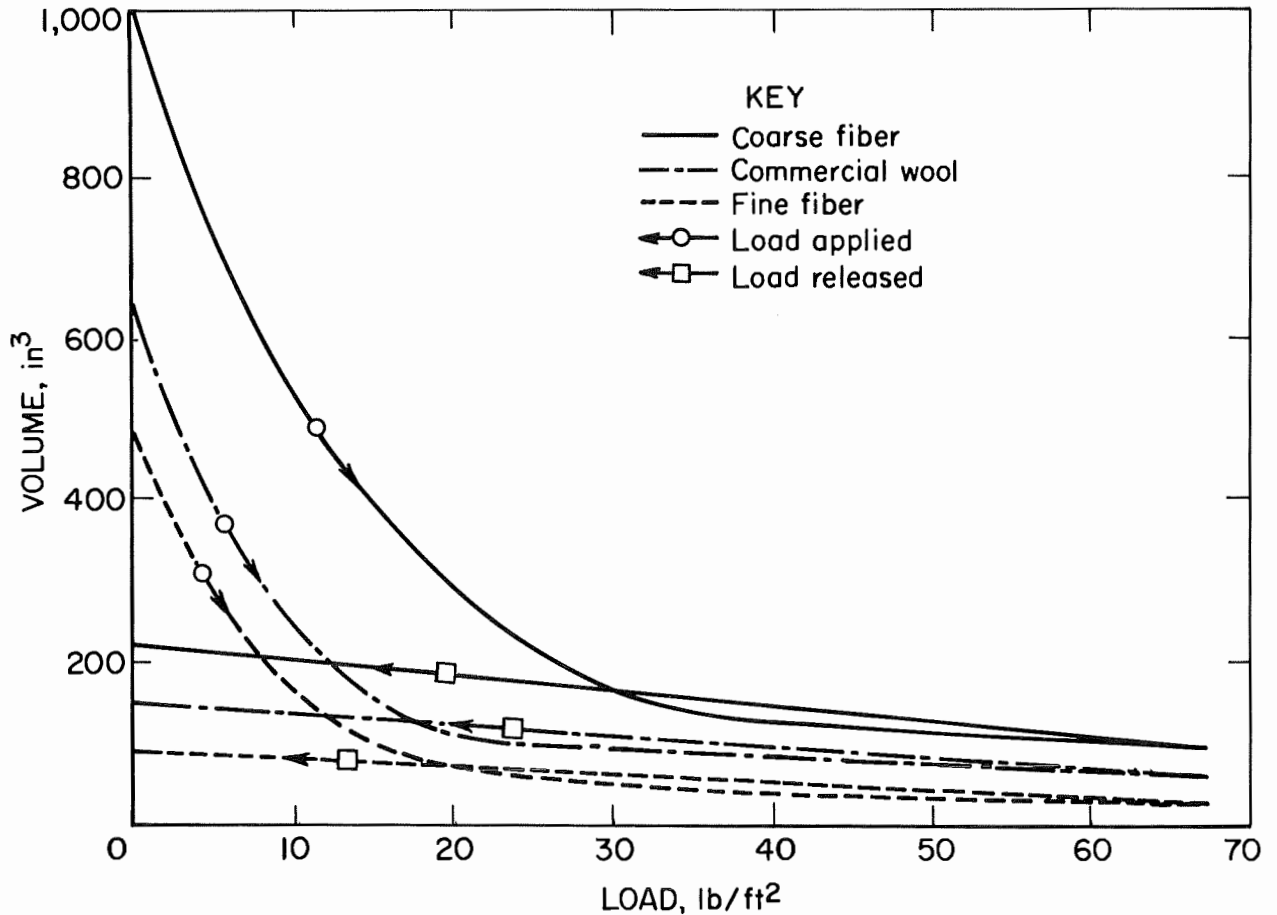


FIGURE 3. - Compressive Characteristic of Glass Wool.

Other fiber qualities obtained included acceptable colors of light gray to white, densities of 2.1 pounds per cubic foot for the fine fiber wool, and 1.0 pound per cubic foot for coarse fiber wool.

The resiliency of the coarse wool product would indicate its probable use as blanket insulation; the fine fiber product with its softer texture could easily find utility as a loose fill insulation where material is blown by air into a confined area.

CONCLUSIONS

Research studies show that glassy fractions from municipal incinerator residue can be used to make glass wool that meets requirements for commercial use. Physical characteristics of the glass wool can be controlled by the composition of the melt, which is varied by the addition of fluxes. Fine fiber wool would be suitable for loose fill insulation in attics or acoustic ceiling tile; the coarse fiber wool would be preferred for blanket insulation in building walls.

Results of an economic evaluation indicate that glass wool made by this process would be economically feasible. When no charge is made for the waste glass and \$75 per ton can be obtained for the glass wool product, an interest rate of return on investment after taxes of about 12 percent can be obtained. If a charge of \$5 per ton is required for the waste glass, a selling price of about \$78 per ton would be necessary to obtain a 12-percent-interest rate of return on investment after taxes.

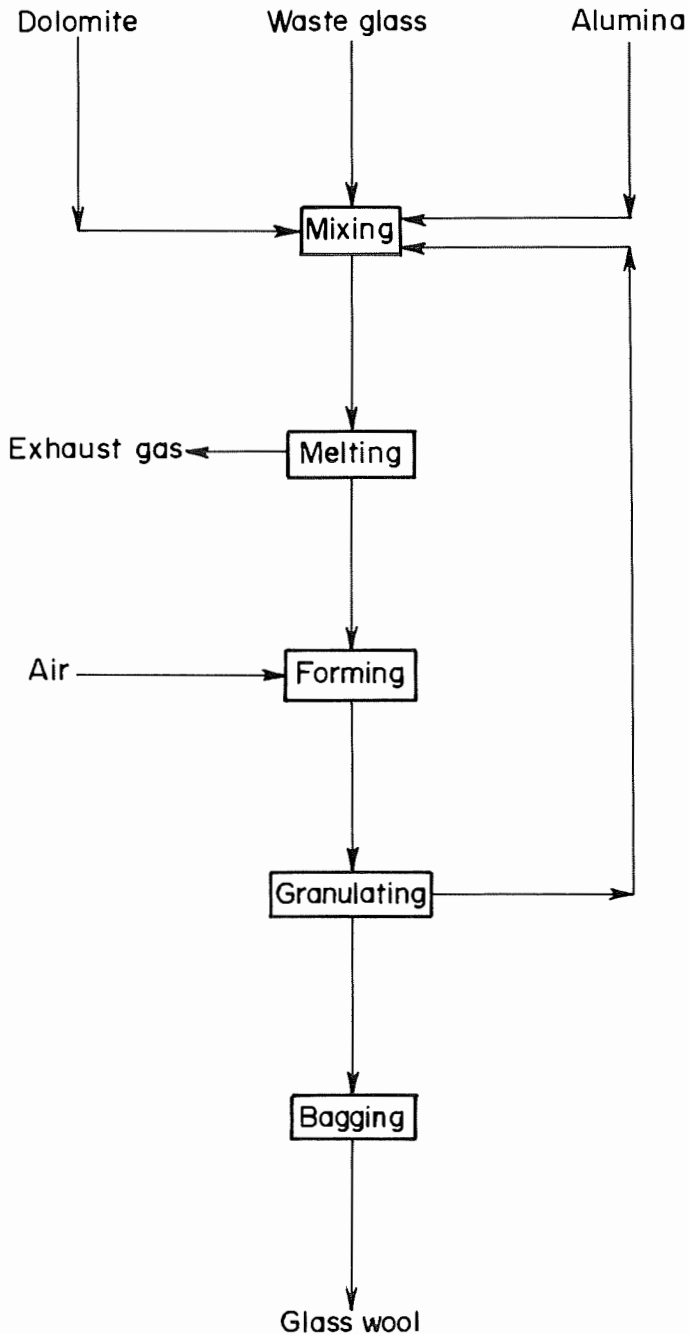
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5. Sullivan, P. M., and M. H. Stanczyk. Economics of Recycling Metals and Minerals From Urban Refuse. BuMines Tech. Prog. Rept. 33, April 1971, 19 pp.

APPENDIX.--ECONOMIC EVALUATION OF GLASS WOOL PRODUCTION

Glass Wool Production¹

An economic evaluation for a process to make glass wool from the waste glass obtained from an incinerator residue separation plant is presented.



Data obtained from the Tuscaloosa Metallurgy Research Laboratory and from the literature were used as the basis of the process. In the process used for making glass wool, waste glass is mixed with uncalcined dolomite, alumina, and recycled cullet and melted in a furnace. The glass formed is fiberized by air, granulated to remove shot, and bagged for shipping. The sequence of operation is shown in figure A-1.

A plant is designed to process 50 tons of waste glass per day from a 250 ton-per-day incinerator residue separation plant to produce 76.7 tons of glass wool per day. The thermal and utility requirements for the process are shown in table A-1.

In the proposed process, waste glass is delivered to the plant by truck, dumped into a hopper, and conveyed to a storage silo. Uncalcined dolomite is delivered to the plant by truck or rail and stored in a silo until needed. Alumina is received in 100-pound bags and stored until needed.

Each of the raw materials is fed onto a belt conveyor and transported to a mixer to form a

FIGURE A-1. - Glass Wool From Waste Glass.

¹ By Paul W. Johnson, chemical engineer, College Park Metallurgy Research Center, Bureau of Mines, College Park, Md.

batch containing the following mixture, which was determined by the Tuscaloosa Metallurgy Research Laboratory:

	<u>Percent</u>
Waste glass.....	46
Dolomite (uncalcined).....	52
Alumina.....	<u>2</u>
Total.....	100

The mixture is then conveyed to hoppers feeding a glass-melting furnace operating at 2,600° F. As the glass melts, it passes from the melting section into the refining section and then into the after-hearth section. From this latter section, the glass leaves the furnace through orifices. Air is blown at 100 psig at right angles to the flowing glass to fiberize the glass in forming rooms. During fiberizing, about 25 percent of the glass forms shot (beads), which has to be removed from the fibers.

TABLE A-1. - Daily thermal and utility requirements¹

	Cooling water, Mgal	Natural gas, MMBtu
Glass wool manufacture:		
Glass-melting furnace.....	0	1,135.0
Compressors.....	21.4	0
Total.....	21.4	1,135.0

¹The electric power requirement for all equipment in the plant is 11,071 kwhr.

The fiberized glass (and shot) is conveyed from the forming rooms on mesh-belt conveyors and passed into granulators that shred the glass fibers and release the shot. This shot is collected and recycled to the furnace. The glass fibers are then conveyed to packaging. It is assumed that the glass wool is packaged in 40-pound bags and stored for shipping.

Economic Evaluation

This cost evaluation is prepared to show the economic potential of a process for making glass wool from waste glass obtained from the incinerator residue separation process. The evaluation is based on published cost data updated by the use of inflation indexes.² Freight costs for the raw materials and land cost are not included since a definite plant location is not considered. However, it is assumed that the plant is within trucking distance of an incinerator residue separation plant.

²Chemical Engineering. Costs Hesitate in Upward Trend. V. 68, No. 5, Mar. 6, 1971, pp. 115-116.

Capital Cost

The capital cost estimate is of the general type called a "study estimate" by Weaver, Bauman, and Heneghan.³ This type of estimate, prepared from a flow-sheet and a minimum of equipment data, can be expected to be within 30 percent of the actual cost. For the first quarter of 1972, the fixed capital cost of producing 76.7 tons of glass wool per day is \$2,431,930. The plant is designed to operate one shift, 5 days per week, 250 days per year. The glass-melting furnace is kept hot at all times except when down for repairs. The total capital cost for the process is shown in table A-2.

TABLE A-2. - Estimated capital cost,¹ glass wool production
(38,350 thousand pounds per year)

Fixed capital:	
Glass wool manufacture.....	<u>\$2,294,270</u>
Subtotal.....	2,294,270
Plant facilities, 4 percent of above subtotal.....	91,770
Plant utilities, 2 percent of above subtotal.....	<u>45,890</u>
Fixed capital cost.....	<u>2,431,930</u>
Working capital:	
Raw material and supplies.....	19,860
Product and in-process inventory.....	78,890
Accounts receivable.....	78,890
Available cash.....	<u>53,970</u>
Working capital cost.....	<u>231,610</u>
<u>Total capital cost.....</u>	<u>2,663,540</u>

¹Basis--M and S equipment cost index = 326.8.

Cost-capacity data of the type presented by Bauman,⁴ Mills,⁵ and Peters and Timmerhaus⁶ are used as the principle sources of equipment costs. Major items of equipment are shown in table A-3. The costs of the major items of equipment and their accessories are tabulated in table A-4. The effect that fluids, solids, or a combination of fluids and solids may have on the items such as foundations, buildings, instruments, etc., as shown on the table A-4, is used to assign factors to obtain the cost of these items. A factor of 5 percent, referred to as miscellaneous, is added to cover minor equipment and construction costs that are not shown with the equipment listed.

³Weaver, J. B., H. C. Bauman, and W. F. Heneghan. Cost and Profitability Estimation. Sec. in Perry's Chemical Engineers' Handbook, ed. by R. H. Perry, C. H. Chilton, and S. D. Kirkpatrick. McGraw-Hill Book Co., Inc., New York, 4th ed., 1963, p. 26-5.

⁴Bauman, H. C. Fundamentals of Cost Engineering in the Chemical Industry. Reinhold Publishing Corp., New York, 1964, 364 pp.

⁵Mills, H. E. Costs of Process Equipment. Chem. Eng., v. 71, No. 6, Mar. 16, 1964, pp. 133-156.

⁶Peters, M. S., and K. D. Timmerhaus. Plant Design and Economics for Chemical Engineers. McGraw-Hill Book Co., Inc., New York, 2d ed., 1968, 850 pp.

TABLE A-3. - Major items of equipment

Equipment	Quantity	Unit size
Mixer.....	1	640 cubic feet per hour.
Furnace.....	1	26 feet wide by 69 feet long.
Compressor.....	2	2,690 cubic feet per minute.
Forming room.....	2	7-1/2 feet wide by 50 feet long by 20 feet high.
Granulator.....	2	1,090 square feet.
Trommel.....	2	440 square feet.

TABLE A-4. - Equipment cost summary, glass wool manufacture, glass wool production (38,350 thousand pounds per year)

Item	Cost ¹		
	Equipment	Labor	Total
Hoppers.....	\$7,780	\$390	\$8,170
Conveyors.....	173,880	30,080	203,960
Weightometer.....	3,500	880	4,380
Feeders.....	27,620	2,430	30,050
Mixer.....	7,400	740	8,140
Glass-melting furnace.....	128,070	143,440	271,510
Compressor.....	229,940	22,990	252,930
Forming rooms.....	1,630	650	2,280
Granulators.....	40,900	4,090	44,990
Trommels.....	35,780	3,580	39,360
Storage bin.....	5,780	290	6,070
Bagging machine.....	1,280	130	1,410
Dust collectors.....	1,680	160	1,840
Total.....	665,240	209,850	875,090
Storage silos.....			² 57,160
Cooling tower.....			² 99,690
Forklift truck.....			8,620
Storage building.....			155,380
Total equipment cost x factor indicated:			
Foundations, x 0.300.....			199,570
Buildings, x 0.200.....			133,050
Structures, x 0.100.....			66,520
Instrumentation, x 0.010.....			6,650
Electrical, x 0.010.....			6,650
Miscellaneous, x 0.050.....			33,260
Total.....			445,700
Total direct cost.....			1,641,640
Field indirect, 10.0 percent of total direct cost.....			164,160
Total construction cost.....			1,805,800
Engineering, 5.0 percent of total construction cost.....			90,290
Administration and overhead, 5.0 percent of total construction cost			90,290
Subtotal.....			1,986,380
Contingency, 10.0 percent of above subtotal.....			198,640
Subtotal.....			2,185,020
Contractor's fee, 5.0 percent of above subtotal.....			109,250
Section cost.....			2,294,270

¹Equipment costs are based on an M and S index of 326.8.²Installed cost.

For the processing section, the field indirect, which covers field supervision, inspection, temporary construction, equipment rental, and payroll overhead, is estimated at 10 percent of the direct cost. Engineering and administration and overhead are each estimated at 5 percent of the construction cost. A contingency of 10 percent and a contractor's fee of 5 percent are included in the section costs.

The costs of plant facilities and plant utilities are estimated as 4 and 2 percent, respectively, of the total process section cost. The costs for plant facilities and utilities include the same field indirect, engineering, administration and overhead, contingency, and contractor's costs as are included in the section cost. Included under plant facilities are the cost of laboratories, warehouses, offices, shops, roads, and fences. The cost of water, power, and gas distribution systems is included under plant utilities.

Working capital is defined as the funds in addition to fixed capital, land investment, and startup costs, that must be provided to operate the plant. Working capital is estimated from the following items: (1) Raw materials and supplies inventory (cost of raw materials and operating supplies for 1 month), (2) product and in-process inventory (total operating cost for 1 month), (3) accounts receivable (total operating cost for 1 month), and (4) available cash (direct expenses for 1 month). The estimated working capital is given in table A-2.

Operating Costs

The estimated annual operating cost is based on 250 days of operation per year, which allows 2 weeks downtime for inspection, maintenance, and unscheduled interruptions. This cost is divided into direct, indirect, and fixed costs.

Direct costs include raw materials, utilities, labor, maintenance, payroll overhead, and operating supplies. The raw material costs do not include freight costs because the plant location is not considered. Electricity, water, and natural gas are purchased utilities. Raw material and utility requirements per 40-pound bag of glass wool are shown in table A-5. Direct labor cost is estimated on the basis of manning the plant with 1.0 man for each position that operates 8 hours per day, 5 days per week. The direct labor assignments are shown in table A-6. The cost of labor supervision is based on an annual salary of \$11,000 per supervisor.

Plant maintenance is separately estimated for each piece of equipment and for the buildings, electrical system, piping, plant utilities, and plant facilities. Operating supplies are 20 percent of the cost of plant maintenance. Payroll overhead includes vacations, social security, and fringe benefits.

Indirect costs are estimated at 40 percent of the direct labor and maintenance costs. The indirect costs include the expenses of accounting, plant protection and safety, plant administration, marketing, and company overhead. Research and overall company administrative costs outside the plant are not included.

TABLE A-5. - Raw material and utility requirements

	<u>Quantity per</u> <u>40-lb bag of</u> <u>glass wool</u>
Raw materials:	
Waste glass.....1b..	26.08
Dolomite.....1b..	29.46
Alumina.....1b..	1.15
Bags.....	1.00
Utilities:	
Electric power.....kwhr..	2.89
Natural gas.....MMBtu..	0.30

TABLE A-6. - Direct labor requirements

	Direct labor assignment			
	Number of men	Shifts per day	Days per week	Total men required
Glass wool manufacture:				
Raw material handling...	1.0	1	5	1.0
Glass-melting furnace...	2.0	3	7	8.4
Forming rooms.....	1.0	1	5	1.0
Bagging machine.....	1.0	1	5	1.0
Product handling.....	5.0	1	5	5.0
Forklift truck.....	1.0	1	5	1.0
Total.....	-	-	-	17.4

Fixed costs include the cost of property taxes, insurance, and depreciation. The annual cost of taxes and insurance is estimated as 1 percent each of the plant cost. Depreciation is based on a straight-line, 15-year period.

The estimated annual operating cost is \$946,720 when no charge is made for waste glass (table A-7).

Product Value

Using the interest rate of return method to calculate the value of the glass wool in 40-pound bags, figure A-2 shows the variation of the product value, based on a 50-percent income tax and no charge for the waste glass, and interest rate of return on investment. Also included in figure A-2 is a curve based on a \$5-per-ton charge for waste glass.

At an assumed value of about \$75 per ton of glass wool (\$1.50 per 40-pound bag), a 12-percent-interest rate of return on investment after taxes is obtained when no charge is made for the waste glass. When \$5 per ton of waste glass is charged, about \$1.57 per 40-pound bag (approximately \$78 per ton) is required to obtain a 12-percent-interest rate of return on investment after taxes.

TABLE A-7. - Estimated annual operating cost,
glass wool production (38,350
thousand pounds per year)

	Annual cost	Cost per 40-lb bag glass wool
Direct cost:		
Raw materials:		
Colored glass at \$0.00 per ton.....	\$0	\$0.000
Dolomite at \$5.00 per ton.....	70,630	.074
Alumina at \$120.00 per ton.....	66,000	.069
Bags at \$0.09 per bag.....	86,290	.090
Total.....	222,920	.233
Utilities:		
Electric power at 1 cent per kwhr.....	27,680	.029
Water, process at 47 cents per Mgal.....	100	.001
Natural gas at 40 cents per MMBtu.....	113,500	.118
Total.....	141,280	.148
Direct labor:		
Labor at \$3.55 per hour.....	132,910	.139
Supervision.....	11,000	.011
Total.....	143,910	.150
Plant maintenance:		
Labor.....	37,040	.039
Supervision.....	9,000	.009
Materials.....	30,700	.032
Total.....	76,740	.080
Payroll overhead, 25 percent of above payroll.....	47,490	.050
Operating supplies, 20 percent of plant maintenance...	15,350	.016
Total direct cost.....	647,690	.677
Indirect cost, 40 percent of direct labor and maintenance.....	88,260	.092
Fixed cost:		
Taxes, 1.0 percent of total plant cost.....	24,320	.025
Insurance, 1.0 percent of total plant cost.....	24,320	.025
Depreciation, 15-year life.....	162,130	.169
Total operating cost.....	946,720	.988

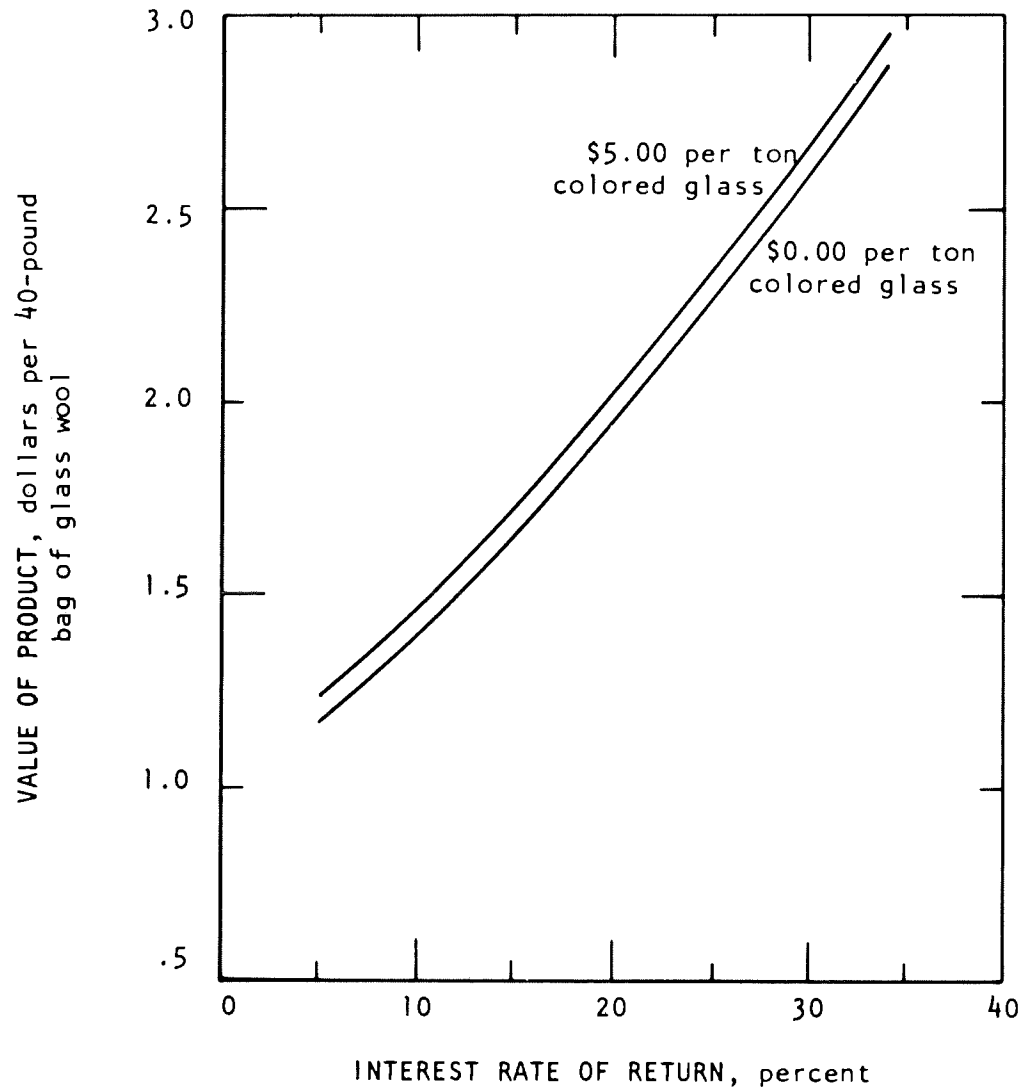


FIGURE A-2. - Product Value as Affected by Interest Rate of Return on Investment.

